

BRADNEY



**A PRACTICAL GUIDE TO THE MOORING
AND ANCHORING OF SMALL BOATS**

INTRODUCTION

In recent years it has become increasingly obvious that the basic principles of anchoring and mooring are often imperfectly understood. Inevitably this has led to equipment failures, either through poor system design or through the selection of unsuitable components with consequent damage, injury and even death.

It is all too common to find extremely expensive craft, the pride and joy of their owners, put at risk through ignorance of a few simple rules. Even worse, whole families can be put in danger through misguided economies by owners or contractors. Surely a classic case of 'spoiling the ship for a ha'porth of tar!' Yet all it needs is a little time spent understanding the principles and a little care in selecting equipment.

This booklet has been produced in an attempt to guide you through the various stages of design, selection, installation and maintenance. It contains practical information for the owner and contractor alike. We hope that you will find it useful and that it will help you to sleep sounder (and safer!) when the wind is whistling in the rigging.

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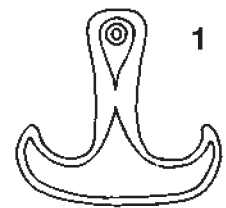
1. A HISTORY OF MOORING & ANCHORING

THE DEVELOPMENT OF THE MARINE ANCHOR

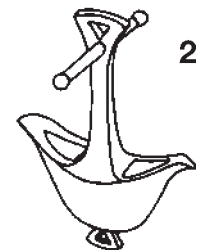
St. Clement, the fourth Pope (88-97 A.D.), is the patron saint of anchorsmiths. Story has it that he was tied to an anchor and thrown into the sea – a not uncommon method of execution in those days.

Egyptian tomb furnishings provide the earliest anchoring records. Ship models dating back to 2200 B.C. have been found equipped with conical stakes and papyrus ropes for mooring the vessels to the shore. Later tombs, around 1600 B.C., have yielded similar models boasting grooved or perforated anchor stones. King Tutankhamen's tomb, 1400 B.C., disclosed anchor stones shaped like the letter 'T'.

Over the next thousand years this 'T' shaped stone developed into a rudimentary stockless anchor or two-armed hook. The design gradually improved and it was made in various materials. Sardinian anchors of around 650 B.C. are believed to have been made of iron. Bronze anchors were cast in the island of Malta around 500 B.C. (Fig. 1). Greek writers of about the same period mention stone anchors fitted with iron hooks.



Early wooden anchors known as 'killicks' were little more than crooked sticks or wooden frameworks weighed down with stones. Similar anchoring methods are still used in a few remote regions. The interesting point, however, is that some of these crude anchors had a rudimentary stock, which brings us to the next major development.

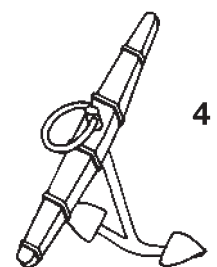


Around 400 B.C., probably in Greece, a two-armed hook was fitted with a stock (Fig. 2). The Greeks were apparently responsible for significant developments in anchor design as Greek coins of around 280 B.C. indicate. These show iron anchors with stocks and rudimentary palms, which are recognizably similar to the Admiralty or fisherman patterns in use today.

As would be expected, anchor development also shows the influence of Rome. Iron anchors of King Herod's time, about 35 B.C., have clearly defined palms and peculiar enlargements on the shanks. These are thought to be a throwback to times when cylindrical perforated stones were tied to anchor shanks. When Lake Nemi, near Rome, was drained in 1929, two 1800-year old Roman anchors were discovered. One was an iron-tipped oaken anchor with a heavy leaden stock belonging to the Emperor Caligula's ship of about 40 A.D. (Fig. 3). The second was a wood-sheathed iron anchor with a removable stock for easy stowing. This invention was lost to the world until it was 're-invented' some 1700 years later!

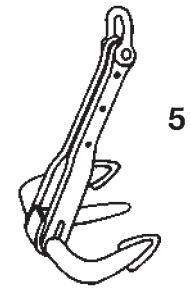


In fact, anchor design changed little over those 1700 years. The same variety of materials – stone, wood, bronze and iron were all used, proportions varied and palms became somewhat more pronounced. By 1700 the prevalent anchor was the 'kedgè' type with a long shank, straight arms at 50 degrees, and of iron construction with a fixed wooden stock the length of the shank or longer (Fig. 4).

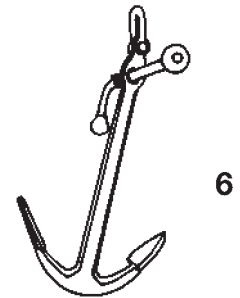


The 19th century was one of innovation. At the beginning of the century iron stocks began to be seen, anchor shanks were tending to become shorter and arms more curved. In 1807 the Royal Navy permitted the use of iron stocks for smaller sizes of anchors. Over a hundred 'improved' anchors were patented in rapid succession, practically all of which are today regarded as freaks (Fig. 5). Anchors were introduced with cant palms, tripping palms, stockless shanks and tumbling flukes, but all struggled to win general acceptance. By 1840 the

Hawkins patent tumbling fluke stockless had developed into a form similar to most of today's stockless anchors. Major purchasers, however, were conservative of change and it was 1846 before the Royal Navy fully accepted the iron stock and sanctioned the use of the anchor now known as the Admiralty pattern (Fig. 6). Although slowly gaining favour stockless anchors were still in the minority. It was not until the 1880's that the great benefit of a stockless anchor was generally realised. All other anchors were very awkward to stow on board, having to be catted into the ship's cathead just aft of her bows. The stockless anchor will stow in a ship's hawse pipe and for this reason it remains today practically the only type of anchor used on ships of any size.



Two other significant developments took place during the nineteenth century. In the 1850's the mushroom type of anchor appeared. This was, and remains, especially suitable for certain types of permanent moorings and has been widely used for lightships and naval moorings. Late in the century there was a revival of the ancient practice of putting the stock through or near the head of the anchor. 'Head stocked' anchors have the advantage of high holding power, especially in soft bottoms. The cruising (Danforth) anchor is an example of this type still very popular today.



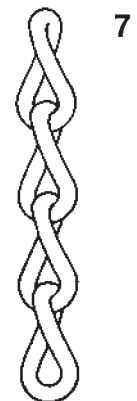
Modern small boat anchors have all been developed to dig into the seabed when subjected to a horizontal pull. Designs are available which offer enormous holding power for their weight – but they must still have sufficient weight. Below about 7.5kg the scale-effect starts to rob them of their effectiveness. Some of the more popular types of modern anchor are discussed in Chapter 2.

THE DEVELOPMENT OF CHAIN

There is ample evidence that prior to the eighteenth century metal chain was used in building, as jewellery, and for prison fetters. Surprisingly, there is only a little evidence of chain being used to anchor or moor vessels.

Somewhat less surprisingly, the first record of anchor chain comes from China, whose civilisation was far in advance of the rest of the world. Around 2200 B.C. the fabled Emperor Yu is reported to have used "iron chains, two fore and aft, which were thrown overboard to steady and stop the vessel." Hebrew legend tells us that Hiram of Tyre supplied chains for King Solomon's ships (950 B.C.). These may well have been brass, as the Bible tells us (I Kings vii) that "Hiram was cunning to work all works in brass." Aristophanes (400 B.C.) informs us that the cables of the Athenian navy were sometimes made of iron. In 322 B.C. Alexander the Great equipped vessels with iron chain so that the enemy could not swim out and cut his vessels adrift. This was obviously an accepted benefit in those days, as Caesar (56 B.C.) found the Veneti tribes using iron chain for the same reason.

There is little or no mention of anchor chains from Caesar's time until the 13th Century. From 1200 A.D. to 1600 A.D. there are occasional references, but it is clear that anchor chains were seldom used. In 1634 Philip White patented in England a method of making iron chains for ships and chain began to be used as a viable alternative to rope. Although George Washington implemented his idea of a barrier chain across the Hudson River to impede the invading British fleet, most chain developments were taking place in England. In 1783 George Matthews made cast malleable chain for ships, an innovation well ahead of its time. It was not until World War I that cast chain was fully developed. In 1808 Robert Flinn of North Shields became the first man to produce consistently good quality anchor chains and these won wide recognition and were an outstanding success. At the same time Samuel Brown took out patents for twisted link chain (Fig. 7), joining shackles and swivels. The change from hemp to chain was gathering momentum.



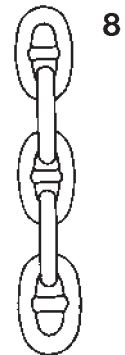
Studs to stiffen the links and to prevent the chain from tangling appeared in 1812 (Fig. 8). In 1816 the Royal Navy standardised on iron chain instead of hemp for all new warships and in 1830 decided to equip all new and existing vessels with iron chains. Testing machines had been developed to prove the quality of the chain and by 1836 the use of iron chains was general and their superiority accepted. Underwriters ceased to charge a higher premium for merchant vessels using iron chain.

In 1846 Lloyd's Register of Shipping changed their rules to demand that all chains for classified vessels be proof tested and marked accordingly. In 1835 they had demanded that test certificates should be produced for chains and in 1858 issued rules as to the length and size of chain cable. These moves eventually resulted in the Anchors and Chain Cables Act of 1899, which remains the basis of present-day testing procedure.

