OCIMF

Effective Mooring

Your guide to mooring equipment and operations




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Chapter 1

Effective Mooring

What does a mooring system do?

A mooring system prevents the ship from drifting away from a berth and holds the ship in place in relation to the loading/discharging arms *or* hoses, which may only have limited freedom of movement. Mooring lines may also assist in heaving the ship alongside a berth and can be used to assist in unberthing.

The mooring system has to maintain the ship's position against forces that will be trying to move it, which may be caused by one or more of the following:

(a) Wind
(b) Current
(c) Tides
(d) Surge due to passing ships
(e) Waves and swell
(O Change of draft and freeboard
(gj Ice

How big are these forces?

At a well sited berth, the greatest forces arise from wind and current, but to design a mooring system capable of resisting the extreme conditions of wind and current would create problems in both size and cost of equipment. It is therefore normal practice to establish arbitrary wind and current criteria and then design the mooring system to meet these criteria.

Commonly used criteria are:

J Wind 60 knots, plus a current on the beam of 0.75 knots, or

• Wind 60 knots, plus a current from ahead or astern of 3 knots

Both wind and current forces are proportional to the square of the wind or current speed, thus the force caused by a sustained 60 knot wind is four times that caused by a 30 knot wind, and the force exerted by a 3 knot current is nine times that exerted by a 1 knot current.

Wind speed increases with height above sea level. For example, a wind of 60 knots at 10 metres will be more than 75 knots at 30 metres but only 30 knots at 2 metres (just above man-high). So that information from different sites can be compared, it is usual to correct all anernomeLer readings to an equivalent height of 10 metres.

Because of the speed/force and speed/height characteristics of wind behaviour, freeboard is a major and sometimes critical factor for safe mooring.

In the case of currents, forces become significant when Ilu: cks.-imneo under **Lhe** keel is small in relation to the draft. In this situation, ami when lh<: cunonl is from Ihe beam, the ship begins to act as a major obstruction to a currunl which inii:;l eilher escape around the bow or stern or accelerate under the **keel.** A **similai bu**t less pronounced effect occurs with currents aligned to the ship's fort: **and** nil **axis**.

A well designed berth will be sited so that the current will **be end on 01 nearly** end on, but Fig.1 shows how the current force due lo a **beam currenl increases** as the "depth/draft ratio" is reduced.

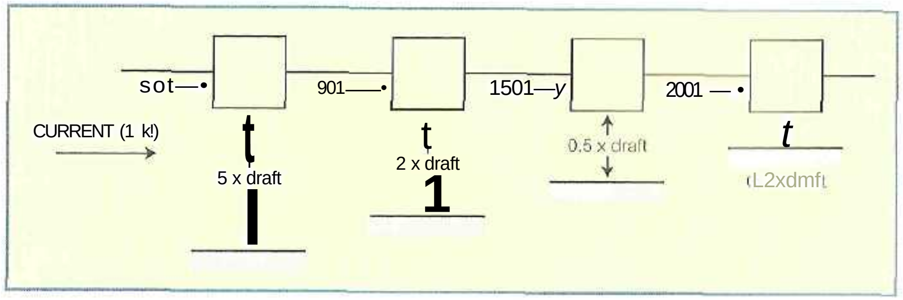


Fig 1 Effect of Underkeel Clearance on Current Force

Ballasting the ship down wilt usually reduce the total forces acting on a ship *as* ***the wind gradient effect is greater than the underkeel clearance effect.***

The following table gives some examples of the forces on various **conventional** ship sizes due to wind (60 knots) and current (3 knots ahead or 0.75 knots abeam).

Summer dwt	. fodX	Transverse Forces tonnes		HRBIBInal Forces tonnes	
		Wind	Current	Wind	Current
18,000	Loaded	33	16	17	6
	Ballast	84	9	21	4
30,000	Loaded	50	42	23	16
	Ballast	112	21	26	9
70,000	Loaded	67	78	25	30
	Ballast	168	21	34	18
150,000	Loaded	98	107	34	42
	Ballast	213	29	46	23
300,000	Loaded	156	171	51	67
	Ballast	336	48	72	25
LNG Carrier	125,000 m^3	396	76	78	30

A ship moves up and down alongside a berth both with the tide and as a result of cargo operations. It is perhaps stating the obvious to see that as a ship rises or falls, the tensions in the mooring lines will change. As they tighten the ship will tend to move in towards the berth; conversely, as the height above the jetty decreases, the lines will become slack and the ship is likely to move away from her proper position. ***The only reliable remedy for this is regular line tending whilst the ship is moored atajetty.***

Forces caused by passing ships, waves or swell are complex and continually varying, although at most berths they will noL create problems for the ship that is using her equipment properly. Where these forces are unusually large, jetty operators should have made some provision to supplement the ship's system. Attention to mooring restraint is especially important in the case of a deep draft loaded ship with minimum underkeel clearance berLhed close to a shipping lane, when the force from passing ships could be large enough to part the lines or pull the ship off the dock if the lines were slack.

Mooring layout

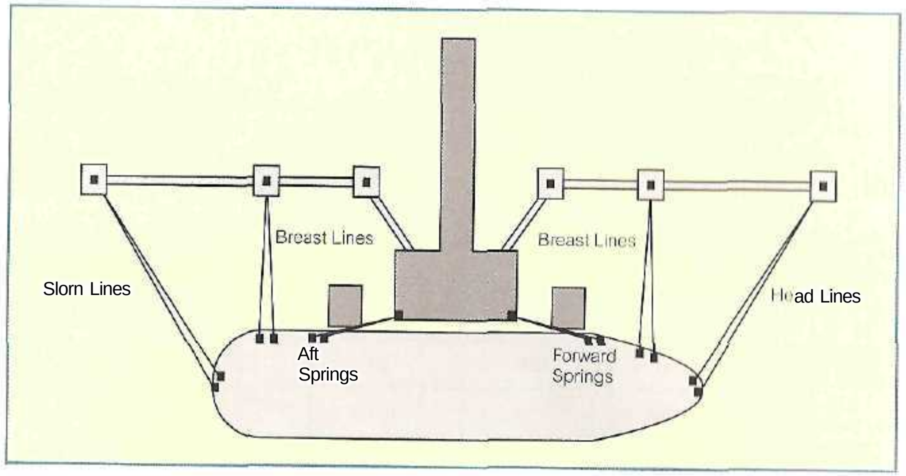


Fig.2 Typical Mooring Arrangement

Whilst it is often difficult in practice to achieve an ideal mooring layout, Fig. 2 shows a typical mooring arrangement designed to resist environmental forces acting on the ship.

These forces, particularly wind, can come from any direction, but when discussing mooring systems the forces are split into longitudinal and transverse components. A ship's equipment can always be employed to the best advantage if the following general principles are remembered:

(a) *Breastlines provide the bulk of the transverse restraint against off-the-berth forces.*

(b) *Springs provide the largest proportion of the longitudinal restraint. It should be noted that spring lines provide restraint in two directions, forward and aft, but that only one set of springs will be stressed at any one* ***time***

(c) *Very short lengths of line should be avoided when possible, as such linns will take a greater proportion of the total load when movement of tin •* ***thlp*** *< tccurs. Short lines are also the ones most seriously affected by "dip" ($99* ***page*** *8).*

Although headlines and sternlines, because of their direction, **hava** Il ffecl of providing some restraint against both longitudinal and transveraa for cm, [hoy actually contribute less to the overall mooring strength than Is commonly H ppnsod,

This is because the direction of the largest forces encountered is usually either nearly transverse or nearly longitudinal, i. e. along the lines of action of breast or spring lines respectively.

The most extreme conditions, i.e. light ship and combined beam wind and current, will usually produce a resultant force vector within about 25 degrees of the beam.

In the example illustrated in Fig. 3, with the headlines leading at 45 degrees to the breastlines, the contribution of the headlines to the total transverse restraint is only about 26% of the whole. Even if the total resultant force aligns with a headline, the line takes only 41% of the load, with the breastline and springline sharing the remaining 59%.

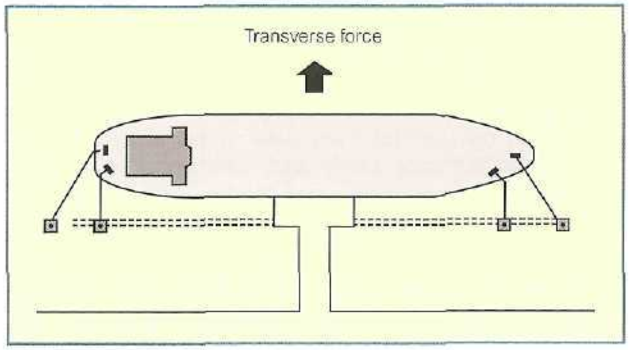


Fig.3 Transverse force

Wires or synthetic fibre ropes

The key factors for any wire or rope are strength, which is usually described by reference to Minimum Breaking Load, (MBL) and elasticity, which is a measure of its stretch under load.

Synthetic fibre ropes are adequately strong and of a reasonable size for mooring small to medium sized ships, but for large sized ships the ropes may become too large to handle unless fitted on self stowing winches. Further, the handling of a large number of such ropes would be difficult.

In addition, most synthetic fibre ropes stretch far more than wires. A typical figure for the extension of a nylon rope at maximum load is in excess of 30%, compared with 14% for a wire. As the mooring ropes of a VLCC may reach 70 to 100 metres, it is clear that a normal synthetic fibre rope mooring system is unlikely to provide the accurate positioning demanded by the loading arms, Whilst smaller ships may be equipped with synthetic fibre linos, il is normal [oi larger ships to be equipped with wires fitted to self stowing wiiu.hrs. Even o.1 smaller ships, wires, if fitted, are normally on self stowing winches foi ease and safety of handling, and on new buildings it is common practice foi the synthetic linir:; LO be fitted to self stowing winches.

A synthetic fibre rope fitted to a self-stowing winch is somelimos provided al each end of the ship. Its purpose is to act as the "first line ashore" as Its lighl weight and buoyancy make for easy handling in a mooring boat, on the jetty, and on board; it can thus be sent ashore easily when the ship is some distance from the berth. It can then be used to assist in heaving the ship alongside the berth, However, because of its greater elasticity it should not be considered as parl ol the actual mooring system unless the other head and stern lines are of a similar material.

With the advent of more and more High Modulous Synthetic t ibre (I IMSK) ropes being marketed it is becoming more common for larger vessels to In; fitted with all fibre rope mooring layouts. The initial cost is higher than a conventional wire mooring layout but benefits can be realised from ease of handling and with that shorter mooring limes, less maintenance costs and, where pennants are used, joining shackles are not always required.

Elasticity

The elasticity of mooring lines is important because it determines how the total load will be shared between a number of lines.

If two lines of the same size and material are run out in the same direction and pre-tensioned, but one is secured to a hook twice as far away as the other, the shorter line will take two thirds of any additional imposed load, the longer one only one third.

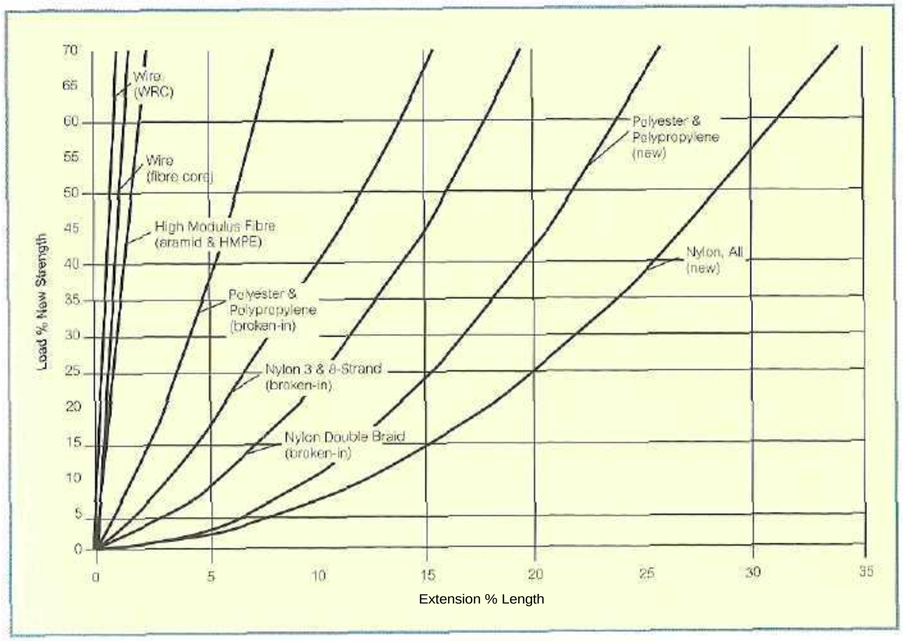
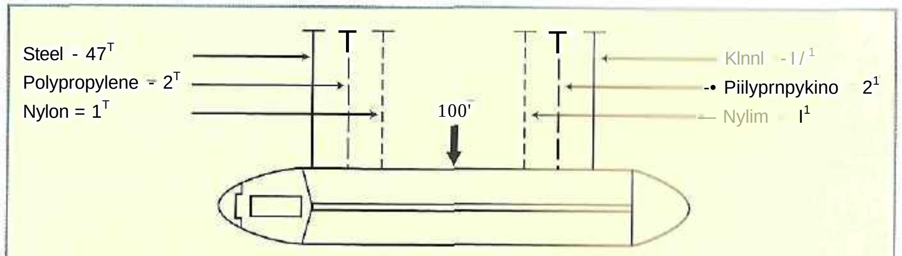


Fig.4

Therefore two or more lines leading in the same direction should, as far as possible, be of the same length.