As with anchors, experiments continued into various ways of making chains. In 1902 an English manufacturer produced solid weldless chain by taking a bar of cruciform section and rolling it between specially shaped horizontal and vertical rollers. These rollers produced the general shape of a chain which was then trimmed and pressed to size. Also in 1902 a patent was taken out for a spirally welded chain. This involved coiling thin flat bars and pressing the coil at welding heat to form a square-sectioned ring. Each ring was subsequently formed and trimmed to the shape of a link.

However, at the start of this century, virtually all chain was wrought iron made by chainsmiths on open hearths, with steam hammers to assist on the larger sizes. During World War I there was a serious shortage of chain mainly due to an insufficient supply of suitable iron. This led to attempts to produce steel chain by firewelding, which were, in the main unsuccessful. Cast steel chain proved to be a viable alternative, however, and had the added advantage of being of higher tensile strength than iron. These factors acted as a major incentive to find a different method and led to the successful production of electrically welded steel chain.

Modern chainmaking has made tremendous advances in recent years, both in quality of steels and in manufacturing methods. Sophisticated high-speed machines incorporate the latest in mechanics, fluidics, electronics and microchip technologies. Chains themselves come in various grades of steel for different applications, some being many times the strength of wrought iron.



2. MODERN ANCHORS

Anchors currently in popular use fall into three broad categories – traditional, lightweight and mooring anchors – while within each category there are numerous designs. Each category of anchor is based on a slightly different design concept and is in consequence more suitable for certain applications than others.

TRADITIONAL ANCHORS

Historically, these anchors reflect the experience of mariners for the past 2500 years, in that they are a compromise between pure dead weight for hard bottoms and the ability to bite and hold in soft bottoms. The following designs remain popular today, for very sound reasons.

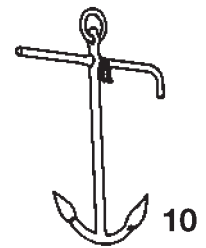
Stockless Anchor (Fig. 9)

The stockless anchor retains its popularity for the very simple reason that it will stow in a hawse pipe. However, most types rely almost entirely upon weight, and that fact makes them unsuitable in small sizes for pleasure boats. For larger vessels they are ruggedly built, handle easily, and without a stock readily disengage from sea bottoms and submerged wreckage. In small sizes they will hold as a rough approximation 2 to 3 times their own weight, and about 5 times in ships' sizes.



Fisherman Anchor (Fig. 10)

The fisherman anchor has changed very little over the years. It will hold 3 to 8 times its own weight, far less than the modern lightweight patterns, but in spite of this has its uses. It will sit well and remains a favourite on rocky shores or in kelp where other anchors often fail to get a grip and constantly develops its maximum holding power with less chain laid out than is required for the lightweights. Its disadvantages are that its palms lack sufficient area to hold well in mud or sand, and if the vessel is allowed to swing round, the chain may become wrapped round the other fluke – the one sticking up out of the bottom. The result of such fouling is to turn the anchor chain into a trip line.



Grappnels (Fig. 11)

Much that has been said about the fisherman anchor is equally true of grappnels. The folding type, particularly in smaller sizes, remains popular for very small craft where its ability to stow neatly, easily and in a very small space is a significant advantage.



LIGHTWEIGHT HIGH-EFFICIENCY TYPES

This century has seen the introduction of various lightweight high-efficiency anchors which will, under certain circumstances, hold as much as 100 times their own weight. Most are recognised by Classification Societies and in view of their higher holding power, they are allowed to be of significantly lighter weight. Holding power is proportional to fluke area (or, more correctly, to aspect area) and they set very well except on bottoms having large amounts of seaweed or rocks. In these latter circumstances they tend to skate along the bottom rather than dig in. It is important to bear in mind that although with lightweights the increased holding power of a bigger anchor comes primarily from the increase in fluke (blade) area, not weight, it must have weight to penetrate. Too small an anchor will be ineffective. There are two basic types with a number of variations and at least one patented design which is an amalgam of design features from the two.

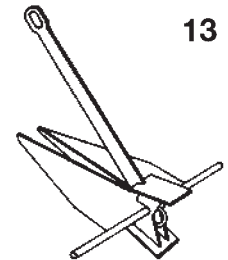
Plough Anchor (Fig. 12)

Developed in 1933, the stockless plough anchor is remarkably effective and in its heavier sizes penetrates kelp and seaweed, shell and overlying gravel better than most lightweights. It is, like all lightweights, extremely efficient in mud and sand, and once buried will remain so even though the direction of pull changes with wind or tide – thanks to the angled hinge on the shank.



Cruising Anchor (Fig. 13)

Anchors generally known as cruising anchors are all variants on the original 1939 Danforth design. With its wide, flat and sharp flukes this type of anchor readily digs itself into mud and sand when it is heavy enough. It has a stock located at the head ('crown') which gives initial stability and alignment to help it dig in. Crown design is such that it offers little resistance both during the burying operation and also when it is being broken out again. It has the advantage of folding flat for deck stowage.



MOORING ANCHORS

Although the types of anchors described previously are often employed for permanent moorings, an anchor specifically designed for the job is a far better proposition. In general it will be cheaper, more ruggedly built, and with few if any projections which can be fouled. It is far more efficient than a concrete block, which even when buried will only hold about its own weight, and of course it is much easier to handle.

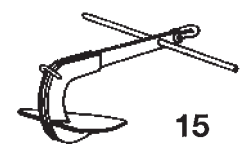
Mushroom Anchor (Fig. 14)

The traditional mushroom anchor has been popular for many years for use on a mud bottom. It takes a firm hold and remains fixed under adverse conditions. The design is such that when successive strains are applied it oscillates and creates suction, thus continuing to bury itself in the mud.



Single Arm Mooring Anchor

A single arm mooring anchor prevents fouling of other vessels at low tide and should have a shackle or hole at the crown to facilitate removal and for securing a marker buoy when desired. The most basic is in effect a one-armed fisherman anchor, and suffers from the fact that its palm lacks sufficient area to hold well. The A.M.12 is a single fluke anchor developed by the Admiralty for permanent Navy moorings. It has proven to be highly successful, combining weight with a reasonable fluke area and has led to a number of cheaper variants, often sold as proprietary designs. The Bradney mooring anchor (Fig. 15) is a high-efficient type with a particularly large fluke area generating very high holding power. It digs in well but like all lightweights, unless it can be inserted manually it needs a reasonable weight for the initial penetration.



3. CHAINS AND OTHER COMPONENTS

Today the range and variety of chains and fittings is probably wider than ever before and to compound the selection problem almost all components are available in various grades. Different strengths for otherwise identical items are achieved through the use of different steels and heat treatments, some more suited to the marine environments than others

STRENGTHS

Chains and fittings are manufactured in different strengths for specific applications, and the strongest component is not necessarily the best for the job in hand. It could be unsuitable for galvanising, or made from a steel which corrodes more rapidly, and it may be disproportionately expensive. As will be seen later, weight is as important as strength in moorings and the lowest and cheapest strength grade usually offers the best combination of properties. Internationally, there are standards covering chains and most fittings and these recognise the following grades:-

Grade 30 (3 or L)

This is the lowest grade with components made from mild steel without heat treatment and strength approximating to that of the now virtually unobtainable wrought iron.

Grade 40 (4 or M)

Normally manufactured from plain carbon steels and heat treated, this is the lowest grade recommended for lifting applications.

Grade 60 (6 or S)

This grade has been largely superseded by grade 80 and is likely to be withdrawn from the International Standards series.

Grade 80 (8 or T)

The highest strength in normal use; components are usually made from alloy steels and hardened and tempered.

Chapter 8 provides more detailed information on these various grades and their suitability for marine applications.

CHAINS

With the exception of stud link chain cable, chains are generally supplied in the grades detailed above. Stud link chain is normally supplied in grades mild steel U1, special quality U2 and extra special quality U3 as specified by Lloyd's Register of Shipping.

Stud Link Anchor Chain

Originally Studs were added to chain to stiffen the links, preventing them from severely deforming when overloaded. They have an added advantage in that they prevent chain from knotting up when twisted, thus avoiding problems when the chain is retrieved with a windlass. Most chain of this type is used on larger vessels and is rarely available in the smaller sizes.

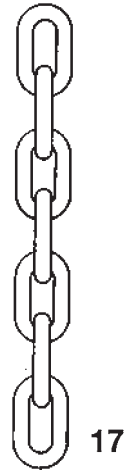
Occasionally, good second-hand chain can be found and this makes an excellent ground chain in mooring where the studs give extra weight. As all grades are designed specifically for marine use they are perfectly suitable for mooring applications.



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Short Link Chain (Fig. 16)

Internationally this is accepted as chain with a link of outside dimensions not exceeding 5 times the material diameter in length and 3.5 times in width – e.g. 10mm chain cannot have links larger than 50mm x 35mm outside dimensions. It should be noted that these are maximum dimensions only and if chain is needed to fit a windlass gipsy wheel it is unlikely that short link will be suitable. Excluding studlink, short link is the strongest, heaviest and most flexible of chains, and as such is the best choice for mooring and anchoring. Unfortunately the links are too short to accept shackles of reasonable size, necessitating the fitting of large end links. In effect short link chain needs to be assembled by the manufacturer into a 'bespoke' mooring which, although ideal, may not always be practicable.



Long Link Chain

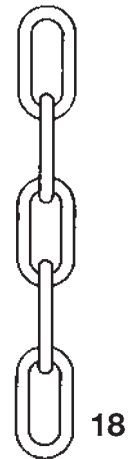
All chains which have links larger than short link are, to be correct, long link chains. In practice, however, chains with links just a little longer than short link – say 6 x 3.5 diameters – are commonly known as middle link. For many users middle link chains (Fig. 17) are a good compromise, as they offer most of the benefits of short link with the advantage that they will accept decent sized shackles without the need for special end links. Chains with links even larger (Fig. 18) are not the wisest choice, as they lack both strength and weight and are more liable to tangling in use.

Twisted Link Chain

As its name implies, twisted link chain has had a twist (usually 90 degrees) imparted to every link. The end result is a chain which has a smoother profile less likely to cause damage through abrasion. It has little use in marine applications and is mentioned here only because it was originally conceived as an alternative anchor chain.

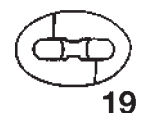
Calibrated Chain

Stud link chain is designed to be used with a windlass and as such is made to internationally accepted standard dimensions with close tolerances. Most other chains, however, are made to specifications which allow wide dimensional variations. In addition there are often variations within the same manufacturing batch due to alterations in machine settings. Obviously such chains are unsuitable for use on pocketed wheels where it is vital that the chain pitch remains constant and correct. To achieve this accuracy chain is calibrated during manufacture. The process involves making the chain deliberately short and then stretching it to its final dimensions. It is important to realise that these can be any dimensions specified by the purchaser and a chain which has been calibrated to fit one make of windlass will rarely work in another.



OTHER COMPONENTS

There is a wide range of other components which could be used in a mooring system and it is important to ensure that those used are of equivalent strength to the chain. Using components which will fit a chain, with no regard for relative strengths, is all too common. As an example, given similar materials, a conventional shackle which will fit directly into short link chain can at best be only about half the strength of the chain. Compatibility of materials is vital, too – the problems of dissimilar materials and electrolysis are only too well known.



Shackles

There are three main types of shackle in common use and a wide range of pin designs. The Kenter shackle (Fig. 19) is really a mechanical connecting link, and is designed for use with stud link chain. By far the most popular shackle types are the dees (Fig. 20) and bows, sometimes known as harps (Fig. 21). Dee shackles are usual where two components are to be connected together, whereas bow shackles are more suitable for use as three-way connectors. For moorings the screwed collared pin (Fig. 20) is the most common, although forelock pins (Fig. 21) are sometimes preferred.



Swivels

There are various designs of swivel available and the user should ensure that the one chosen will accept the correct size shackle or shackle pin. A chain swivel (Fig. 22) for example, is too small to be effective unless fitted with a large link at each end – or, of course, unless incorporated into an all-welded assembly by a chain manufacturer. Mooring swivels (Fig. 23) will take a shackle eye at one end and a shackle pin at the other. Oval eye and long bow swivels (Fig. 24) will accept shackle eyes at both ends.

Rings, links and other fittings

The range and variety of fittings which may be used in a mooring and anchoring system is far too wide to cover comprehensively in this booklet. Rings, egglinks, bridle plates, slip hooks, stoppers, eyebolts, ringbolts – all have their places. Suffice to say that compatibility in materials, strengths and dimensions is essential. Somewhat more must be said of mechanical connecting links, which appear at first sight to offer an attractive solution to the problems posed by shackles and short link chain. In practice, however, the majority of designs either have short life in salt water or need to be welded after assembly to ensure reasonable strength. They are invaluable for emergency repairs or to use as a stop-gap measure, but are in the main unsuitable for permanent installations.



4. DESIGN CONSIDERATIONS

There is one cardinal rule for successful anchoring – use plenty of weight – and this is equally applicable to permanent moorings. Anchors will only work effectively if the pull on them is nearly horizontal, but equally important is the fact that no mooring system is safe if it does not effectively dampen out shock loads.

FORCES EXERTED ON MOORINGS

It is an extraordinarily difficult problem to calculate the forces which may be exerted on a mooring in any one of the many possible combinations of tidal and climatic conditions. They are largely dependent on three main factors – wind drag, current drag and wave loading – each of which is in itself immensely variable.

1. Wind drag

This is the load resulting from the combination of wind pressure and suction on the hull above water, the superstructure and the rigging. Calculating a meaningful figure is complex. Aerodynamic loads increase with the square of the wind velocity. Effectively, this means that if the wind speed doubles, the wind force acting on the boat goes up four times. If it trebles, it goes up nine times. Having arrived at a figure – which itself is not so easy when it is realised that a yacht's rigging can contribute up to a third of the total air load – it then becomes difficult. The figure so far is based on frontal area (cross section facing the wind), but takes no account of tidal current or waves causing swinging at anchor. A modern high performance craft with little undergear will dance around merrily and spend most of her time not facing directly into the wind.

2. Current drag

In most instances current drag is a relatively minor load although it can be significant if the boat has a very large area below water or is anchored in, or even across, a strong current.

3. Wave action load

Wave action is likely to impose by far the highest loads on a boat and her ground tackle. She will heave, pitch, rear and yaw, but if she is allowed ample freedom the actual loads applied to the anchor (or anchors) will be modest. As will be seen later, this freedom is achieved through weight providing resilience in the mooring system and to achieve this the design needs to take into account these factors and conditions:

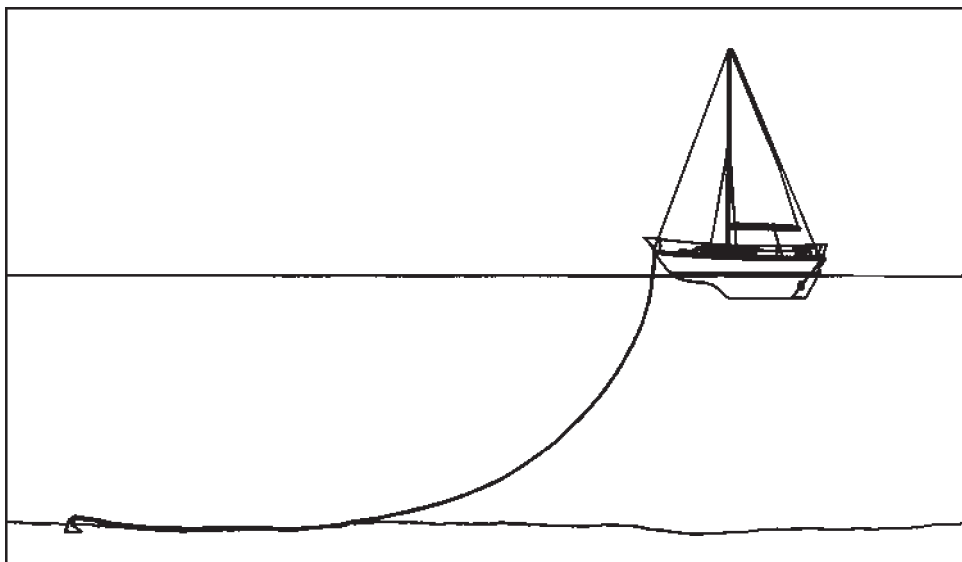
1. Maximum depth of water.
2. Rise and fall of spring tide.
3. Maximum current speed.
4. Prevailing wind and strength.
5. Abnormal conditions of wind and sea.
6. Site conditions – sheltered or exposed.
7. Type of bottom – sand, mud, shale etc.
8. Type, size and number of craft to be moored.

This may seem an impossibly daunting task, but fortunately we have the benefit of other people's experiences over many years. The types of calculations necessary for mooring design are valuable and the Appendix includes size tables which will provide useful guidelines, although there really is no substitute for local knowledge and experience.

SNATCH OR SHOCK LOADS

Shock loads, primarily caused by wave action, are the single biggest danger in anchoring or mooring. A normal load on the system can suddenly increase ten,

twenty – even fiftyfold. This can cause damage to bow fittings, break mooring tackle – or most likely, drag the anchor or even break it out. It is obvious that something stuck in the mud can be dislodged with a series of sharp blows more easily than with a steady pull. The only defence against shock loading is to let the effect die down before it gets as far as the anchor, and this is where weight is so important. Pure dead weight causes the chain of an anchored vessel to hang in a catenary curve and it is the 'spring' of this curve that dissipates the shock of a sudden surge and brings it under control without damage (Fig. 25). An anchor chain of infinite strength, but of no appreciable weight, would not be able to cushion shocks and would break the anchor loose or damage the boat when it jerked taut. Increasing the scope (using a longer chain) increases the weight and catenary curve, and increases the cushioning effect proportionately. By this means it is possible to eliminate practically all shock loads – or at the very least, to reduce them to manageable limits. As a general rule the minimum practical scope is 3 to 1. This means that the length of chain is three times the depth of the water. In winds of 30 knots, for maximum cushioning effect a scope of 7 to 1 will be needed, and even more in worse conditions. In very deep water the movement of the boat will have less effect on the catenary curve, so the scope can be reduced somewhat. Such scopes are rarely practicable in a permanent mooring and the cushioning effect has to be achieved in other ways. This question is dealt with in the next chapter.