If two lines are the same length, the same breaking strength, and have the same lead, but one is a wire of 1.5% full load elongation and the other is synthetic of 30% full load elongation, the wire will take 95% of the extra load, the synthetic only 5%.

Hence, two or more lines leading in the same direction should always be of the same material. Never mix wire and synthetic fibre ropes leading in the same direction if you can avoid it.



(A) Effect of Hawser Material

(B) Effect of Hawsor Length

Fig.5 Demonstrates the significance of material and **length oi lines**

Elasticity of a given type of line also varies with diameter, **with a largei** rope extending less than a smaller rope. Although this is unlikely to be an important factor, as mooring lines on a ship are usually of uniform diameter, il should be borne in mind when ordering new mooring lines.

Vertical angle (Dip)

Whenever a line is unable to act in exactly the same direction as the Inrctj il is trying to withstand, its holding power is reduced. Hence a short line to a mooring hook substantially lower than the ship's fairlead will be of limited value. The effectiveness is proporLional to the cosine of the angle the line makes to the hori/ontnl. i.o. for 30 degrees the line is 87% effective and, for 45 degrees, 71% **effective (I lg,** 6).

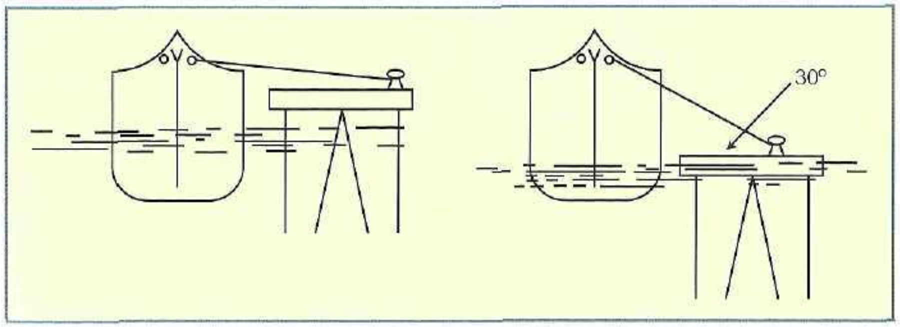


Fig. 6 Vertical Angle (Dip)

Mixed mooring

Not every ship is fortunate enough to possess an all-wire or all-synthetic mooring outfit and in such cases the best must be made of a mixture of wires and synthetic fibre ropes. Where this is the case, the best procedure is to use, wherever possible, the wires for the spring and breast lines, and the synthetic ropes for headlines and stern lines,

Synthetic fibre tails

Although moorings with low elasticity (such as wires or HMSF) provide the most effective mooring system, that same low elasticity can also pose its own problem, particularly at berths where sea and swell, or perhaps passing ships, could impart shock (dynamic) loadings to the mooring system. In such cases there may be insufficient elasticity to prevent failure of the mooring lines.

This problem can be overcome by introducing a degree of elasticity by attaching synthetic fibre tails to the end of the lines. With wire these are attached by means of a special joining shackle designed to minimise wear on the wire. The use of an ordinary "D" or "bow" shackle (See Fig. 7) should be avoided as this will quickly damage both wire and tail. When attaching a synthetic fibre tail to a HMSF rope, a joining shackle is not usually required, though manufacturers instructions should always be followed.

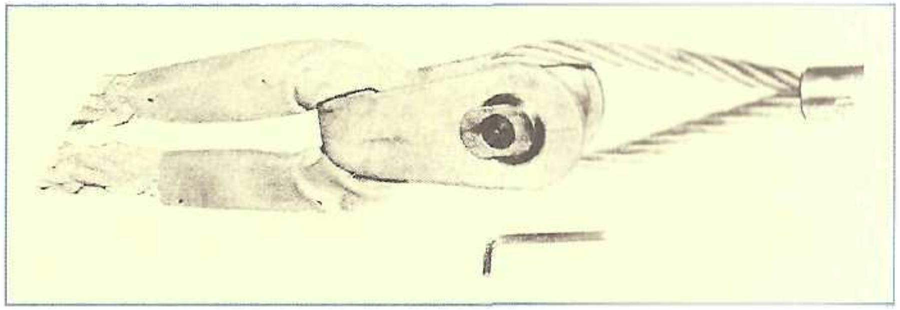


Fig. 7 Joining shackle

In order to keep the additional elasticity to the minimum required to prevent line failure, the length of the tail should not exceed 11m, and because synthetic fibre tails are likely to deteriorate more rapidly than wire, they should be at least 25% stronger than the lines to which they are attached and should be inspected frequently or replaced at regular intervals. The eyes of the tails should be covered in leather or plastic sheathing to protect them from chafing.

When tails are used, the shackle may cause increased weal on Hie oyu nl the wire, and this area should be inspected at regular intervals. There aro dlffomnl lypes of shackle used to attach wires to synthetic fibre tails. Reference should tin made to manufacturer's operating instructions and note in particular the dlffornnco in use of shackles for attachments.

Marine loading arms

The objective of good line tending is to ensure that all lines share Iha load to the maximum extent possible and to limit the ship's movement off, oi alongside, the berth. As more and more oil transfer jetties are utilising Marine Loading Arms (MLAs), there is an additional requirement to keep the vo:;:;i![close lo optimum position alongside the jetty.

MLAs have 'working envelopes', or maximum operalioruit limitations In lerms of ability to outreach from the jetty. Amongst the factors taken Into a< < ounl in the envelope are the limited changes in horizontal position due lo vessel dull (movement off the berth) and ranging (movement up and down). There > nhnuld bn nllhui a visual indication of the envelope and/or be accompanied with alarms lo Indli alooxi ossive range and drift.

Some MLAs also have Emergency Release Systems (I HJS) which ,II.....lialod al a specified alarm stage, in order to prevent damage to the arm, end/or spillage of oil.

The function of the ERS is to permit a safe and clean separation of the loading arm from the ship, with complete closure of valves prior to disconnection.

Quick release hooks

Many terminals are now fitted with Quick Release Hooks on the dolphins and jettys. These allow for moorings to be slipped quickly and by a minimum number of personnel. They should be provided with a SWL not less than the MBL of the largest rope anticipated and be supplemented by capstans or winches and fairleads to enable the handling of large ship's moorings.

Remember, the mooring integrity of a ship alongside is not something that happens of its own accord. It needs good knowledge and use of the ship's equipment, an awareness of good mooring principles, and careful planning.

THIS DOES NOT FINISH ONCE THE SHIP IS FINALLY MOORED BUT CONTINUES ALL THE TIME THE SHIP IS ALONGSIDE.

Chapter 2

Mooring Winches

Mooring winches can be driven by steam, hydraulic or electric motors. Each type has it own operational characteristics and precautions. It is important that personnel operating these winches are familiar with the different characteristics and have been trained in their operation.

Render and heave

Whatever the power source, all mooring winches will be affected to a greater or lesser degree by a characteristic known as "Render/Heave Ratio". The term "Render" is defined as the force required to turn the winch in the opposite direction when set to heave with the driving force applied.

With hydraulic and electric driven winches, the render value is constant but with steam winches the render value varies. This is because the torque available is dependent upon the position of the pistons.

It should be noted that the heaving power is always less than the render force and it is impossible to heave in after a winch has been rendered unless there is a change in the forces acting on the moorings.

Some ships are equipped with self-tensioning winches with the intention of eliminating the need for line tending. These are designed so that a specified line tension can be pre-set, and the winch will render (pay out) when tension in the line exceeds this value, and will recover (heave in) when it is less than this value.

However, experience has shown that the use of such winches whilst the ship is alongside is not a safe practice because the winch restraint is limited to its render load, which is small compared to what it can hold on the brake. It is possible for the winches at opposite ends of the ship to work against each other when an external force caused by either wind or current or both is applied to one end so that the ship could "walk" along the jetty. In the simple illustration given by Fig. 8 a ship is shown moored by one line at each end.

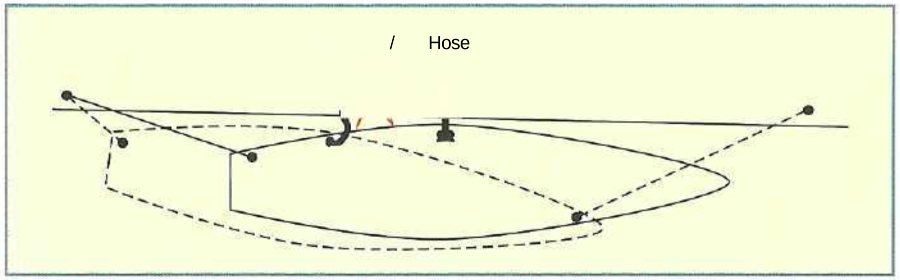


Fig. 8 Possible effect of vessel walking along a jetty

Should the bow winch render a little for any reason (i.e., **a change In direction** or **force** of wind or current) some rope will pay out, which cannol bo hnnvud onto the drum again because the *heaving force of a winch is always* ***iess than*** *its render force* and it is not possible to heave in until the external force which **caused** it to render is reduced. Consequently, the ship moves **astern a little and the** after mooring begins to slack. The aft winch then heaves in that slack and re-tensions the line. If the disturbance is repeated or continuous the **ship** will **move** progressively astern.

Mooring winches should not be left in automatic self-tensioning mode once the ship is secured alongside. On completion of mooring, the winch should be left with the brake on and out of gear.

Winch brakes

The holding power of winch brakes varies from ship-to-ship, but will always be designed to exceed the "render" value of the winch.

The above statement is dependent upon several factors which are discussed below:

Correct layering

The number of layers of line on the drum effects the brake holding power.

The force at which the brake will slip will vary, dependent upon the number of layers of line left on the drum, and the more layers of line on the drum the greater **will** be **the** reduction of brake holding power. This is illustrated in Fig. 9.

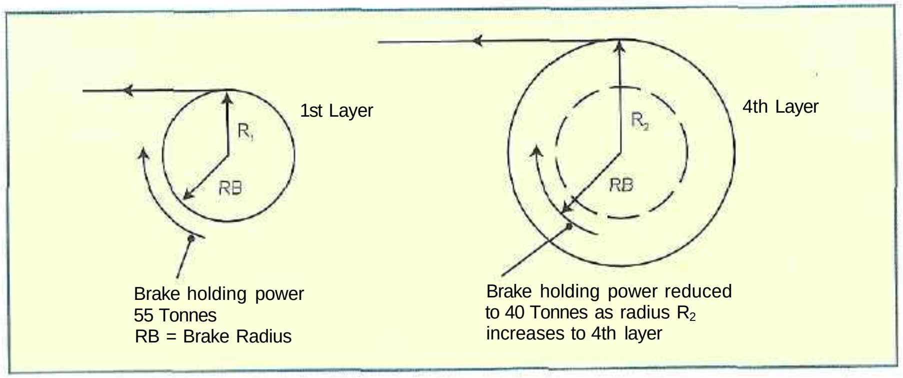


Fig. 9 Correct layering on drums

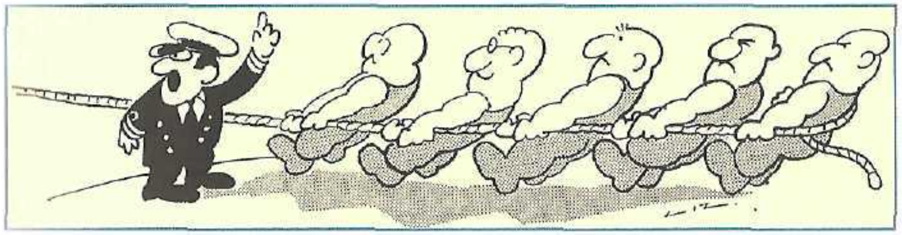
Non split drum winches

The brake holding capacity for these winches (non split drum) will always be quoted for a specific number of layers. In order to minimise any reduction in brake holding power, **the line should** always be reeled on to the drum in a symmetrical pattern and not allowed to pile up on one side or in the centre. However, due to the length of line involved, it may not always be possible to achieve this in practice.

The following table shows a typical loss **of** brake holding capacity for each layer, based on 100% on the first layer:

LAYER	BRAKE HOLDING CAPACITY	
1st Layer	100%	Say 55 tonnes
2nd Layer	88%	48 tonnes
3rd Layer	80%	44 tonnes
4th Layer	73%	40 tonnes
5th Layer	67%	37 tonnes

Where possible, check for brake holding values by referring to manufacturer's literature or ship's plans. If the brake holding capacity is known, but the layer to which it applies is not, for the sake of safety assume it applies to the 1st layer and make allowances accordingly.



'a heaving system of some kind'

Split drum winches

This design minimises crushing damage and occurrences of buried turns. The brake holding capacity for these winches (Fig. 10) is always quoted foi only a single layer of line on the tension drum.