25. The Catenary Curve

HOW ANCHORS WORK

All anchors depend on their ability to bury themselves in the sea bed to achieve their holding power. To do this they need a certain amount of weight, sufficient to start the burying process, and a near horizontal pull. This is where chain weight and the catenary curve are again vital. The chain must lead from the anchor horizontally or parallel with the bottom, even under strain. Any lead upwards decreases the anchor's holding power, the loss depending upon the angle and type of anchor. Most anchors will break out of the ground once the angle of pull reaches about 10 degrees from the horizontal. The essential features of an efficient anchor are as follows:

1. It must have sufficient weight for initial penetration.
2. It must bury itself deeply when subjected to a horizontal pull.
3. Once buried it must have the greatest possible resistance to movement in the direction of pull.
4. It must remain rotationally stable even when pulled through the sea bed.
5. It must break out of the ground easily when pulled upwards.

Holding power

The holding power of any anchor varies with its size and with the bottom, and is not a fixed value. The sea bed is far from uniform even within a relatively small area and anchor performance is affected not only by the nature of the bottom – mud, sand, silt, shingle etc. – but also by local inclusions of rocks, scrap metal and the like. Compared with sand, soft mud reduces holding power by about a third, whereas firm clay can increase it by as much as two thirds. Once an anchor's own dead weight has caused it to initially penetrate, as it moves horizontally so it continues to bury itself deeper. If it is too light to effect this initial penetration it will skate over the surface. Having embedded itself, resistance to movement through the sea bed is related to the amount of material that would be removed by the anchor if it pulled out. It follows that in principle an anchor with the largest effective fluke (blade) area has the highest holding power, subject of course to it being of sufficient strength. Effective fluke area varies with the angle that the fluke takes up in operation. Too shallow an angle reduces the effective area and the holding power, whereas too steep an angle prevents the anchor from fully penetrating the sea bed. Such an anchor develops insufficient downward pressure and will plough up the surface without digging in any deeper. Obviously, material that is more compacted is more difficult to displace, so an anchor also needs to be streamlined to achieve penetration without unnecessary ground disturbance. An anchor which digs deeper will again be in contact with more compacted material and have proportionately greater resistance to movement. Once it has fully penetrated, the actual weight of an anchor has very little effect on its holding power.

The effect of increased loads

If the load on an anchor increases it will move forwards and penetrate deeper into the sea bed until the resistance to movement equals the load. As the load continues to increase, eventually it will be so deep in the ground that the chain begins to angle upwards. When the upward pull equals the downward force generated by the anchor, it is at maximum penetration and has developed maximum holding power. Any further increase in load will pull the anchor horizontally through the sea bed.

5. PERMANENT MOORINGS

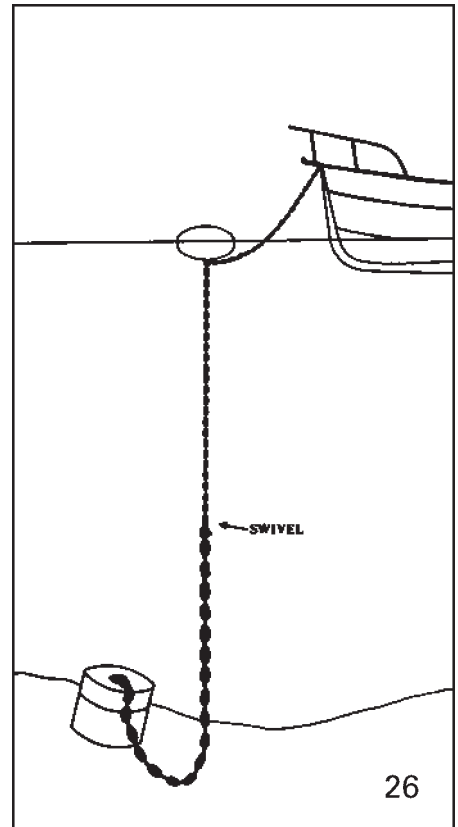
A boat left unattended for long periods is extremely dependant upon her mooring, which must be totally reliable and able to withstand the worst conditions likely to arise. To achieve this both the type of component and the method of layout must be carefully considered.

SINGLE ANCHOR MOORINGS

Although a single anchor mooring which lets the boat swing freely with the wind and tide does not generate unduly high loads, it does present one problem. To work successfully it normally demands a minimum scope of around three times the maximum depth of water and in consequence also needs swinging room which is rarely available. The problem can be partially overcome by using a heavier chain, or preferably a length of very heavy chain at the bottom attached to a lighter chain leading to the buoy. The object is to again to provide an adequate shock absorbing effect, but such an arrangement needs to be very carefully calculated. Its success depends on achieving the correct combination of weight and length, and less scope makes the size calculation much more critical. Such systems are often used in conjunction with 'clumps' (Fig. 26) or purpose-built sinkers.

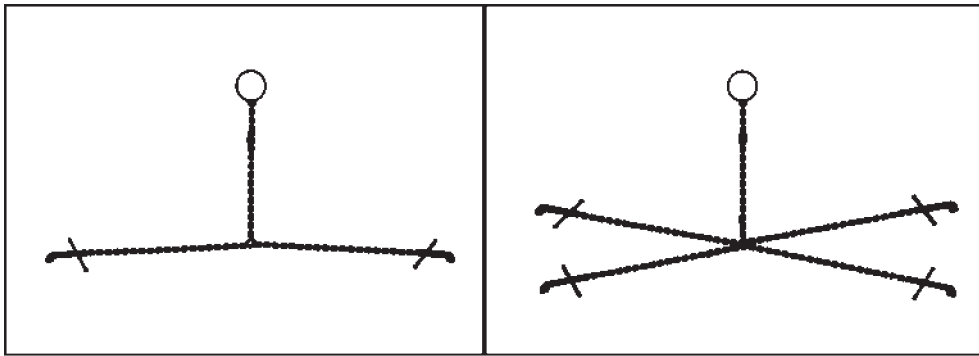
Clumps

A 'single anchor' mooring is the only type of mooring where a clump is preferable to an anchor. In this type of system an anchor is likely to turn and re-set itself in the sea bed with each change in wind or current. This will plough up the bottom and reduce holding power, increasing the likelihood of the anchor dragging or fouling the chain. If a clump is used, however, it should be appreciated that its effectiveness will vary with the nature of the sea bed and with the design of the clump itself. A weight which just sits on the bottom will resist a horizontal pull of less than its own weight – and it will weigh less under water than in air. Buried in mud or sand its resistance to pull will increase substantially and holding power can be further improved by good design. A properly proportioned sinker will create suction to such a degree that when buried its holding power can be increased by as much as four times.



MULTIPLE ANCHOR MOORINGS

The worst possible mooring is one which uses two anchors or clumps which hold the boat fore and aft so that she is constrained to lie with wind and sea on the beam. In these circumstances shock loads will increase dramatically, possibly with disastrous consequences. Fore and aft moorings can work satisfactorily, but expert design is essential. In general it is preferable to use a single pendant (riser) to a mooring buoy, with two or more anchors on a bridle (ground chain). The pendant should be short link chain, or possibly middle link to facilitate shackle connections. Ground chain is normally long link, although good used studlink chain serves admirably. Two-anchor moorings are widely used in sheltered rivers and channels where current flow is up and down, and have proved to be entirely satisfactory. Where heavier seas are likely, or where current flow is less predictable, three anchors may be employed, and in really exposed situations four or more (Fig. 27). The principle is to have anchors spread so at least one will resist the load from whichever direction that load may come. Whatever system is adopted it is essential that all single-pendant moorings incorporate a swivel to prevent the pendant from being 'wound up' and thus shortening the scope.

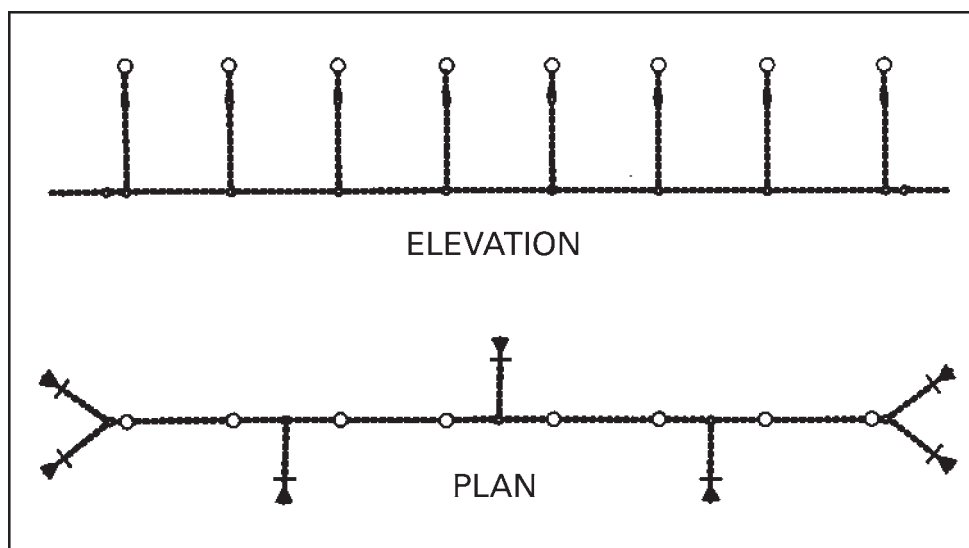


27. Typical single-pendant moorings

With these types of mooring systems a shorter scope will work satisfactorily. The reason for this is that the ground chains eventually bed themselves into the sea bottom and so add to the degree of inertia latent in the mooring. This increases its capacity to absorb shock loads, so that instead of the load being absorbed by the catenary curve in the pendant alone, it is shared between the pendant and the bridle. While ground chains should be laid in a straight line it is unnecessary and, indeed, undesirable to have them taut. A degree of slack allows the bridle to bury itself in the sea bed and share the job of shock absorbing with the pendant. Too much slack, however, will result in the chain dragging along the bottom and shock loading anchors as the direction of pull changes. From this it is apparent that ground chains should be as long and as heavy as practicable, and given that the arrangement of ground chains is satisfactory the pendant can be as short as 1.5 times the depth of the water at high tide – although longer is better if there is room. Obviously, any pendant needs a buoy capable of supporting all the gear not lying on the sea bed at high water. The modern trend is to take a pickup chain from the buoy to the boat, with a small pickup buoy attached to this chain.

TROT MOORINGS (Fig. 28)

A trot mooring consists of a long and heavy ground chain anchored at each end, with risers at intervals so that a single assembly serves to moor a number of boats. Additional anchors may be required to hold the ground chain in position, particularly if the main current flow is across the line of the chain. Anchors are often laid on triangular bridles themselves attached to the main ground chain, so that any imposed stress is redistributed to two or more anchorage points. The usual design principle applies equally to trot moorings in that sufficient resilience must be built in to accommodate shock loads.



28. Typical trot mooring

PONTOONS, FISH CAGES AND SIMILAR STRUCTURES

Structures which utilise a number of separate single leg moorings present the same sort of problems as conventional systems, except that swivels are only necessary for single point turning moorings and can be omitted from the design. Anchors are superior to sinkers, each anchor being attached to a heavy ground chain. Ground chain should be as long as practicable and preferably at least twice the depth of water. The ground chain is itself attached to a riser which goes direct to the structure. Depending on the type of structure, a buoy may be necessary to help support the weight of chain.

LAYING A MOORING

When any type of permanent mooring is assembled there are a few basic rules to bear in mind. Unless the mooring is a complete all-welded assembly shackles or some other form of mechanical connectors will have to be used. These are almost invariably weaker size for size than chain and although in a well designed system loads should be modest it makes good sense if all components are of roughly comparable strength. Therefore shackles (and swivels) should be chosen which are at least one size larger than the chain. Rings, often used between bridle and pendant, need to be substantially larger to achieve equivalent strengths. Shackle pins are another problem area. Screw pin shackles are by far the most popular and many have their screw threads cut after galvanising. Consequently the threads corrode rapidly, pins work loose, and eventually the shackles fall apart. There is no easy solution, but at the least all shackle pins should be very securely moused (wired) or if possible arc welded after assembly. A thick solid wire should be used for mousing and never wire rope, where deterioration is rapid and possibly hidden from view.

It is difficult to recommend correct lengths for ground chains as so much depends on system design, local conditions and the size and type of chain being used. With multiple anchor moorings laying is much easier if the ground chain is somewhat longer than the water depth, however, so that one anchor may be on the sea bed before the next is released. Maximum length is in practice only governed by local facilities for handling what may well be a pretty heavy piece of chain!

Placing an anchor or sinker precisely can be a problem unless the mooring site dries, although the basic method is the same for all types of mooring. Taking a conventional two anchor mooring (with a heavy ground chain between the anchors and a single riser in the middle) the procedure is as follows:

1. Make up the complete assembly including the buoy on the quayside, ensuring that all shackle pins are securely wired or welded.
2. Lower the first anchor with a rope through the crown. Mooring anchors are rarely self-righting, so care must be taken to ensure that the anchor falls onto the bottom the right way up.
3. Pay out the chain while heading straight towards where the second anchor will be laid.
4. Lower the second anchor, again with a rope through the crown. Use this rope to tow the second anchor away from the first, thus straightening the chain.

Although anchors will bed in once a mooring is in use, it is good practice to help the process by towing the rising chain away from each anchor in turn. It is particularly advisable to bed in anchors for rigid structures where undue slackness in mooring legs can cause problems. Considerable force is needed to bed in a large anchor, however, necessitating the use of a powerful vessel or winch.

MAINTENANCE

Although every system of maintenance must be based on regular inspection, the precise procedure to be followed for any mooring depends upon local conditions. If a mooring is exposed to strong tides and rough weather it will naturally wear more rapidly. Normal wear and tear is not, however, the only cause of damage to mooring components. Corrosion, erosion and electrolysis can all be responsible for rapid and dramatic removal of metal. Consequently moorings on new sites need to be carefully monitored until a wear pattern can be established.

If possible moorings should be lifted for winter storage, or alternatively the riser may be sunk and marked with a buoy. Either of these procedures can double a mooring's effective life. Another useful tip is to position the swivel, which wears quite rapidly, at the top of the riser, where it can be easily inspected in situ. Finally, no time should be lost in making an inspection of a mooring where movement has been detected or is suspected.

Permissible wear

The degree of wear that can be safely permitted before replacement again varies with individual circumstances. A ground chain will often be far larger than strength requirements dictate, as it is bought primarily for its weight. Risers, however, have to be supported by a buoy and so tend to be nearer to the minimum acceptable size. As a guide one should not allow anywhere more than a 15% reduction below the chain diameters recommended in the Appendix. Remember that the ends of a link (where adjacent links are in contact) wear more rapidly, so particular attention should be given to these areas. Badly rusted chain should never be used, particularly if the surface has been removed to expose the grain of the metal.

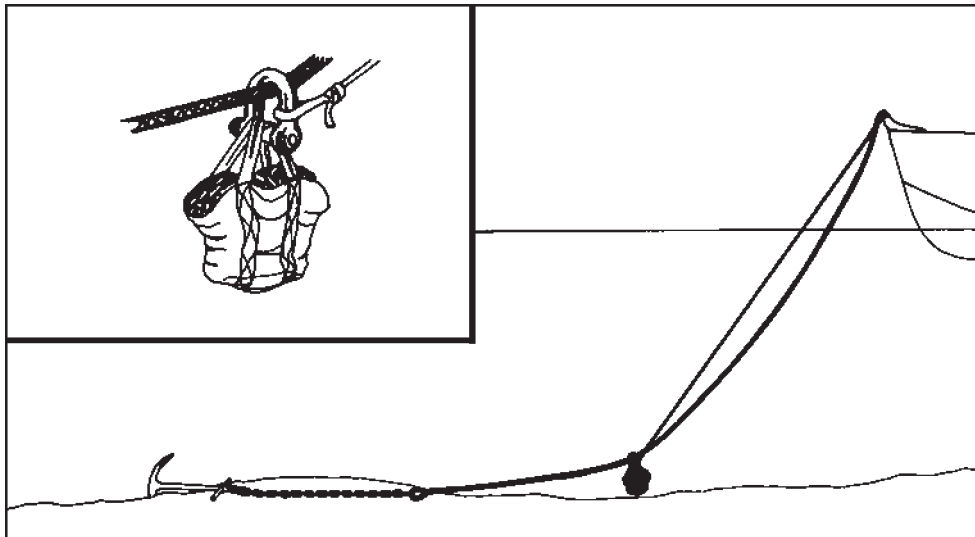
6. ANCHORING

Anchoring should never be treated lightly and care must be taken in choosing the spot, preparing equipment, and in letting the anchor go. The first consideration is to determine the kind of bottom and reference to Admiralty charts may well help in this respect. Hard sand is ideal, rock should be avoided. Between these extremes soft sand and mud offer reasonable holding power, but there may be difficulties in persuading the anchor to hold in shell, gravel or where there are quantities of seaweed. For this reason it is not a bad idea to carry two types of anchor – a modern lightweight and a traditional fisherman pattern for use where the bottom may cause the lightweight to skate over the surface. The chart should also indicate bottom contours and depth of water. Obviously a steeply sloping sea bed can be a problem when a boat turns and one needs to know the depth of water in order to ensure adequate scope. Both the bottom contours and depths can be checked with an echo sounder but do remember to allow for a rising tide! At the opposite extreme, if the site is likely to dry out, go around the boat with a pole to establish what the bottom is like, or take soundings with a lead and line. Finally, thought must be given to possible changes in the weather and a position chosen accordingly.