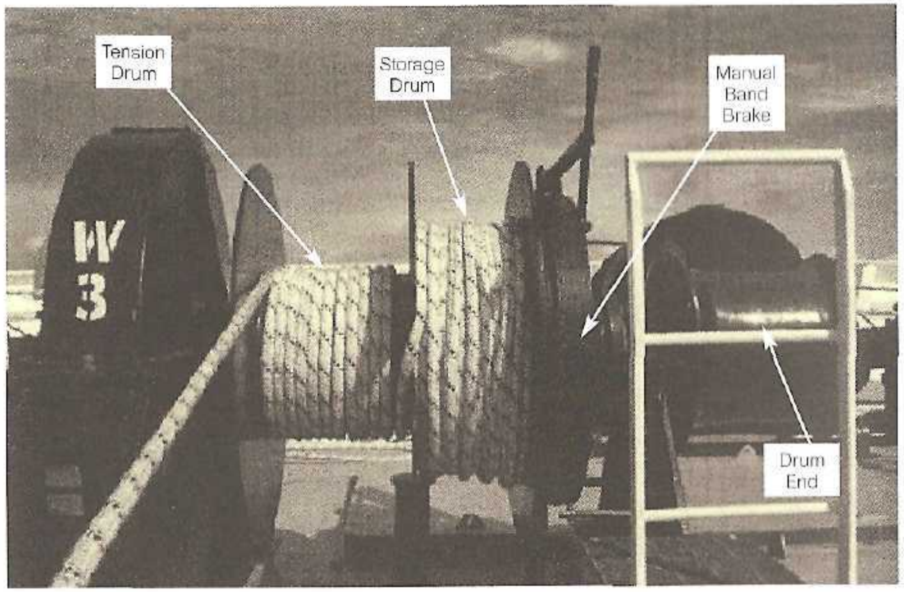


Fig. 10 Typical split-drum winch

When using this equipment, the following should be borne in mind:

(a) Manhandling the line from storage drum to the tension drum may be difficult and requires care and sufficient personnel;

(b) Regular attention should be paid to ensure that the appropriate number o\ turns are mainatined on the tension drum throughout the time the ship is alongside. No more than one layer of line should be maintained on tho tension drum when the line is under load.

Correct reeling

The line must be reeled on the winch drum in the right direction and manner.

Band brakes are designed for the line to pull directly againsl the fixed end of the brake band. Fig.11 shows the correct method of reeling.

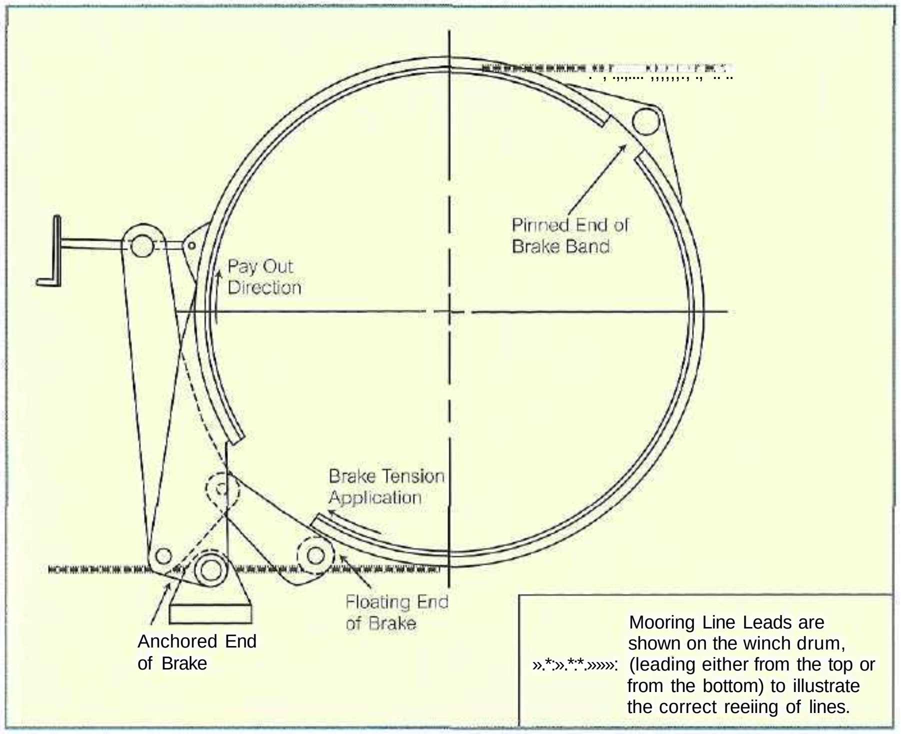


Fig. 11 Correct reeling

Reeling the line on to the drum in the wrong direction may reduce the brake holding power by up to 50%. Winch drums should be marked to indicate the correct reeling direction.

Winches fitted with disc brakes are not subject to this problem,

Brake condition

The physical condition of the winch brakes effects the holding power. Oil, moisture or heavy rust on the brake linings or drum can seriously reduce the brake holding power.

Moisture can be removed by running the winch with the brake applied very lightly, although care must be taken not to cause excessive wear. Oil impregnation cannot be removed so linings should, if so affected, be replaced.

Whenever brakes are opened up for any reason, the brake drum should be examined for build-up of rust or worn brake material and should be descaled as necessary.

Brake linkages must be free and greased. If the linkages are not free [here will be **a** loss of brake holding power and the winch operator could be under the impression that the brake is fully applied when in fact it may not be. Severe stresses could also be imposed on mechanical parts of the brake.

Before the end of a sea passage, when the brakes will have been exposed to the air and sea, it is essential to check them and ensure that all control and operating handles are oiled or greased and are free and easy to use, that all linkages are greased, and that the brake drums and linings are clean and (as far as possible) dry.

Testing brakes

Deterioration of the brake holding capacity will be caused by normal wearing down of the brake linings. Brake holding capacity should therefore be tested annually or after excessive loading has been experienced. Test results should be recorded. Brake linings renewed if there is any significant deterioration of holding power.

Reference should be made to *Mooring Equipment Guidelines.*

Application Of brake

When there is a load on the line, the fact that the brake is not fully applied will be all too obvious. However, it is sometimes difficult to tighten manually applied brakes to their maximum possible extent when there is little load on the line. Different people are of different builds and can apply different forces to the brake applicator.

Therefore, when the freeboard is increasing during cargo discharge or with a rising tide, brakes should be tightened at frequent intervals even if there is no sign of slipping. As the load in the line increases, redistribution of stresses in the brake band will often relax the load on the applicator, allowing the brake to be tightened further.

Ships with hydraulic brakes will probably have a torque indicator which shows the actual torque applied to the brake, and this should always be maintained at the level designated by trie winch manufacturer.

Incorrect use of brake

The brake is a static device for holding a line tight and it is not intended as a means for controlling a line, If a line has to be slacked down, the winch should be put into gear, the brake opened and the line walked back under power. It should never be slacked down by releasing the brake as this causes increased and uneven wear on the brake band, it is uncontrolled and thus unsafe, and if two lines in the same direction have equal loads then the entire load will be suddenly transferred to the other line, which may then part.

Brake holding capacity

The value of the brake holding capacity in relation to the size of line is important; there would be little point in a mooring system where the line parts at a load less than the brake holding capacity. ***Brakes should have a holding capacity of about 60% of the breaking load of the tins, which will permit slippage before the line*** *breaks.*

This factor should be considered when renewing lines and reference should be made to the ship's specification or appropriate drawings.

It should be remembered that the brake holding power is always greater than the heaving power, and that once the brake starts to slip (render) it is impossible to heave in unless the forces causing the slippage are reduced.

Exceptional circumstances

Occasionally, unanticipated changes of load, perhaps caused by extreme winds, waves, swell or tide, may cause the brakes to slip and the ship to be at risk of moving off the berth. Should this occur, do NOT release the brakes and attempt to heave the ship alongside, as this is impossible (see Brake holding capacity above), and any attempt to do this will only worsen the situation. Tug assistance should be requested, the engine should be made ready for manoeuvring, and hoses should be disconnected.

If the problem is caused by high winds, consideration should be given to reducing the freeboard by the addition of extra ballast where possible.

Winch in gear

Leaving the winch in gear with the power on and set to "heave" can increase the brake holding capacity. However, this should only be considered in an emergency situation and should not be carried out in normal operations as it is possible to:

(a) exceed the breaking strain of the line and the safe working load of leads and rollers;

(b) damage the winch by distorting the shaft.

As an example, if the render value is 35 tonnes and the brake holding power is 65 tonnes, the total holding power is 100 tonnes, If a line with a new breaking load of 108 tonnes is used and allowing **a** 20% reduction for wear and tear, then the breaking load is only 86 tonnes, and the line will probably part.

It is also ineffective where one winch drives two *or* more drums, as it is not normally possible to engage all the drum shafts whilst at the same time maintaining equal tension on the lines.

This practice should only *be* ***considered in an emergency situation.***

Freezing weather

During periods of freezing weather it may be necessary to run the steam winches continuously to prevent serious damage to the cylinders, steam pipes, etc. Alternatively, some winches are provided with a steam-to-exhaust by-pass valve that can be adjusted to allow sufficient steam to pass through the stem to prevent the pipes freezing up.

On certain winches, when the brake is applied and the drum is out of gear, the winch motor still drives the drum shaft. If the wire is under load, this load is transferred to the drum bearings and the rotating shaft, resulting in eventual[1] wear of the bearings. Where this is the case, it is preferable to utilise the steam and exhaust by-pass valves to prevent damage in cold weather.

Some hydraulic systems also have a warm-up circulating line. Reference should be made to manufacturer's instructions.

Joining a new ship

It should be obvious that people using the ship's mooring equipment must be trained in its operation and capabilities.

Always check the following when joining a new ship:

(a) **Mooring line size, length and type;**

(b) **Type of winch:**

Self-tensioning, split drum, steam, electric or hydraulic;

(c) **Heaving power and render value of the mooring winches;**

(d) **Type of brake mechanism;**

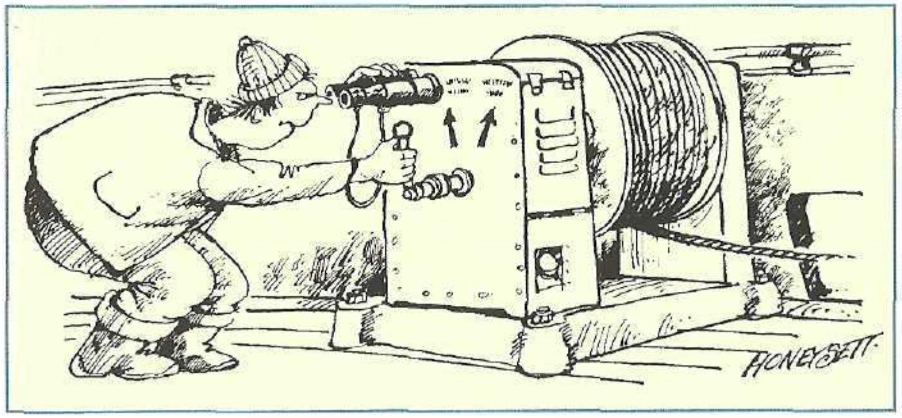
(e) **Brake holding capacity of the mooring winches, and to which layer it is applied;**

(f) **Whether the combined render value and the brake holding power of each winch is more than "MBL less 20%" for the line attached to it;**

(g) **General condition of mooring lines (splices, age, etc.);**

(h) **Last test date of winch brakes;**

(i) **That the the rope is reeled the correct way round the drum.**



"...ensure controls are clearly marked"

SAFETY REMINDERS

Ensure that the "heave-in" and "slack-out" directions are clearly marked on the winch handles and controls.

Steam pipes in vicinity of an operator or rope handler must be lagged or adequately guarded against accidental contact.

Do not allow oil leaks from hydraulic winches to go unnoticed, it could be YOU that slips on that pool.

Do not try to assess the tension in a line by kicking or standing on it; this is dangerous as well as being futile.

Chapter 3

Steel Wire Ropes

Construction of wire ropes

When a high Minimum Breaking Load (MBL) together with reasonable ease of handling was required, it was traditional to select wire ropes, (though nowadays the use of alternatives such as HMPE is becoming more common).

A wire rope consists of a number of strands laid up around a central core of fibre or wire. Each strand in turn consists of a number of wires laid up to form the strand.

It is normal to describe the rope in terms of the number of strands and number of wires per strand, e.g. 6 x 36, 6 x 41 (Fig. 12).

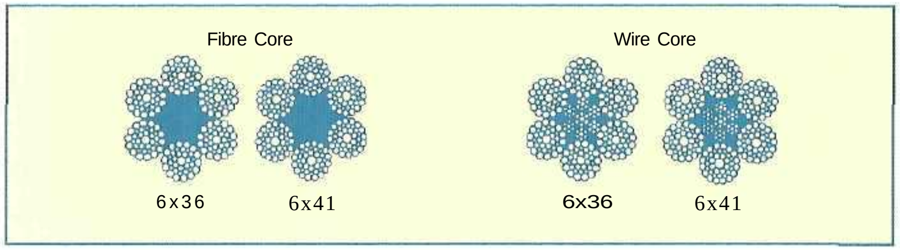


Fig. 12 Strands and wires per strand

The first number is the number of strands in the rope and six round strands around a central wire or fibre core is the normal construction for marine use. (Ropes of eight strands, or multiple strand design, or triangular strand design are also available but are normally restricted to specialist applications.) The second number is the wires in each strand; ropes with more wires have greater flexibility and fatigue resistance but have less resistance to abrasion, whilst those with fewer wires have less flexibility and fatigue resistance but more resistance to abrasion. A standard mooring wire is of 6 x 36 or 6 x 41 construction.