The anchor should be prepared for lowering and the chain arranged so that it can run freely. If rope is used laid ropes should be coiled, multiplaits flaked down. The tail end of the anchor chain or warp must, of course, be fixed to the boat. The usual method is to attach it inside the chain locker – which, incidentally, should be well drained and preferably lined with an inert material. If using chain it is prudent to incorporate a rope between the chain and the fixing in the chain locker. The length should be such that some of the rope can run out onto the foredeck. This will allow the scope to be increased by adding extra rope fairly easily. In an emergency the chain could be quickly buoyed for recovery later and the rope cut. Finally, some way is needed to establish how much chain has been run out. Paint markings rapidly vanish, particularly if the chain passes over a windlass. Unless the windlass is equipped with a meter, knotting short lengths of cord into the chain at predetermined intervals is probably the most practical solution.

Positioning a boat prior to dropping anchor is by no means as simple as it seems. There are a number of factors to be taken into account all at once – the effect of wind and current, the position of other boats already at anchor, and the length of anchor chain that needs to be laid. Firstly, try to estimate where other boats have placed their anchors and try to visualise the amount of scope they are using. Choose a position far enough away, so that there can be no danger of collision should conditions change. When coming to anchor, head into the wind or current, whichever has the greater effect. If other boats are present this is easy, as all that is needed is to come in parallel with them – although if possible anchor astern, rather than alongside. Particular care must be taken if it is blowing and other boats are sheering about. In these circumstances the positions of the boats may give little indication of the position of their anchors.

When actually letting go, pay out chain or rope slowly. If allowed to go out in a rush it can foul the anchor or pile on top of it when it hits the bottom. Then the anchor will not dig in and is reliant solely on weight. The correct technique is to let the boat gather stern way, or to motor slowly astern while paying out the rope or chain. When a length equal to twice the depth is out, lightly snub the cable to 'set' the anchor. Then continue to pay out until the desired scope is achieved – a minimum of 3 to 1 for chain and 5 to 1 for rope. Remember that this means that the length of cable laid out is 3 or 5 times the high water depth. If in a crowded anchorage it may not be possible to achieve this minimum scope so compensate by 'backing the anchor'. This means sliding a weight (a 'sentinel') on a traveller or large shackle down the cable to a point just short of the depth of water (Fig. 29). The effect of this is twofold. Firstly it significantly increases the catenary curve and secondly it ensures that the pull on the anchor is more nearly horizontal.



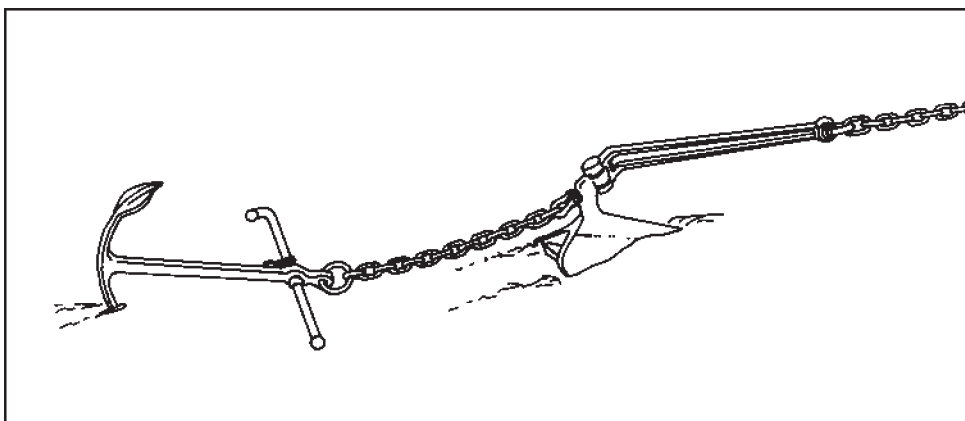
29. A Sentinel

Having done this, all should be secure, with the anchor well and truly dug in. Check on shore marks to ensure that the anchor is not dragging and double check (if using a chain cable) by holding the chain itself outboard of the bow fitting. If the anchor is dragging, vibrations can be felt being transmitted through the chain. This does not work with rope, however, where a strong current will cause similar vibrations.

Once at anchor it may be that the boat will not lie comfortably, either through particular wave formations or eddies. There are two simple things that can be tried before deciding to re-anchor elsewhere. Firstly, drop a sea-anchor (a 'drogue') astern. This needs to be nothing more elaborate than the canvas bucket normally kept on board. Alternatively, fixing the helm to effect a wind-induced sheer will present a different prospect to the oncoming waves and may well result in an improvement. When anchoring in these sorts of conditions make absolutely sure that the cable cannot jump out of the bow fitting. If it does it will almost certainly result in serious if not disastrous structural damage.

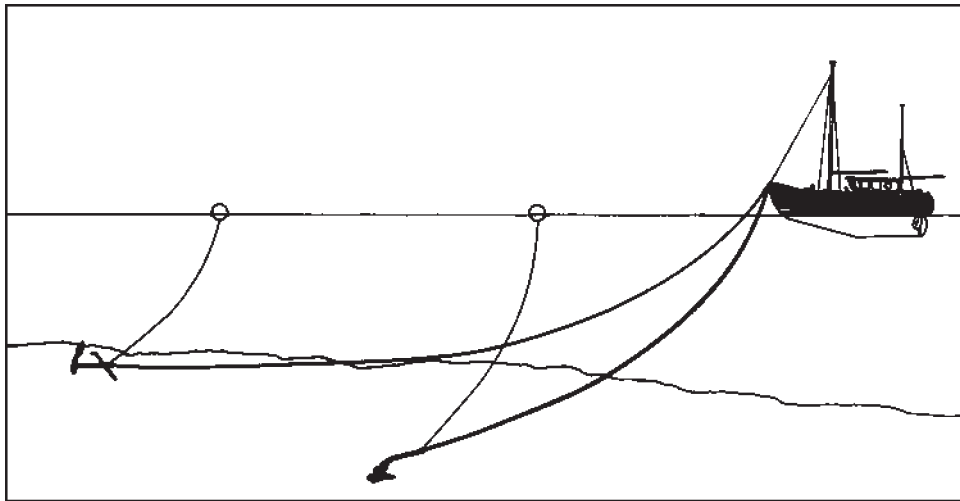
Using two anchors

All boats should carry two anchors for the very obvious reason that an emergency may leave no alternative but to slip the cable. Normally these will comprise a modern light weight as the main or bower anchor and a fisherman pattern as the kedge or for use on rocky bottoms. There are, however, certain circumstances where it is highly desirable to use both anchors, either to provide added security or to limit the amount of swinging room needed. This does not imply their use in tandem. The practice of connecting a kedge by a length of chain shackled to the crown of the bower should generally be avoided. Although holding power is obviously increased, if there is no alternative but to cut and run, unless three anchors are carried the reserve has gone as well! For this reason, whenever two anchors are used it is prudent to buoy them.



30. Anchors in tandem

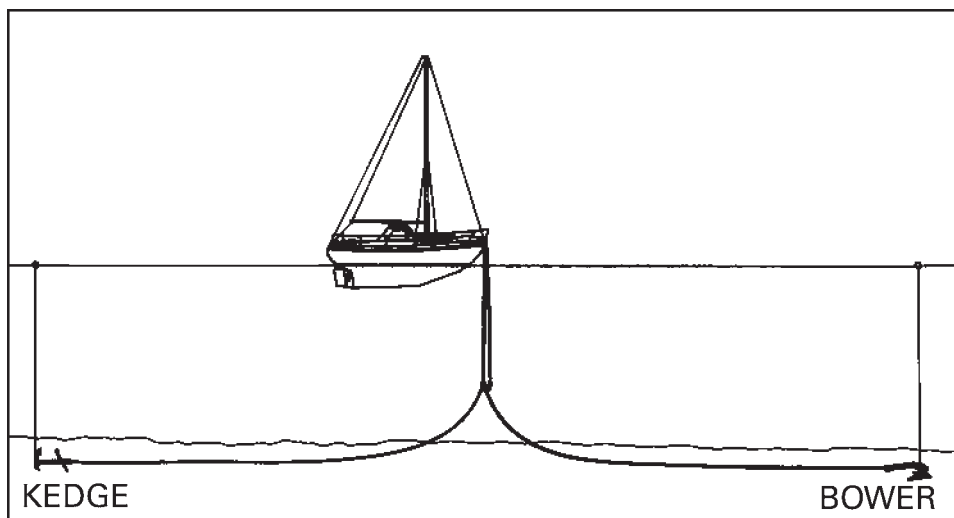
Apart from the obvious fore-and-aft arrangement, there are two other quite different ways in which two anchors can be used successfully. The first gives vastly increased holding power for rough conditions, whereas the second has the prime advantage of reducing swinging room to a fraction of that required with a single anchor.



31. Two anchors for rough conditions

If it is necessary to anchor in an exposed position where strong winds are expected from a particular direction, two anchors will be of great benefit. Having anchored to the bower in the normal way, motor or sail to a position well to one side and level with the bower. Then lower the kedge and pay out cable until both cables are of equal length. Aim for a final position giving an angle between the two cables of 30 to 40 degrees and of course, plenty of scope.

The layout to reduce swinging room is achieved as follows. Firstly try to decide from which direction the highest loads will come, and motor in that direction for about 30 metres from the intended final position. Lower the bower anchor, reverse for some 60 metres, and lower the kedge. Then motor ahead, paying out cable to the kedge while simultaneously taking up the slack on the bower. When midway between the anchors, haul in each cable as hard as possible and fasten the kedge cable onto the bower cable with a rolling hitch or large shackle. The tail end of the kedge should be retained on board. Finally, lower the bower cable until the rolling hitch is well below the keel. This arrangement copies the standard two anchor, pendant and bridle permanent mooring with the equivalent reduction in the swinging room required.