Several constructions are available and the following definitions and illustrations will be of assistance in identifying the different wire types:

Definitions

Lay - the twisting of strands to form a rope, or wires to form a strand, during its manufacture.

Right-hand or Left-hand Lay - the angle or direction of the strands relative to the centre of a rope.

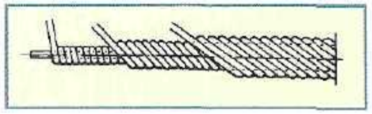


Fig. 13 Cross Lay

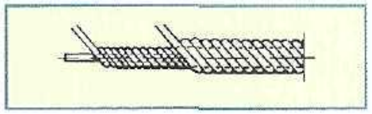


Fig. 14 Equal Lay

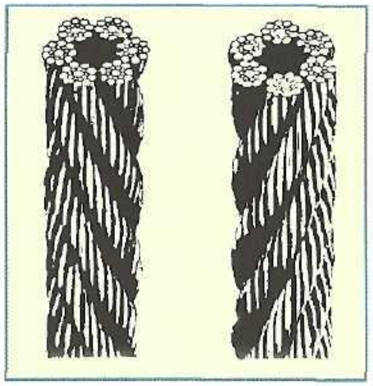


Fig. 15 Ordinary Lay

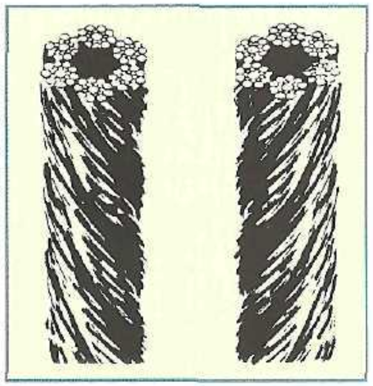


Fig. 16 Lang's Lay

Cross Lay (Fig. 13) and Equal Lay (Fig. 14) - terms describing the lay of the wires used to make up the strands.

Ordinary Lay (Fig. 15) - a method of making a rope where the lay of the wires in the strand is opposite to the lay of the strands in the rope.

Lang's Lay (Fig. 16) - a method of making a rope where the lay of the wires in the strand is the same as the lay of the strands in the rope. Although this construction has better wearing properties than ordinary lay, because it tends to untwist it has only limited use. It is not used for mooring lines.

Aggregate Breaking Load - the sum of the breaking loads of all the individual wires used to form a wire rope.

Minimum Breaking Load (MBL) - the smallest load at which a wire rope breaks when tested to destruction. This value is usually the manufacturer's guaranteed breaking load and is the figure that should be quoted when ordering wires.

Spinning Loss -- due to deformation of individual wire strands during manufacture, the actual breaking load of a wire rope is always less than the aggregate breaking load. The difference is referred to as Spinning Loss.

Yield Point - the point at which the ratio of strain/stress increases sharply. This is the point at which a wire may become permanently distorted.

Equal Lay construction gives superior performance over a Cross Lay rope of the same diameter because:

(a) It possesses up to 14% higher MBL due to lower spinning loss. This is because all the layers of wire have the same pitch or length of lay, and each wire in each layer lies either in the trough between the wires of the under layer or alternatively along the crown of the underlying wire.

(b) No wire crosses over the crown of the underlying wires as in Cross Lay construction, thus reducing internal wear by the elimination of cross cutting.

A standard 6-strand Equal Lay/Ordinary Lay construction is usually adopted for mooring wires, and wires of diameter 22-40 mm are usually 6 x 36 construction, and larger wires 6 x 41. Mooring wires are usually Right-hand Lay unless otherwise specified.

Wire ropes can be supplied in different grades of steel though a minimum tensile strength of 180 kg/mm2 is recommended because, for a given diameter of wire rope, an increased MBL and general better performance is obtained.

Wire ropes can be supplied in Right-hand Lay or Left-hand Lay. Unless otherwise specified, a Right-hand Lay will normally be supplied,

Wire ropes can be supplied with fibre cores or steel wire cores. Fibre cores will give easier handling and are ideal for use with smaller wire sizes and where a wire is to be handled manually and say "turned up" on bitts or bollards.

Where the wire ropes are used on storage drum type winches with little manual handling, it is advantageous to use a steel wire core. Wires constructed using a steel wire core offer a greater resistance to the crushing forces experienced on lhese winches, suffer a smaller loss of MBL when bent, are about 7-8% stronger and extend slightly less (0.25% - 0.5% as opposed to 0.5 - 0.75%) than a fibre core wire rope of the same diameter (Fig. 17 refers).

Mooring wires are usually galvanised in order to provide better resistance to corrosion,

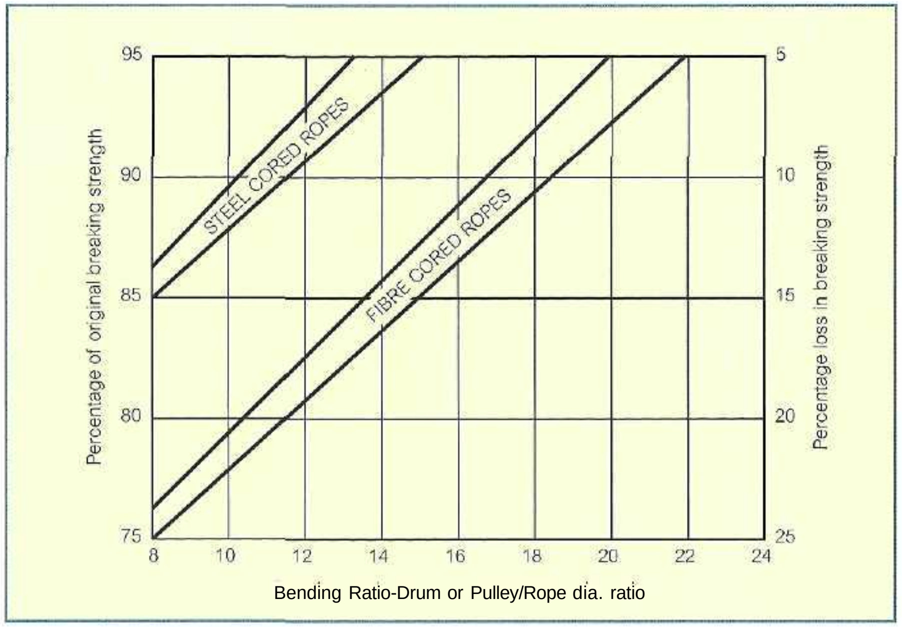


Fig. 17 Reduction in breaking strength

To summarise, the wires most frequently found on self-storing winches will be of the following constructions:

(a) Equal Lay

(b) Ordinary Lay

(c) Right-hand Lay

(d) Steel wire Core

(e) Usually of engineering grade steel, i.e. 180 kg/mm2

(f) 6 x 36 or 6 x 41

Wire rope is used in preference to some synthetic fibre ropes because it possesses:

(a) Low elasticity, i.e. limited stretch. When a wire is first used under load there is a slight permanent extension known as "constructional" stretch which results from a slight rearrangement of the wires. After this the wire experiences an elastic stretch which is recoverable and linear up to about 65% MBL; above this the stretch increases non-linearly until the line breaks.

(b) A strength/diameter ratio superior to most synthetic fibre ropes (apart from synthetic fibres such as HMSF).

(c) A smaller diameter making it suitable for use on storage reels that can be directly linked to the winch.

When delivered, a certificate should accompany all mooring wires from the manufacturer indicating, amongst other things, the minimum-breaking load. These certificates should always be consulted if it is necessary to ascertain the specification of a particular wire,

Maintenance of steel wire moorings

It is essential to grease or oi! steel wire mooring ropes at frequent intervals as rusting will reduce the strength of the wire in a very short time, however, many terminals take exception with the sheen left on the water by this practice.

Wire rope deteriorates gradually throughout its entire service life. To keep abreast of deterioration, wire ropes must be periodically inspected. Because moderate degradation is normally present, the mere detection of rope deterioration does nol usually justify rope retirement.

There are two major none-destructive inspection methods for the detection and assessment of rope degradation: Visual inspections and Electromagnetic (EM) inspections.

Among the basic visual inspection procedures are (1) the "rag-and-visual[ri] method and (2) rope diameter measurements.

The rag-and-visual method is a simple yet useful method for detecting a wide variety of external rope deteriorations. Using this approach, the inspector lightly grasps the rope, which moves at inspection speed from the winch, with a rag or cotton waste. External broken wires will often porcupine and, as the rope moves, snag the rag or cotton waste. The rope is then stopped at that point, and the inspector assesses the rope condition by a visual examination.

Frequently, broken wires do not porcupine. Then a different test procedure must be used. The rope is moved two or three feet at a time and visually examined at each stop. This method is tedious and, because the rope is often covered with grease, many external and internal defects elude detection.

Another visual inspection tool is measurement of the rope diameter. Rope diameter moasurements compare the original diameter when new and subjected to a known load, with the current reading under like circumstances. A change in rope diameter indicates external and/or internal rope damage. Inevitably, many sorts of damage do not cause a change of rope diameter.

Visual inspections are inherently not well suited for the detection of Internal rope deterioration, therefore, they have limited value as a sole means of wire rope inspection. Visual inspections are simple and do not require special instrumentation. When combined with the knowledge of an experienced rope examiner, visual inspection can provide an indispensable tool for evaluating many forms of rope degradation.

EM inspection of wire rope gives detailed insight into the condition of a rope. The EM inspection methods use coils or permanent magnets to induce a magnetic flux in a seclion of the rope. Any anomaly in the rope causes a change of the magnetic flux in the rope and especially of the leakage flux that surrounds the rope. Unfortunately this method of inspection requires the services of an outside contractor as this equipment is not found on ships.

Investigations have shown that deterioration of the wire can occur undetected on the bottom layers of tho winch, especially when a wire has seen some service and has been turned "end for end".

Regular *visual* inspection is vital, particularly around eyes which are shackled to synthetic fibre tails, as the shackle tends to increase wear on the wire at this point (see page 10).

If "dry" or darkened patches are observed, the depth and degree of corrosion should be checked. An effective way to do this is to place the wire on a solid surface and strike it with a hammer. This will cause the rust to fall away and will part the weakened strands, exposing the severity of the corrosion.

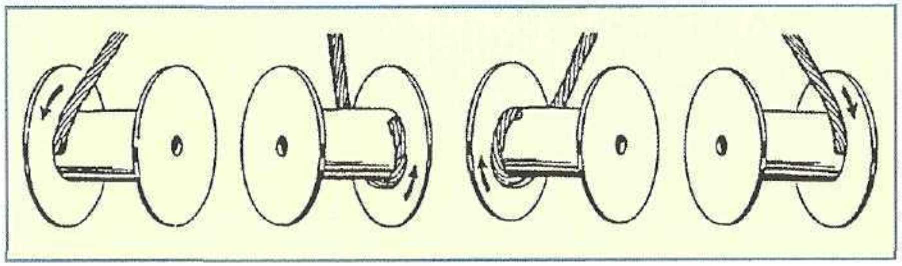
Snags in a wire also indicate a reduction in the strength.

Wires must be replaced if the numbers of broken strands (snags) exceed 10% of the visible strands in any length of wire equal to 8 diameters.

The practice of sighting a wire before use could also prevent an injury or accident.

Selection of anchor point for 1st layer of wire on a drum

When fitting a new wire to a mooring winch, or replacing an old wire after inspection and greasing, it is important that the wires are replaced as shown in Fig. 18.



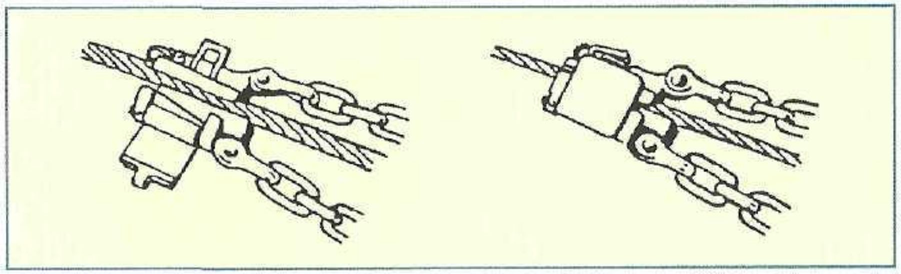
Wires with Righthand Lay   Wires with Lefthand Lay

Fig. 18 Replacing wires

Stoppers for use with steel wires

There are two methods of stoppering a steel wire prior to turning it up on the bitts.

One method is to use a specially designed stopper such as the Carpenter Stopper (Fig. 19). The second and only other recognised method of stoppering wires is to use a length of chain.



Open   Closed

Fig. 19 Carpenter Stopper

Rope must never be used as a stopper on wires because it does not grip the *wire we!! enough.*

Where a carpenter type stopper is used, it is recommended that the stopper be of equal breaking load to the wire size for which it is designed. An important safety feature of this type of stopper is that when in position, it is self-tightening and can be left unattended. Further, it will not damage the wire when under load, provided it is of correct size and design for the circumference and lay of wire rope on which it is to be used.

Where carpenter type stoppers are not available, it is important to note the following:

When securing a chain stopper to a wire, use only a "Cow Hitch" (also known as a "Lanyard" hitch) (Fig. 20), **never** a "Clove Hitch".

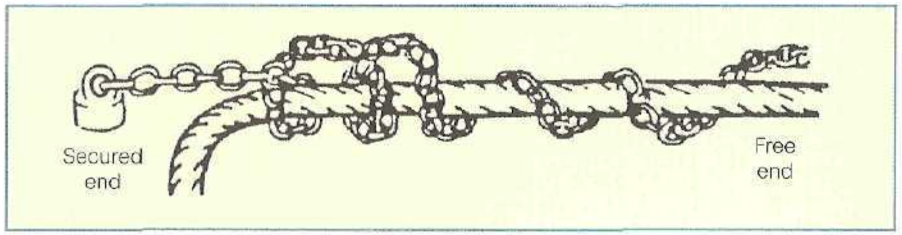


Fig. 20 Cow Hitch

Stoppers exceeding 20 mm diameter are virtually unmanageable and hence this is the largest size likely to be encountered. All chain stoppers should be proof load tested to twice the SWL and certificated.

Warning: In most cases, the stopper will break at a lower load than the wire.

When ordering the chain stopper, it is important to specify the following:

Size - diameter of link.

Type of chain - close link, higher tensile steel, i.e. tensile strength in the order of 63 kg/mm2. (Superior grades and higher breaking loads are available if required.)

The following table shows typical breaking loads for Grade 40 steel chain. (Note: The diameter is the diameter of the steel forming the link of the chain.):

12 mm diameter	7.2 tonnes
16 mm diameter	12.7 tonnes
20 mm diameter	19.9 tonnes

Length of chain usually 3.5-4.5 m.

CARE OF WIRE

AVOID **LEADING WIRES AROUND SHARP EDGES.**
It damages the wire, and seriously reduces the wire's strength. If a wire is run through a lead that is not aligned with the winch drum, the wire will be damaged where it rubs on the edge of the spool, and this practice should be avoided.

AVOID **CROSSING THE WIRE ON THE DRUM.**
Crushing or flattening also seriously reduces the wire's strength.

AVOID **KINKING THE WIRE.**
This opens the lay and leaves the wire permanently weakened.

AVOID **LEADING WIRES THROUGH EXCESSIVE ANGLES,**
Because the wind or current loads or both could exceed the wire's MBL on the outboard section of wire (T, in Fig. 21) and break the wire before the winch brake renders. Should both the winch brake and steam holding power be combined, the risk of wire breakage is increased.

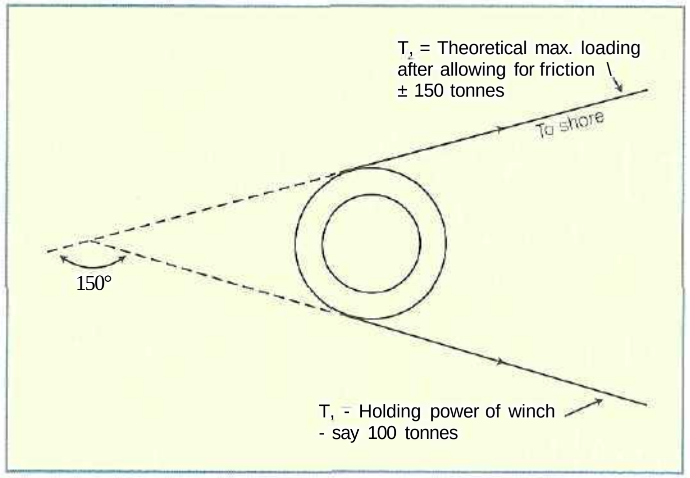


Fig. 21 Friction and holding power

Do not open a new coil of wire without using a turntable or similar apparatus, in order to avoid kinking the wire.

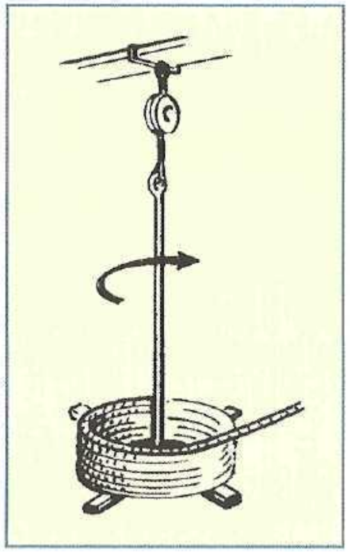


Fig. 22 New coil turntable

Splicing wire

Modern practice is for mooring wires to be supplied with eyes formed by means of a ferrule applied mechanically by the manufacturer. If the eye is damaged, it can be cut off and a new eye spliced in the wire. If this is done there should be a minimum of 5 full tucks and 2 half tucks. However, a manual splice will effectively reduce the MBL of the wire by 10-15%, and it is preferable to have the eye re-made by a mechanically applied ferrule, as soon as practicable. It will be found that it is extremely difficult to put an effective manual splice in a large mooring wire, and for this reason the practice is not recommended.

Particular attention should be paid to the area around the ferrule during rope inspection as it has been known for this to be a concentration area for corrosion.

Short splices should not be used on wires fitted to self-stowing winches as the splice could further deform or damage the wire on the reel.

SAFETY REMINDERS

ALWAYS STAND WELL CLEAR OF A WIRE UNDER LOAD.

NEVER STAND IN THE BIGHT OF A WIRE.

ALWAYS WEAR GLOVES WHEN HANDLING WIRES,

Synthetic Fibre Ropes

Use of synthetic fibre ropes

Mooring ropes are normally made of HMSF, nylon, polyester, polypropylene, or a polyester/polypropylene mixture. Cable laid ropes are still found in use but can be relatively stiff in handling and can kink if not handled properly. Eight strand plaited ropes *sometimes called square braid* are virtually unkinkable and are very flexible but suffer increased fatigue due to their construction. Fig. 23 shows a 3-strand rope, Fig. 24 shows an 8-strand plaited rope and Fig. 25 shows a sheathed and plaited construction known as double braid or braid-on-braid often used for specialised purposes (i.e. first line ashore equipment), which consists of a plaited inner rope covered by a tightly plaited sheath which may be of a different or similar material tc the inner rope.

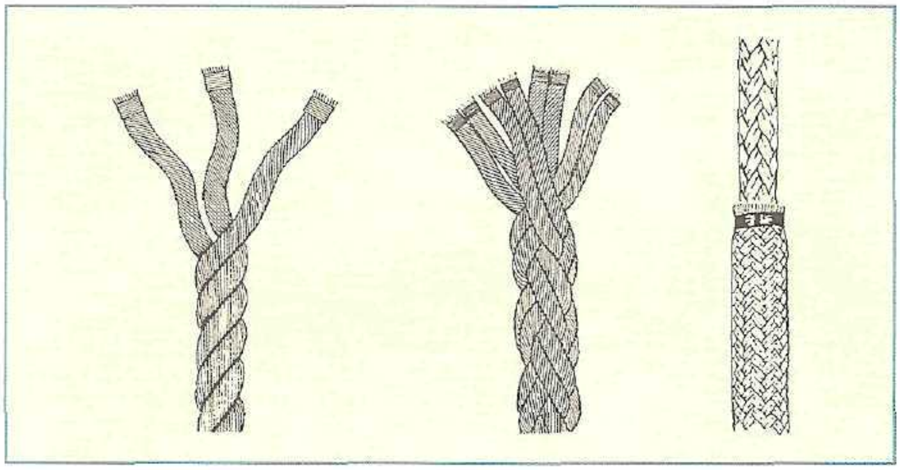


Fig. 23 Fig. 24 Fig. 25

As mentioned in Chapter 1, mooring ropes are available manufactured from HMSF fibres. These have very low extension under load (approaching that of wire) and a higher breaking load than other synthetic fibres of the same size. Experience has shown that different constructions of the same size and material of rope, may have entirely different life cycles.

Types of material used

High Modulous Synthetic Fibre Rope - generally refers to rope made from High-modulous fibres such as Aramid and High-modulous polyethylene (HMPE). These fibres are much srongerthan conventional synthetic fibres such as nylon, polyester and polypropylene.

ARAMID fibre typically has high strength and low stretch. The ropes do not float, however they have good cut resistance but only fair Ultraviolet (UV) and abrasion resistance. They are typically covered to increase abrasion resistance. They do not melt but char at high temperatures.

HMSF ropes have high strength per weight ratio, low stretch characteristics and good UV resistance. They do have very good fatigue (cuts, tension, abrasion and bending) resistance but limited temperature resistance.

HMSF ropes, for the same reason as wire, usually require the use of synthetic fibre rope tails to introduce some elasticity. Further detailed guidance can be found in the OCIMF publication *'Guidelines on the Use of High-Modulus Synthetic Fibre Ropes as Mooring Lines on Large Tankers'.*

NYLON has exceptional resistance to sustained loading. It is highly resistant to chemical attack from alkalis, oils and organic solvents, but will be damaged by acids. However, its high elasticity makes it unsuitable for tanker moorings, where the ship's movement has to be restricted to avoid damaging loading arms. It does not float. NB: When wet, nylon has only 80% of its dry sLrength. It is the dry MBL which is quoted and due allowance should be made when comparing with other fibres, or when ordering nylon lines.

Specific Gravity 1.14. Melting Point 250 °C

POLYESTER-this is the heaviest of the man-made fibres. It is not as strong as nylon but it possesses the lowest extension under load of all man-made rope fibres, except HMSF, and has an exceptional abrasion resistance. H also has high resistance to acids, oils and organic solvents, but will be damaged by alkalis. It does not float.

Specific Gravity 1.38. Melting Point 230°C - 26CTC

POLYPROPYLENE - this has approximately the same elasticity as polyester but is significantly weaker than either polyester or nylon. Polypropylene has a low melting point and tends to fuse under high friclion. It has poor cyclic load characteristics. Prolonged exposure Lo the suns ultraviolet rays can cause polypropylene to disintegrate due to actinic degradation. Polypropylene is lighter than water and can be used for floating messenger lines. Otherwise, the use of polypropylene for moorings is not recommended.

Specific Gravity 0.91. Melling Point 170 °C

POLYESTER/POLYPROPYLENE-this is considerably lighter than polyester although heavier lhan polypropylene, and has a strength about 50% between the two. It is

resistant to chemical attacks by acids, alkalis and oil. It does not float. It should be noted that there are numerous blends of these two materials under different brand names.

Specific Gravity 1.14. Melting Point 170 °C (Polypropylene material).

ARAMID - another high strength, low extension synthetic fibre rope. It is heavier than all the man-made fibres except polyester. It has good cut resistance but only fair resistance to abrasion and UV resistance. It does not float.

Specific Gravity 1.4. Melting Point 260 "C

Many manufacturers now produce ropes of unconventional construction in an effort to achieve a reduction in weight and/or elasticity, and an increase in strength. When such ropes are used, the manufacturers' literature should always be consulted in order to ascertain the properties and MBL of the rope. These obviously vary greatly depending on materials used.

As an example, a forty millimeter diameter mooring rope gives the following approximate minimum MBL's:

Nylon:	30 tonnes
1st generation HMSF:	83 tonnes
2nd generation HMSF:	119 tonnes
Polyester:	27 tonnes
Poypropylene:	19 tonnes
Aramid:	78 tonnes

When delivered, a certificate from the manufacturer that will indicate the minimum-breaking load should accompany all mooring ropes. These certificates should always be consulted if it is necessary to ascertain the specification of a particular rope.

Synthetic fibre ropes give little or no warning when about to break, and possess low resistance to chafing when under load.

When making synthetic fibre ropes fast to bitts, do not use a "figure of 8" alone to turn them up. Use two round turns (but not more) around the leading post of the bitts before "figure of eighting". This method allows better control of the rope, is easy to use and is safer It also prevents an effective reduction in SWL caused by the compressive forces imposed by figure of eighting.

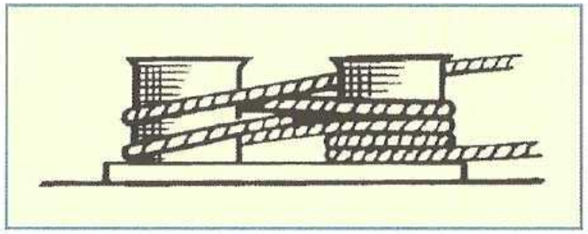


Fig. 26 How to secure a rope correctly

Rope care

(a) **Ropes must** be **kept** clear **of** chemicals, chemical vapours or **other harmful substances.** They should not be stored near paint or where they may be exposed to paint or thinner vapours,

(b) Ropes should not be exposed to the sun longer than is necessary, as ultraviolet light can cause fibres to deteriorate.

(c) Ropes must be visually inspected at regular intervals, and these inspections should include, as far as possible, inspection of the inner strands.

[Excessive wear in synthetic fibre ropes is indicated by powdering between the strands and results in permanent elongation. This indicates a reduced breaking load, and consideration must be given to replacing the rope. If damage is localised, the worn or damaged part can be cut out and the rope spliced.]

The inspection should include checking for the security of strands in splices.

(d) Ropes must be stowed in a well ventilated compartment on wood gratings to allow maximum air circulation and to encourage drainage.