32. Two anchors for reduced swinging room

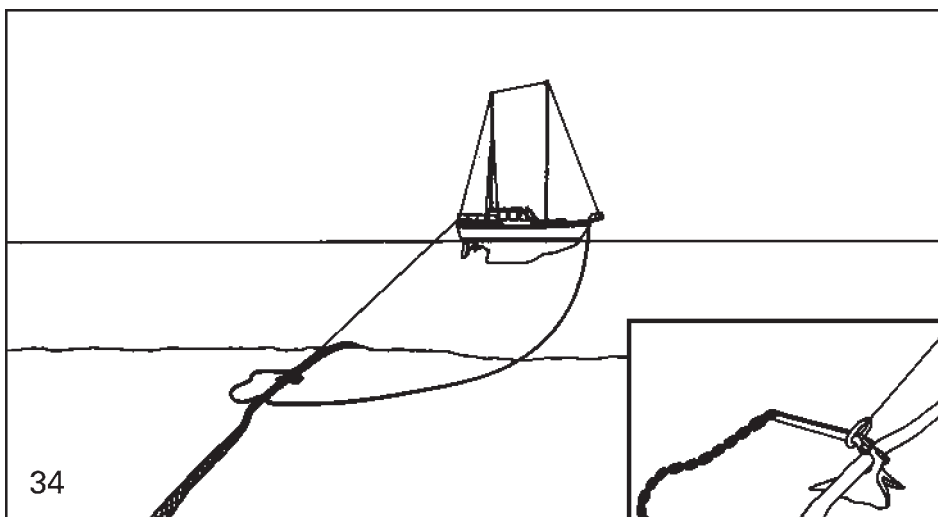
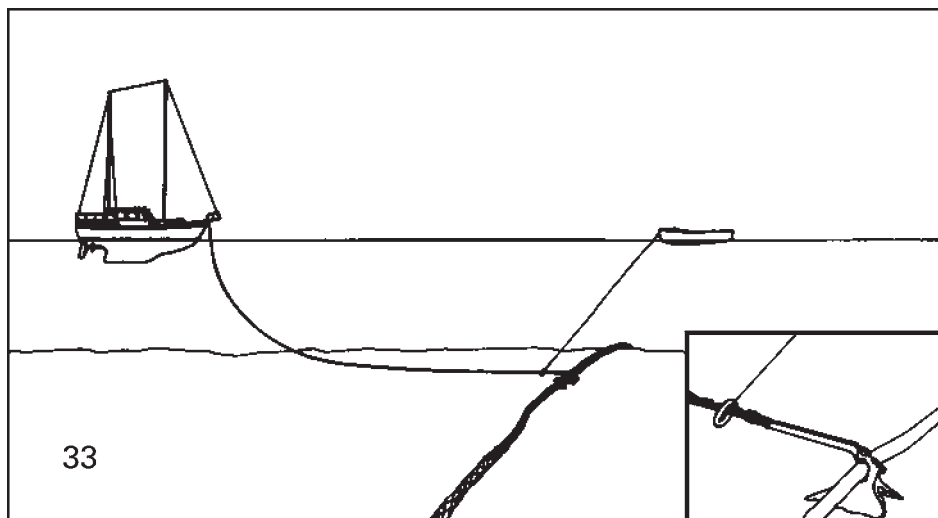
There is one point which should be understood when using either of these last two double-anchor arrangements. In both cases a boat may circle her mooring and wind the two cables around each other with a consequent shortening of scope.

They should therefore only be used as temporary expedients, and are entirely unsuitable for long term moorings.

Tripping lines

Sooner or later it is almost inevitable that an anchor will become fouled on the sea bed. Then a buoyed tripping line attached to the crown anchor is invaluable – but at all other times it will be an unnecessary extra annoyance. Tripping lines can be fouled by other boats or picked up in error, and have an infuriating habit of wrapping themselves around anything within range. In these circumstances they will do exactly what their name implies – trip the anchor! A length of chain inserted into the line will help to ensure that it hangs vertically from the marker buoy, or the line can be lightly attached to the anchor chain itself so that it can be broken away when needed. Neither is a perfect solution, however, and the choice of whether or not to use tripping lines remains a difficult one.

There are, in fact, a couple of things that can be tried to free a fouled anchor without using a tripping line. The first, obviously, is to sail or motor around so as to vary the angle of pull on the anchor. If this fails then it is unlikely that the anchor will be freed without somehow exerting a backward pull on it. With a head-stocked or stockless anchor this can sometimes be achieved by sliding a large ring or shackle on the end of a line down the anchor cable. The ring must then be persuaded to run along the cable and along the anchor shank as far as the crown. Probably the best way to do this is to take the end of the line on board the tender and to take the tender in a direction over and past the anchor (Fig. 33). Once the ring is in position the line should be kept slack and taken back on board the boat. Finally, motor the boat over and past the anchor, tightening the line just before the anchor cable comes under load (Fig. 34).



Safety

Handling anchors and chains – especially on a wet and heaving foredeck – is fraught with danger, and should be approached with great care. Anchors by definition tend to be heavy and unwieldy, and it is only good sense to give some thought to making the job of handling and stowage as easy and safe as possible. Chain and rope have their inherent dangers, too. Never take a turn around the hand and be careful where the feet are positioned, or a nasty injury could result. The cardinal rule is to take time and do everything methodically and in sequence. Make sure that everything can be lashed down securely and easily and, equally important, that in an emergency it can be brought into action quickly. A little forethought and planning can prevent easily avoided and often serious accidents.

7. CHAIN versus ROPE

At first sight, an elastic rope – such as one of nylon, which has the ability to stretch by up to 20% – offers a very attractive alternative to chain. It has a high strength to weight ratio and will absorb loads well, returning to the original length without loss of strength once the load is removed. In practice, however, there has been a high incidence of failures with ropes in moorings.

Strength

One of the difficulties with rope is that of establishing the correct size for the application. The problem of calculating forces exerted on a mooring have already been emphasized. With chain, provided that there is sufficient scope and weight, these are largely academic, as the catenary curve will absorb whatever loads are likely to be generated. A rope is too light to create this curve, however, and one that is too strong will pull the anchor loose before it stretches enough to get any spring action. Conversely, if it is too weak it could stretch to breaking point.

Chafe

Chafing is by far the most common cause of rope failure and it is surprisingly difficult to prevent. Anti-chafing gear is essential wherever the rope is likely to be abraded and frequent careful inspection is imperative. Danger areas are where it passes through a fairlead, where it is connected to a buoy or swivel and, of course, where it can rub on the bottom. With regard to the latter the only safe way is to make sure that even at low water springs it never touches the sea bed. This almost invariably means that a length of chain has to be used to connect the rope to the bridle or anchor. As an additional safeguard the chain/rope junction could be buoyed, or the rope could be protected by a plastic sleeve.

Scope

The one critical factor which affects holding power is the angle of the pull on the anchor. However it is achieved, it must be near to horizontal and this is much more difficult to ensure when anchoring with rope. To achieve the desired angle of pull it is common practice to use a length of chain between the anchor and the rope. This has the added advantage of lessening the likelihood of the rope chafing on the bottom, but even with this, greater scope is required. As a rough guide such an arrangement needs a 5 to 1 minimum scope compared to 3 to 1 for chain. The weight of chain hanging from a boat reduces sheering about and its shorter scope demands less swinging room, giving it a distinct advantage over rope in confined harbours.

Connections

Rope also presents some problems in joining it to other components. Even a skilfully executed eyesplice will weaken a nylon rope by up to 15%, whereas a badly made one, like most knots, will effectively halve its strength. Other ropes will present other difficulties; some modern synthetic types, for example, are particularly 'slippery' so knots and splices are more suspect. Laid ropes may be spliced to chain quite easily or can be fitted with thimbles to facilitate the use of shackles, but braided or plaited ropes are more difficult to work with.

Conclusions

Chain of course has its drawbacks too. It will wear, rust, and is generally awkward, heavy and dirty to handle. In its favour are the facts that it stows easily, worn sections can be replaced, and it offers the overriding benefit of distributed weight. Finally, it does not deteriorate in sunlight, so maintenance can be safely limited to a periodic visual inspection. All things considered, chain surely remains superior for this application.

8. SELECTING CHAINS FOR MARINE APPLICATIONS

Every year there are numerous reports of users experiencing problems with chain in a marine environment. The question of assuring reliability in this particular application is not as simple as it first appears. There are a number of causes of premature chain failure, the most obvious one being poor product quality. Others are associated with some form of corrosion or abrasion.

PRODUCT QUALITY

Excluding wear, chains break in service for one of four reasons: poor quality, brittle material, misuse or excessive loads being applied. Quality is the responsibility of the original manufacturer and can only be assured by careful control of the manufacturing processes and by thorough testing of the finished product. Virtually all chain is sold with a test certificate stating that a certain proof load has been applied, but this alone is not enough. Most grades of chain should not break until subjected to a load of at least double the proof load. By then the chain will have stretched and this combination of high breaking load with stretching ensures good resistance to shock loads. Consequently all chain makers should take samples for destruction tests as a regular part of the manufacturing process. Reputable manufacturers will be able to provide documentary evidence of testing procedures, but certainly with imported products this is not always the case. There are proven instances of chains imported with signed test certificates which consistently failed at well below the specified proof loads.