(e) Do not store ropes in the vicinity of boilers or heaters; do not store them against bulkheads or on decks which may reach high temperatures.

(0 Ensure that fairleads and warping drums are in good condition and free from rust and paint. Roller heads should be lubricated and freely moving to avoid friction damage to the rope.

(9) Do not surge ropes around drum ends or bitts, as the friction temperature generated may be high enough to melt the fibres.

(h) If it is necessary to drag ropes along the deck, ensure that they pass clear of sharp edges or rough surfaces.

(0 When using winch stored ropes, do not run them through leads which are not on a direct line from the drum, as they are liable to chafe on the edge of the spool.

Rope stoppers

Wllh the numerous different types of synthetic fibre ropes now available, and the **great** strength of such ropes, it is essential that when "stoppering off" a mooring line **Ens** correct rope stopper is used. Experience has shown that the ideal rope for shippers should satisfy the following requirements:

(,i) The stopper should be a synthetic fibre rope.

(10 The stopper should be used "on the double".

(c) The stopper should be very flexible and the size should be appropriate for the size of moorings, that is, about 50% of the rope diameter.

(d) The stopper rope should be of low stretch material.

(e) The man-made fibre ropes used for the stopper should be made from high melting point material, i.e. polyester or polyamide.

(l) The double rope used for the stopper should, where possible, have a combined strength equal to 50% of the breaking load of the mooring rope on which it is to be used. There is no requirement for fibre handling tail ropes to be proof tested.

Fig. 27 shows the correct method of stoppering off a synthetic mooring rope. The stoppering rope may be made fast by a turn around the leading bitt, if no ring is available.

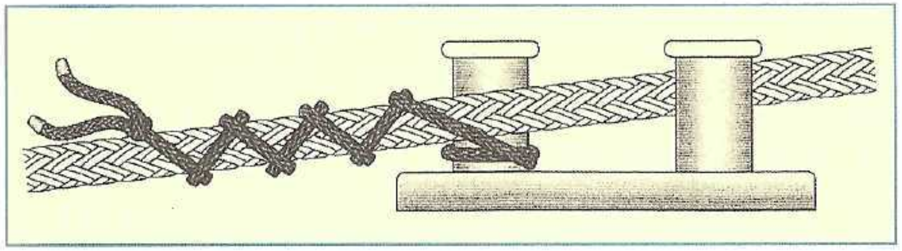


Fig. 27 Stopping off a synthetic fibre rope

Splicing

All splices must have a minimum of 5 tucks using ALL the rope strands and it is important to whip the ends of all the strands before starting the splice. In the case of plaited ropes, manufacturers normally issue detailed instructions as to how they can be spliced.

When a rope is spliced, its breaking load is reduced by about 10%, However, this figure does not increase if more than one splice is made in a rope.

Splicing of HMSF ropes should only be completed by a competent person and in compliance with manufacturers instructions.

Snapback

The most serious danger from synthetic ropes is "snapback" which is the sudden release of Ihe energy stored in the stretched synthetic line when it breaks. The primary rule is Lo treat every synthetic line under load with extreme caution; stand clear of the potential path of snapback whenever possible! Synthetic lines normally break suddenly and without warning. Unlike wires, they do not give audible signs of pending failure and they may not exhibit any broken elements before completely parting.

When a line is loaded, it stretches. Energy is stored in the line in proportion to the load and the stretch. When the line breaks, this energy is suddenly released. The ends of the line snap back striking anything in their path with tremendous force.

This snapback is common to all lines. Even long wire lines under tension can stretch sufficiently to snap back with considerable energy. Synthetic lines are much more elastic, and thus the danger of snapback is more severe.

Stand well clear of the potential path of snapback (see Fig. 28). The potential path of snapback extends to the sides of and far beyond the ends of the tensioned line.

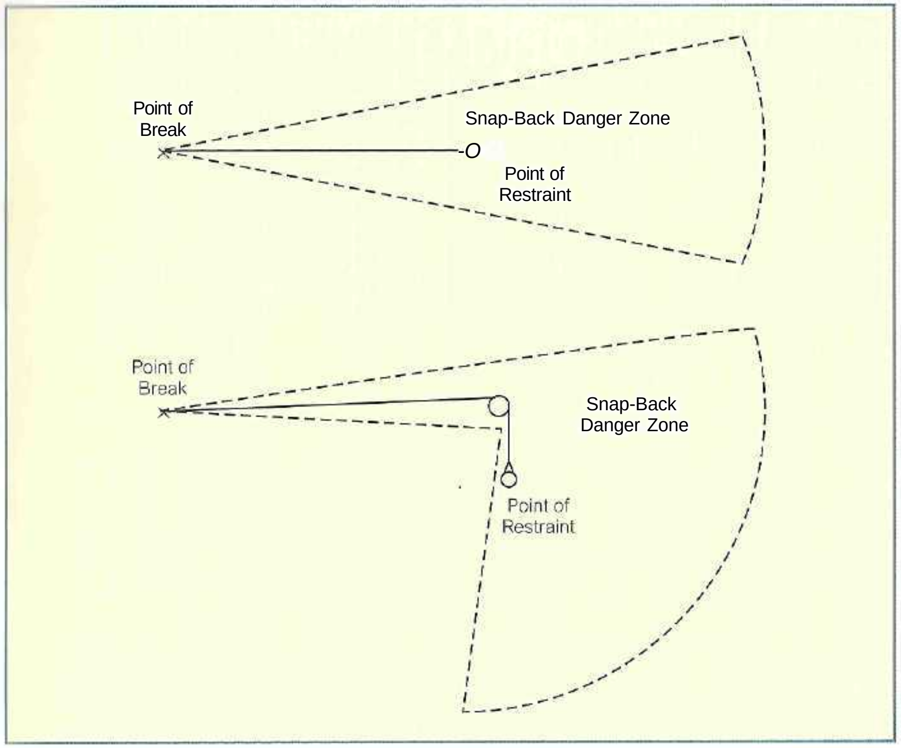


Fig. 28 Snapback zones

A broken line will snapback beyond the point at which it is secured, possibly to a distance almost as far as its own length. If the line passes around a fairlead, then its snapback path may not follow the original path of the line. When it breaks behind the fairlead, the end of the line will fly around and beyond the fairlead.

It is not possible to predict all the potential danger zones from snapback. When in doubt, stand aside and well away from any line under tension.

When it is necessary to pass near a line under tension, do so as quickly as possible. If it is a mooring hawser and the ship is moving about, time your passage for the period during which the line is under little or no tension. If possible, do not stand or pass near the line while the line is being tensioned or while the ship is being moved along the pier. If you must work near a line under tension, do so quickly and get out of the danger zone as soon as possible and plan your activity before you approach the line.

It should be noted lhat HMSF synthetic fibre ropes have similar breaking characteristics to wire ropes. However, it is noted thai snapback from these materials will be along the length of the line and not in a snaking manner as found with wire ropes. Snapback in some HMSF ropos is contained, with slrands breaking in **a** cascade effect which significantly reduces the snapback.

SAFETY REMINDERS

Do not surge synthetic fibre ropes on the drum end; in addition to damaging the rope, as it melts it may stick to the drum or bitt and jump, with a risk of injury to people nearby. ALWAYS walk a winch back to ease the weight off the rope.

Do not stand too close to a winch drum or bitt when holding and tensioning a line; if the line surges you could be drawn into the drum or bitt before you can safely take another hold or let go. Stand back and grasp the line about one metre from the drum or bitt.

Do not apply too many turns over the warping drum end; generally 4 turns should be taken with synthetic lines - if too many are applied then the line cannot be released in a controlled manner.

Do not bend the rope excessively,

Do not stand in the bight of a rope.

Do not stand close to a rope under load; it may part without warning,

Do not leave loose objects in the line handling area; if a line breaks it may throw such objects around as it snaps back.

Do not have more people than necessary in the vicinity of a line.

READ ANY GOVERNMENT NOTICES, COMPANY INSTRUCTIONS OR 'CODES OF PRACTICE' ON BOARD YOUR SHIP

Offshore Operations

Conventional or Multi-buoy Moorings (CBM or MBM)

Although there are many variations, one layout of such a berth is shown in Fig. 29, with the ship moored in position using both anchors **forward** and with the stern secured to buoys located around the stern.

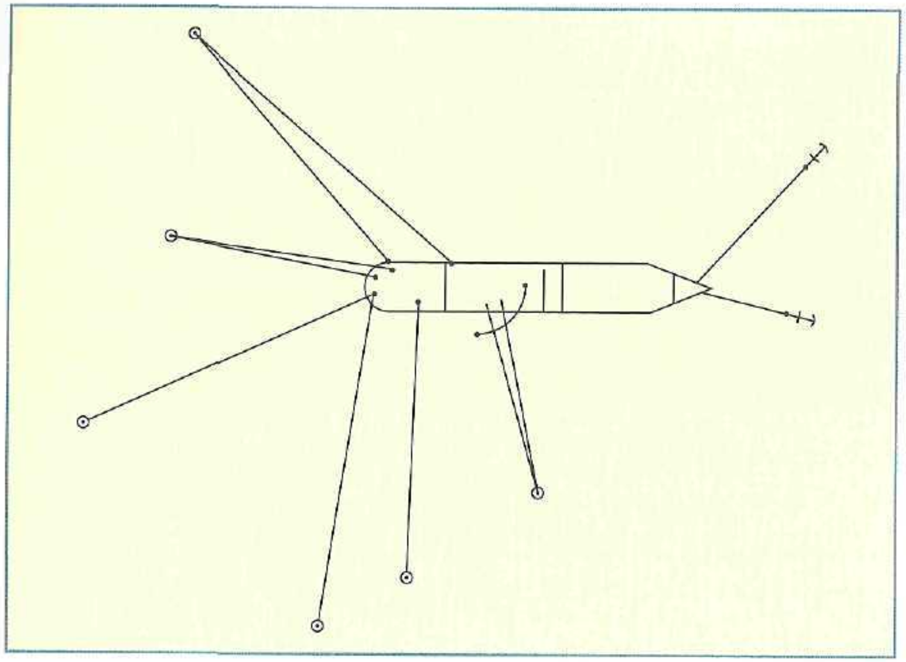


Fig. 29 CBM moorings

The mooring operalion is often carried out without Lugs, and requires the full and efficient use of all the ship's mooring equipment.

The operation starts with the ship carrying out a "running moor" and, while it is most common for the manoeuvre to be started with the stern buoys on the port side of the ship to take advantage of the propeller thrust when the engine is going astern, there are however, some berths where for a particular reason the manoeuvre has to be started with the buoys to starboard. Fig. 30 shows the different stages of the operation.

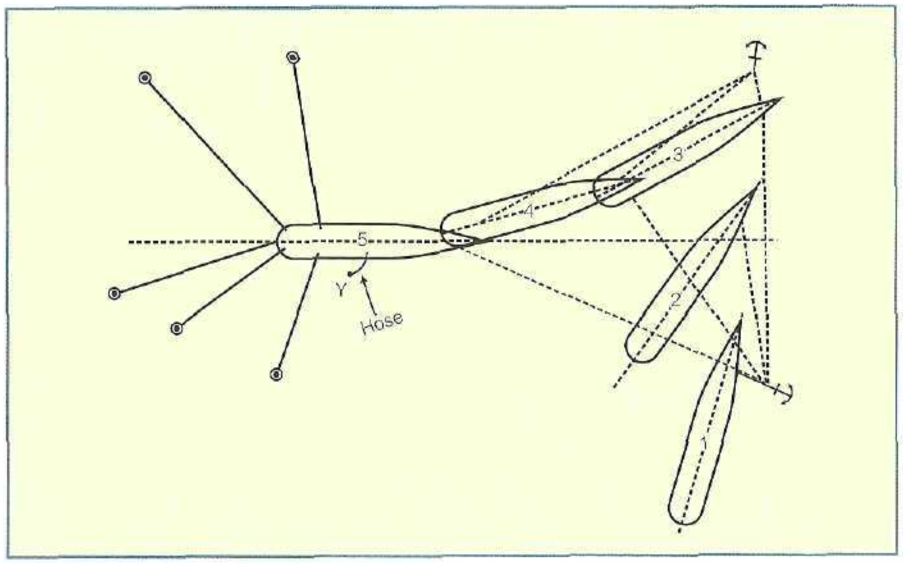


Fig. 30 Running moor to CBM

The tanker steams slowly towards the forward end of the berth in a line almost perpendicular to her final position. At the correct moment, the starboard anchor is let go and the cable is run out as the ship moves ahead, whilst the engine is operated astern; when the ship is stopped in the water the port anchor is let go. By careful manoeuvring of the engines and helm, and by paying out on the port cable whilst heaving in on the starboard cable, the stern of the ship is swing round so that it passes clear of the nearest buoy at the same time as the ship is backing into the sector between the buoys. Mooring lines have to be run to the buoys as quickly as possible in orderto assist controlling the swing and heaving the ship backwards into the berth.

Considerably higher loads than those experienced during a normal berthing operation are imposed on the lines, and it is recommended that only lines on drums are used during such an operation. Because of these higher than normal loads, all the equipment should be thoroughly checked beforehand, and only good quality lines should be used. The number of personnel required should be kept to the essential minimum and restricted to experienced seamen. The mooring team should be briefed beforehand and under the direct supervision of an experienced officer.

At many CBM's, the ships' moorings are often supplemented by shore wires run from the buoys or from sub-sea platforms. The handling of these heavy wires around

the warping drum of a winch and then onto bitts, should be done carefully by experienced seamen. When stopping off the wires prior to securing to bitts, correctly sized carpenter stoppers should be used.

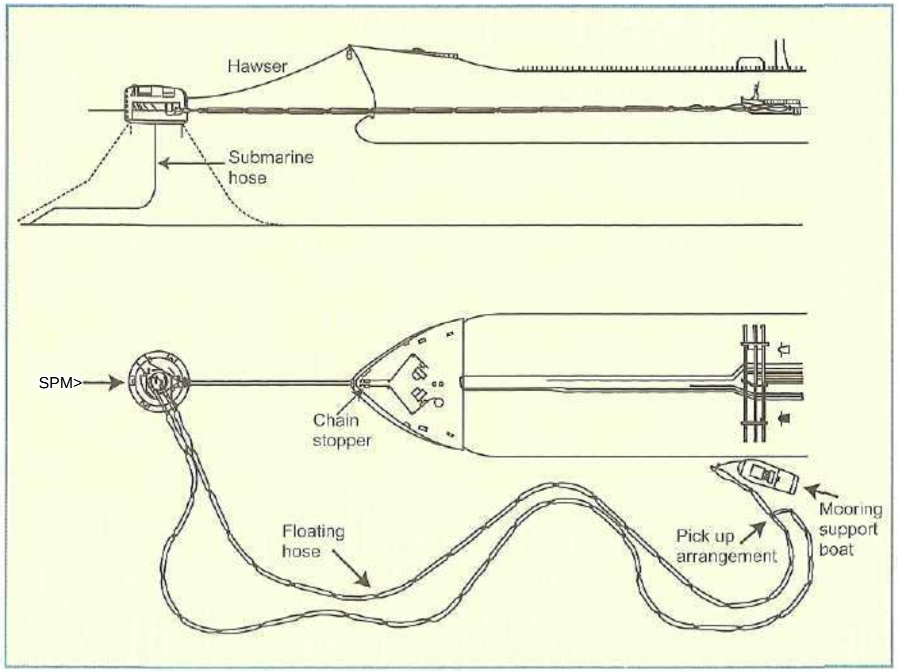
There are often lengthy periods when mooring boats are around the stern, or mooring lines are in the water, and good communications between poop and bridge are essential to avoid boats or lines from being caught up in the propeller.

Because the whole operation initially depends on dropping the first anchor in the correct place, leading lines or ranges usually mark the approach line and dropping point. If the anchor is let go too far away it is virtually impossible to heave the ship into the berth using the lines alone; the best option is to heave up and start again.

When unberthing, if using shore wires, they should be stoppered off, and transferred to the winch drum then walked back, using slip wires as necessary. Full-length wires should never be let go "on the run", due to the dangerous whipping action of the wire.

I lie ship's lines are then heaved in as the anchors are both weighed and the ship moves forward clear of the buoys. The windward mooring line is usually the last one lo be let go, in order to prevent the stern dropping onto the lee buoys.

Single Point Mooring (SPM)



Fig, 31 Single Point Mooring (SPM)

At a buoy SPM the tanker bow is secured to the buoy using specially supplied moorings that are attached to a swivel on the buoy, allowing the tanker to swing around the buoy in response to wind and tides.

Because the ship is only moored at one point, the entire load is borne by the one or two mooring lines used, in the order of 70-100m in length. In addition to the normal static loads, considerable dynamic (shock) loads are experienced as the ship moves to wind, tide and sea, It is therefore impracticable for the ship's normal mooring lines to be used, and the terminal always supplies special mooring lines. There are one or two lines each of 120-190mm diameter made from nylon or polyester, giving very high minimum breaking loads.

[illegible]um B[illegible] Loads		
	Nylon	Polyester
120mm	305 tonnes	219 tonnes
168mm	570 tonnes	430 tonnes
192mm	760 tonnes	550 tonnes

Obviously with the ship moving significantly the hawsers would quickly chafe on the fairlead. To overcome this, chafe chains are attached to the end of each hawser and it is these chains which pass through the fairleads and are connected on board to specially designed chain stoppers (see Fig. 32) located on the fo'c's'le for this purpose. The chains are 76mm diameter links with safe working loads of 250 tonnes.

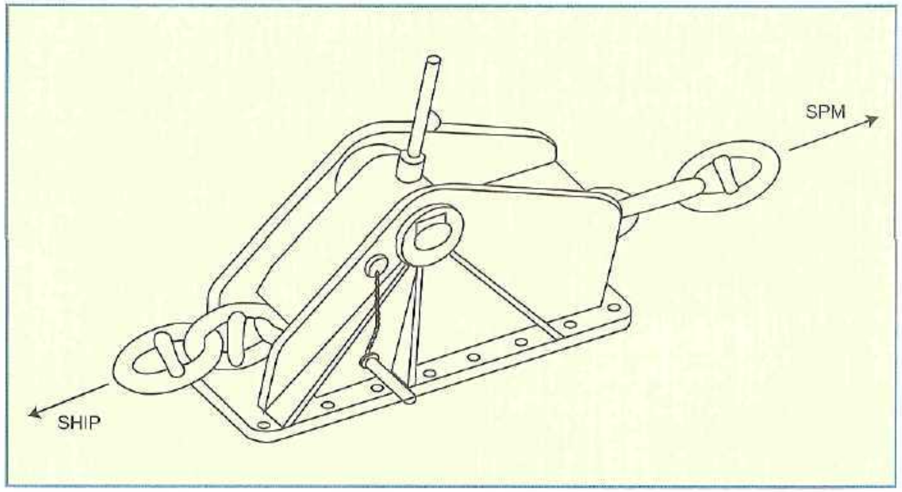


Fig. 32 Chain Stopper

The chains and hawsers are supported by a buoy and attached to the end of the chain is a floating pick up rope.

Before the ship commences her approach to the buoy, a messenger line should be ready on the fo'c's'le running through one of the bow fairieads. This messenger (approximately 24mm, and of sufficient strength for the operation) should pass through the chain stopper before going to a winch. A direct and straight line lead of the pick up rope from the fairlead to the winch drums is preferable, so that the use of pedestal leads can be avoided, or at least minimised, and the whole operation can be carried out on a "hands off" basis.

A mooring assistant stationed on the bow normally supervises the mooring operation. He should be accompanied by a responsible officer who is in radio contact wilh the bridge to pass on the master's instructions.

In order to avoid damage to submarine pipelines and SPM anchor chains, **the** ship's anchor should not be dropped except in an extreme emergency. Most terminals require anchors to be secured during the mooring operation, to avoid inadvertant release.

When the ship is close to the SPM, the messenger is lowered to a mooring boat where it will be connected to the pick up rope and when the boat is clear this should be heaved on board. The pick up rope should be heaved in until the chafe chain passes through the fairlead and reaches the required position. Care should be taken when winching in the pick up rope and chain to ensure that there is always some slack in the mooring assembly. It can be very dangerous to the mooring crew if the assembly becomes tight before connection is completed, and the ship should be carefully manoeuvred to ensure that this does not occur ***The pick up rope must never be used to heave the ship into position or to maintain its position.*** Once the chafe chain is in position it should be secured to the stopper as quickly as possible.

Once the chain is connected the pick up rope should be walked back until the weight is transferred to the stopper.

Although tending of moorings is not required, an experienced crewmember should be posted forward at all times to observe the moorings and the SPM and to advise if the tanker starts to ride up to the buoy or starts to yaw excessively.

When unmooring, the weight of the chains should be taken on the winch before lifting the stopper. The chains should then be walked back into the waLer and the pick up rope slowly paid out through the fairlead.

When mooring to either a CBM or an SPM, always have a few items of essential equipment such as a large axe, sledgehammer and crow bar readily available to the crew.

Mooring to FPSO's, (Floating Production Storage and Offloading units) and FSU's (Floating Storage Units)

FPSO's are generally a purpose built or converted tanker's hull, anchored in place with oil stabilising equipment fitted on to its deck, connected to the oil wells on the sea bed by sub-sea risers.

FSU's are again generally a converted tanker's hull which receives stabilised crude oil from a production platform, and is used as storage for Ihal platform's produced oil.

There are different types of FPSO/FSU offshore mooring systems. The most common system is the tandem arrangement where the export tanker is connected bow to stern or bow to bow with the FPSO/FSU using a taught hawser and floating hose arrangement similar to those on SPM's. Some FPSO/FSU arrangements utilise a remote SPM, and some FSU's use "side by side" offloading, similar to STS arrangements.

FPSO's/FSU's can be stationed in a number of different ways. From the point of view of the exporting tanker moored in tandem, the important difference is the ability of the FPSO/FSU to rotate in azimuth (weathervane). Those that are unable to rotate in azimuth are usually "spread moored", and are held in position by a number of anchors. Spread moored FPSO/FSUs are generally only suited to tandem offloading in benign environmental conditions. Those that rotate in azimuth, swivel around an internal turret or external gantry arrangement. Some of these may have the ability Lo conlroi their own azimuth though thrusters or azimuth pods.

A lot of FPSO's in harsher climes use dedicated "shuttle tankers" with specialised bow loading equipment and in a lot of cases Dynamic Positioning (DP) gear which keeps the vessel on station astern of the FPSO without putting any tension on the Mooring Hawser. Non DP specialised vessels moor directly astern but use hawser tension (with engines operating astern at low revolutions or due to weather) in order lo maintain position astern of the FPSO; these vessels generally operate within a smaller weather window than the DP versions.

Both the above types of arrangements use specially trained crews who are familiar with this type of operation and receive no assistance from the terminal in mooring and connecting hoses. (See Fig. 33)

The dedicated tankers will be equipped with Emergency Shut Down (ESD) equipment for quick release of hose and hawser, linked to the FPSO by a telemetry system. This system will enable the tanker to stop the transfer automatically and release all gear for a rapid departure without causing pollution or harm to equipment.

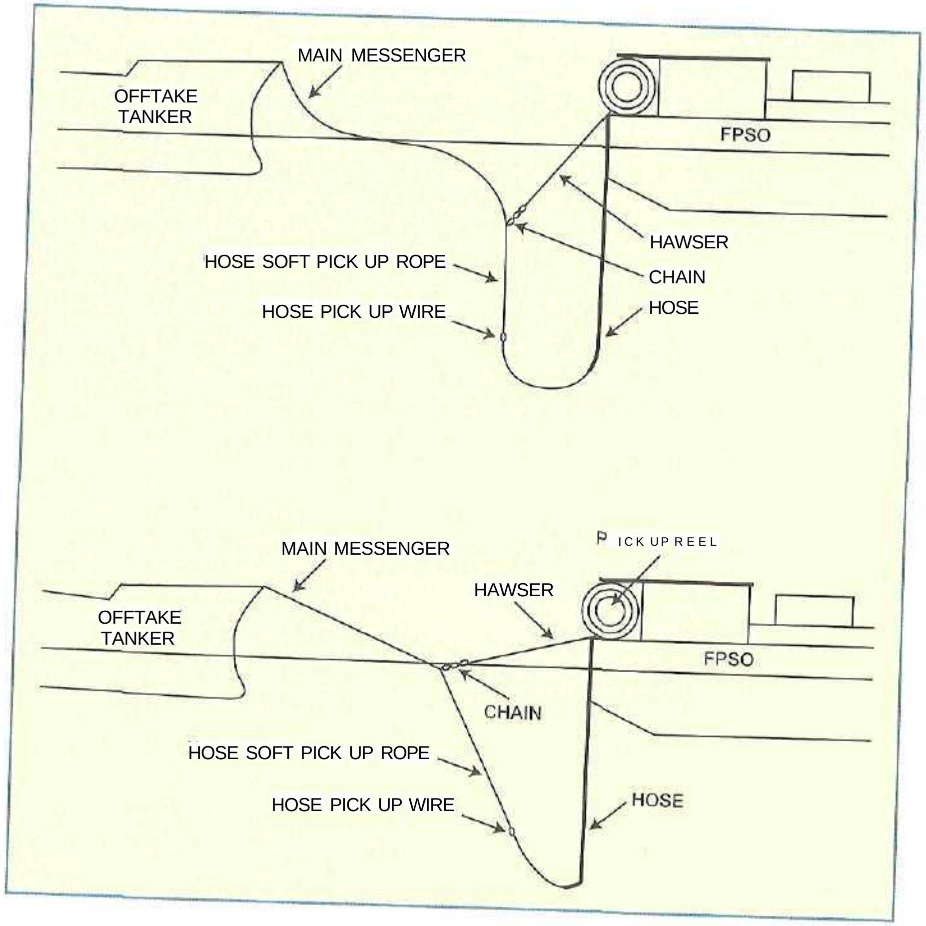


Fig. 33

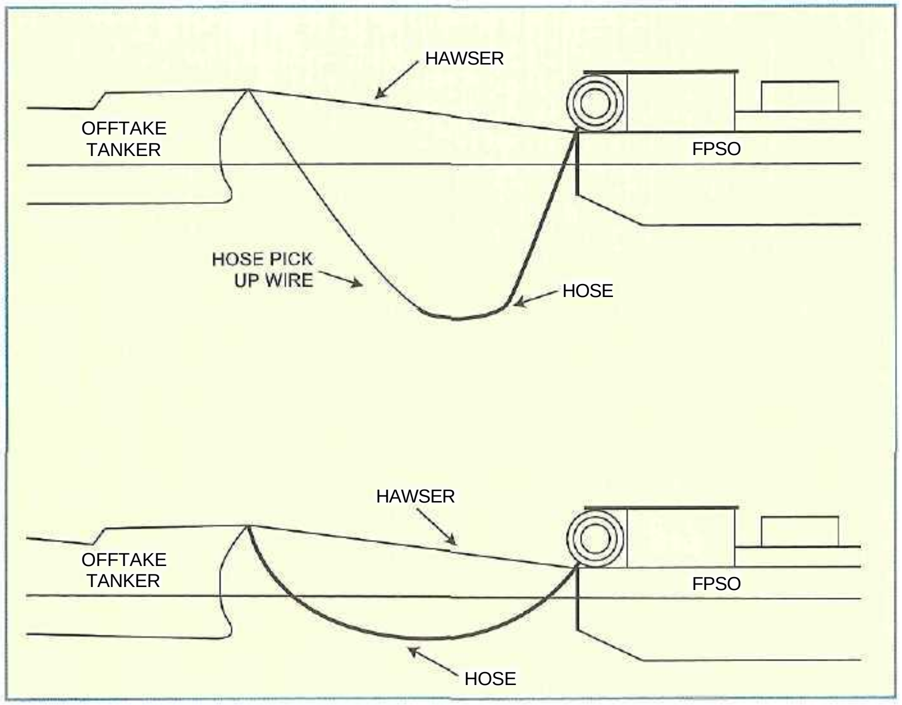


Fig. 34 Mooring to FPSO

In more benign waters, standard tankers are used to offload from the FPSO, again the mooring principle is the same, with the bow secured to a chafe chain at the end of a large diameter hawser, by AKD stoppers.