The second cause of chain fracture is brittle material. This is by no means uncommon, but the reasons for brittleness are too technical to cover in this booklet. Generally it can be avoided by knowledgeable selection of materials and good manufacturing technique. One cause of brittleness must be emphasized, however, as it is of particular relevance to the marine user. Galvanising an alloy chain can, unless carried out with expert knowledge, render it useless and liable to snap without warning.

The problem of chain breaking through excessive loads is easily avoided. The importance of scope and weight in moorings has already been stressed. Sufficient shock absorption from the catenary curve is essential and for both security and economy it makes sense to use the heaviest and longest chain that is practical.

CORROSION AND ABRASION

It is all too common for marine chains to erode very rapidly, although this is rarely due solely to corrosion. In certain conditions electrolytic action can remove material at an alarming rate. Semi-colloidal suspensions of sand and silt will cause chain links to literally grind themselves away. Severe turbulence can actually sandblast the chain and will aerate the top layers of water creating a scrubbing action to shorten chain life. Local waters may be contaminated by effluents with similar effect, so what can be done? Recent work suggests that in some instances electrolytic action can be somewhat reduced by fitting sacrificial anodes to moorings, but the other problems remain. All that can be done is to select materials which experience and research suggests are those most suitable, and this alone can substantially increase chain life.

MATERIALS FOR CHAINMAKING

At this stage it is clear that there are two points on which a potential purchaser must seek assurances. Firstly he should ensure that the chain is produced by a reputable and knowledgeable manufacturer and that it is fully tested. Secondly he must establish to his complete satisfaction that the material is suitable for the application. Materials which may be considered for marine chains are as follows:-

Wrought iron

Wrought iron has been traditionally used for fire-welded chains. Compared with other materials currently in common use it unquestionably has superior resistance to corrosion. Unfortunately it is no longer made in the U.K. on a regular basis. Furthermore there must be serious doubts about the quality of any iron chain produced in recent years. Lack of good quality iron and the demise of fire welding have effectively ended wrought iron chain, which in any event was a troublesome commodity due to its tendency to embrittlement necessitating regular heat treatment.

Carbon Steels

In general, plain carbon steels are used to produce what are known as mild steel and higher tensile steel chains, grades 30 and 40(M), to various British and international standards. These standards are, however, performance standards only, in that while they demand certain mechanical properties of the chain they do not specify materials. This has led to a widespread practice whereby chain dealers offer sub-standard, reject, surplus or secondhand chains all as mild steel chain. This practice is misleading and can be dangerous. At best such chains will give a (sometimes dramatically) shorter life. At worst, such as when a secondhand or reject high grade alloy chain has been galvanised, the product can be disastrously unreliable.

Alloy Steels

These are steels which, in addition to the carbon, manganese, sulphur and phosphorus found in carbon steels, contain alloying elements such as nickel, chromium and molybdenum. After heat treatment alloy chains offer higher strength size for size and find widespread applications in lifting and mining. However, for most marine applications higher weight is an advantage, not a disadvantage. Metallurgists agree that (with the exception of stainless steels), the lower the carbon and alloy content the greater the resistance to corrosion. It follows from this that alloy steels will always corrode more quickly than low carbon mild steels.

Stainless steels

There is a wide range of so-called 'stainless' steels, many of which are far from stainless in a marine environment. Those specifically selected for marine use are suitable for many above-water applications, but there are sound technical reasons which preclude their use for permanent mooring chains. Apart from this, they are far too expensive to consider in the sizes and weights of chains necessary for moorings, although some are used as windlass chains in preference to the usual galvanized carbon steel. They are available in strength grades 30 and 50.

CONCLUSIONS

Considering all these factors it is obvious that the best compromise is a mild steel chain manufactured from steel in which the carbon and manganese contents have been kept as low as possible. Acceptable steels should contain no more than 0.3% carbon and 1.5% manganese and the lower the better. This range permits the use of grade 40 higher tensile steel chains for specific applications or where mild steel is not available. While this will not answer all the problems it is a good compromise and will preclude reject alloy chains. To ensure that they are getting the correct product purchasers should ask their suppliers for the following additional information:

1. Source of chain or, at least, country of origin.
2. Cast analysis for the material. This is particularly important when secondhand or reject chain is being considered.

By following these guidelines the user may confidently expect to obtain a good, reliable product with a reasonable life.

APPENDIX

SUGGESTED SIZES

The following tables are for guidance only, as much depends on local conditions and boat type. Larger sizes should be used on craft with unusually large windage, such as heavy rigging or large beam or superstructure. The suggested sizes assume reasonable shelter from the elements consistent with hull size and that an adequate scope is used. Vessels built to Classification Society requirements have their equipment sizes specified by those societies.

If in any doubt, choose a larger size – it will be money well spent both in terms of added security and extra life – but remember that all other components need to be of compatible size.

When establishing the sizes of anchors for permanent moorings the tables assume a single craft on a conventional two-anchor bridle and pendant system. Some reduction in weights is permissible where more than two anchors are used.

Multiple moorings are too varied to cover in these tables, but an approximation of the sum of the anchor weights required can be arrived at through simple multiplication.

Anchoring

Overall Length		High Holding Power*		Stockless		Fisherman		Chain Size	Nylon Rope
feet	metres	Bower	Kedge	Bower	Kedge	Bower	Kedge		
0-15	0-4.5	7kg	5kg	9kg	7kg	9kg	7kg	6.5mm	10mm
15-20	4.5-6	9kg	7kg	11kg	8kg	11kg	8kg	8mm	12mm
20-25	6-7	11kg	8kg	15kg	11kg	14kg	10kg	8mm	12mm
25-30	7-9	15kg	11kg	23kg	16kg	21kg	15kg	8mm	14mm
30-35	9-11	20kg	14kg	27kg	19kg	24kg	17kg	8mm	14mm
35-40	11-12	23kg	16kg	30kg	21kg	27kg	19kg	9.5mm	16mm
40-45	12-13	27kg	19kg	36kg	26kg	32kg	23kg	9.5mm	
45-55	13-16	34kg	24kg	45kg	32kg	40kg	28kg	11mm	
55-70	16-21	45kg	32kg	65kg	45kg	57kg	40kg	12.5mm	

*Many types of anchors are categorized as high holding power and there are substantial variations in their respective performances. As an example, a cruising anchor theoretically has a much higher holding power than a plough anchor. However, in practice these variations are not necessarily consistent, since one type of anchor may be more effective than another in any given sea bottom. Furthermore, a certain minimum weight is required to ensure satisfactory initial penetration. For these reasons and in common with Classification Society practice the table does not differentiate between the various types available.

Permanent Moorings

Overall Length		Single Arm Fisherman Type	Bradney Pattern	Ground Chain	Riser Chain	Pick-up Chain
Feet	metres					
0-20	0-6	15kg	10kg	11mm	8mm	6.5mm
20-24	6-7	18kg	12kg	12.5mm	9.5mm	8mm
24-28	7-8.5	21kg	14kg	12.5mm	11mm	9.5mm
28-31	8.5-9.5	24kg	16kg	16mm	12.5mm	9.5mm
31-35	9.5-11	30kg	22kg	19mm	14mm	11mm
35-40	11-12	35kg	25kg	22mm	16mm	11mm
40-50	12-15	48kg	35kg	25mm	16mm	12.5mm
50-60	15-18	60kg	45kg	28mm	19mm	14mm
60-70	18-21	80kg	60kg	32mm	22mm	16mm

Approximate Chain Weights

Chain size	Stud Link		Short Link		Middle Link		Long Link	
	lb/ft	kg/m	lb/ft	kg/m	lb/ft	kg/m	lb/ft	kg/m
6.5mm			0.6	0.9	0.6	0.8	0.5	0.7
8mm			0.9	1.4	0.8	1.2	0.8	1.1
9.5mm			1.3	2.0	1.2	1.8	1.1	1.6
11mm			1.8	2.6	1.6	2.3	1.4	2.1
12.5mm	2.6	3.9	2.3	3.4	2.0	3.0	1.8	2.7
14mm	3.3	4.8	2.9	4.3	2.6	3.8	2.3	3.4
16mm	4.0	6.0	3.8	5.5	3.3	5.0	3.0	4.5
19mm	6.0	8.5	5.5	8.0	5.0	7.0	4.5	6.5
22mm	7.5	11.0	7.0	10.5	6.5	9.5	5.5	8.5
25mm	9.5	14.0	9.0	13.5	8.0	12.0	7.5	11.0
28mm	12.0	18.0	11.5	17.0	10.0	15.0	9.0	13.5
32mm	15.5	23.0	15.0	22.5	13.5	20.0	12.0	18.0

This booklet is written on the basis of our present knowledge and experience. It is intended for guidance only and we cannot be held liable for any inaccuracies or for events resulting from the adoption of these recommendations.

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