The main difference is, as with SPM's, the hose strings are connected to the conventional midships manifold, these being brought to the ships side, in position for lifting, with the aid of a hose handling boat.

A hold back tug is also often made fast to the stern of the offtake tanker to maintain station at the FPSO.

These types of FPSO will have shore assistance from Pilots and loading masters as well as, in some cases, rigging crew for hose connection.

All FPSO Terminals will have specific weather limits which specify the maximum conditions in which mooring and offtake operations are permitted to take place. This weather criteria should be taken as an extreme and preparations for stopping the operation should be initiated before these weather limits are reached.

As noted above there are a variety of different combinations, however the prime interest to the export tanker operator is the approach, mooring, station keeping once moored, and the offloading system.

The differing layouts of these terminals will be explained in Field Specific Operations manuals which should be provided to vessels using the terminal. Masters of such vessels should be briefed by Terminal representatives before any operation is commenced, as well as notification of requirements before arrival.

Mooring operation

The mooring approach is usually made in line with the direction the FPSO/FSU is lying. Sometimes with 'spread moored' FPSO/FSU's, the approach will be conducted at a slight angle to take advantage of transverse thrust in case of an astern abort. Usually "pull back" tug or tugs are used to help control the approach by exerting a restraining force at the stern *of* the export tanker Often these tugs can be very powerful multi-purpose field service boats as opposed to purpose designed ship-handling tugs. Such tugs are not usually suitable for pushing but can be capable of exerting high bollard pull forces on the export tanker well in excess of the SWL of the bitts and fairleads to which the towline is attached.

- **Unless the export tanker is fitted with a special aft towing strongpoint, it is preferable that the towline is made fast by a "single eye" on one post of the largest available bitts through a fairlead in the same fore and aft line as close to the centre line as possible. If the towline has to be turned up, ensure that the first one or two turns are around the leading post (see OCIMF *Mooring Equipment*** *Guidelines).*
- **Once connected all personnel should stay well clear of the bitts and chocks throughout mooring and loading.**
- **PLEASE NOTE THAT OCIMF HAVE PUBLISHED RECOMMENDATIONS TO SHIP OWNERS THAT FAIRLEADS AND BITTS USED FOR TUG ESCORT OR PULL BACK DUTIES ON TANKERS OVER 50.000T DWT SHOULD BE AT LEAST 200T SWL.**
- **The strong preference is for "pull back" tugs to provide the complete tow line arrangement, terminating at the ship end in a single soft eye. Use of ships mooring wires on self-stowing drums (or removed from drums and turned up) is not recommended.**

Ship-to-Ship Transfer Operations {STS)

The STS transfer of crude oil and petroleum cargoes has become common practice. They are performed fora variety of reasons including standard operational considerations such as draft limitations of the large vessel, and also emergency purposes such as when one ship is aground or disabled. When organisers are planning an STS transfer operation they should ensure that the ships to be used are compatible in design and equipment and that all operations, including mooring, can **be** conducted safely and efficiently.

An STS transfer operation should be under the advisory control of one individual who will be either one of the Masters concerned, or an STS superintendent.

One of the **two** ships, normally the larger, maintains steerage way at slow speed (preferably about 5 knots) keeping a steady course heading. The manoeuvring ship then manoeuvres alongside. It is recommended that the manoeuvring ship approaches and berths with her port side to the starboard side of the constant heading ship. STS transfer operations involving one ship already positioned at anchor are also quite frequent. For such operations, one ship anchors in a pre-determined position using the anchor on the side opposite to that on which the other ship will moor.

Mooring operations should be managed to ensure safe and expeditious mooring line handling. Moorings should be arranged and rigged to allow safe, effective line tending when the ships are secured together. This is especially true on board the manoeuvring ship whose mooring lines will normally be used, but should also be addressed on the constant heading ship where rope messengers have to be made ready between fairleads and deck winches. The order of passing mooring lines during mooring, and of releasing lines during unmooring should be agreed in advance of the operation.

The mooring plan adopted will depend upon the size of each ship and the difference between their sizes, the expected difference in freeboards and displacement, the anticipated sea and weather conditions, the degree of shelter offered by the location, and the efficiency of mooring line leads available. Most STS service providers will have a standard mooring plan, suitable for the particular location. It is important to ensure moorings allow for ship movement and freeboard changes to avoid over stressing the lines throughout the operation, but that they are not so long that they allow unacceptable movement between the ships. Mooring lines leading in the same direction should be of similar material. Lines should only be led through closed chocks or leads suitable for STS operations. The use of stopper bars to retrofit open chocks is not recommended.

It is normal for the mooring lines lo be deployed from the manoeuvring ship. However, when prevailing weather conditions or weather forecasts require it, sending lines from both ships can increase the number of mooring lines. Loads should not be concentrated by passing most of the mooring ropes through the same fairlead or onto the same mooring bitts. Use should be made of all available fairleads and bitts.

A ship's standard complement of mooring lines is generally suiLable forSTS transfer operations but ships equipped with steel wire or high modulus synthetic fibre mooring lines should fit soft rope tails to them. The connection between the primary line and the soft rope tail is made with an approved fitting e.g. Mandel or Tonsberg Shackle.

Rope tails should be at least 11 metres long and have a dry breaking strength at least 25% greater than that of the wires to which they are attached in accordance with OCIMF *Mooring Equipment Guidelines.* Soft rope tails fitted to wire moorings also introduce the benefit of making the cutting of mooring lines easier in an emergency and, for this purpose, long-handled firemen's axes or other suitable cutting equipment should be available at all mooring sLations.

Strong rope messengers should be readied on both ships and in addition, rope stoppers should be rigged in way of relevant mooring bitts. Where possible, heaving lines and rope messengers should be made of buoyant materials. A minimum of 4 messengers should be provided and ready For immediate use.

Non-pyrotechnic line-throwing equipment may be used to make the first connection. Crews should be advised beforehand and further warned immediately before the equipment is used.

Excessive or uneven tension in mooring lines should be avoided because it can significantly reduce the weather threshold at which the forces in mooring lines will exceed their SWL. Attention should be given to this throughout the STS operation in order to ensure changes to the relative freeboards do not create excessive strain in the moorings. Studies have demonstrated that peak loads on individual head and stern mooring lines can be minimised if the lead angles are similar and thus more effectively share the mooring loads.

For further details please refer to the ICS/OCIMF *Ship-to-Ship Transfer Guide (Petroleum/ Liquefied Gas).*

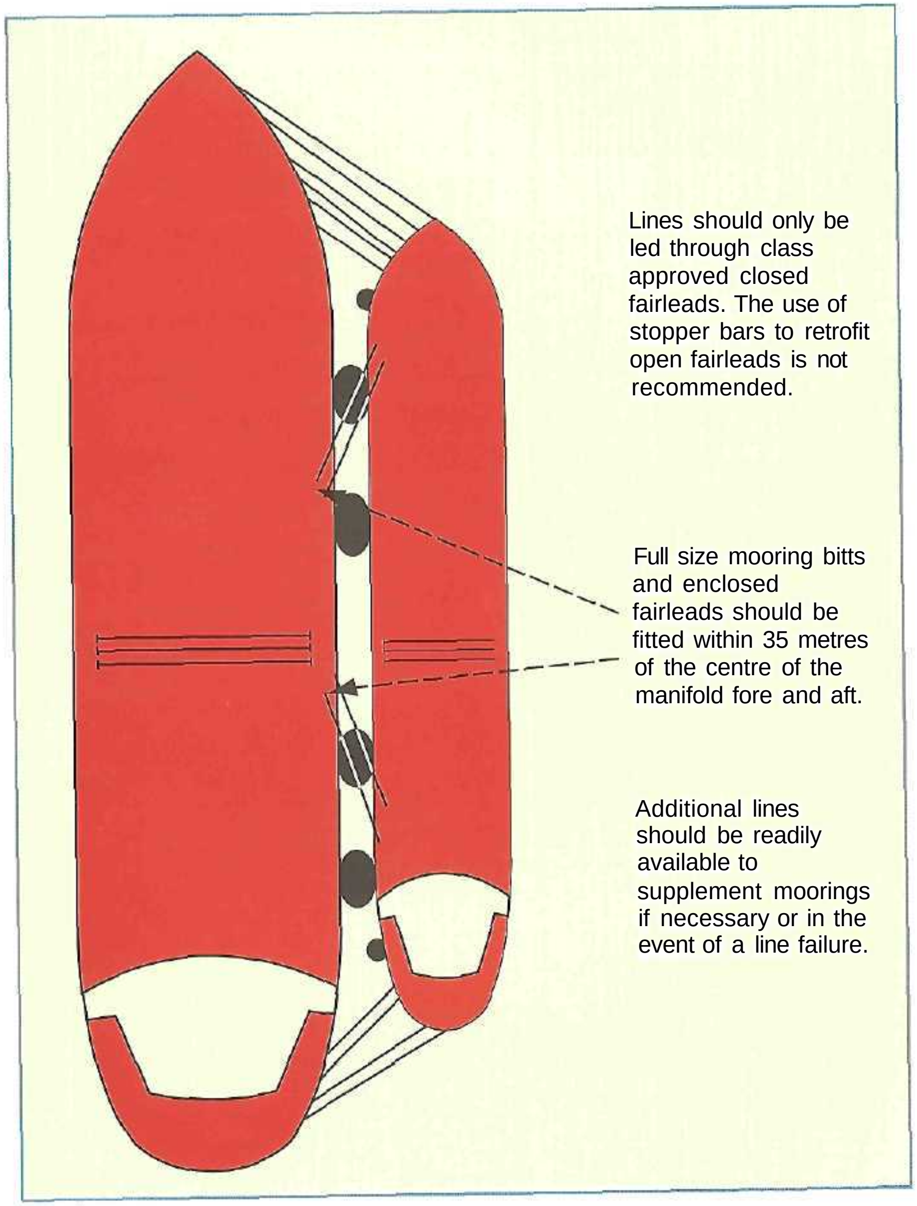


Fig. 35

Chapter 6

Windlasses and Anchoring

It is essential that you read your company's rules and regulations concerning anchoring. They will give clear directions for anchoring procedures. Nevertheless, anchor losses sometimes occur on all classes of vessel and have mainly been attributed to:

(a) Too great a vessel speed over the ground.

(b) Too little cable being paid out during the initial lowering of the anchor prior to letting go.

The risk of anchor and cable losses, particularly on large ships such as VLCC's, may be minimised by:

(a) Ensuring minimum or nil speed over the ground. An indication of speed over the ground can be determined by a number of means including navigational aids and by observation of the wake whilst engines are running astern.

(b) The fitting of a speed limiter to the windlass.

(c) In all cases, the anchor should be "walked" (i.e. lowered with the windlass in gear) out of the hawse pipe until just clear of the water

(d) Anchoring with the windlass in gear. This gives good control over the anchor and cable throughout the operation. It also helps to maintain brake efficiency by reducing wear of the brake lining.

In all cases, care must be taken to avoid over speeding of the windlass engines to avoid damage.

Brakes

These will be most effective if tightened up at the moment that the maximum weight comes on to the anchor cable. Further adjustment should then be unnecessary, as the changes in load due to changing tides and wind will be borne by the cable stopper.

Cable stoppers

Cable stoppers form an integral part of the anchor cable restraining equipment and are designed to take the anchoring loads. Cable stoppers must be used when the vessel is anchored, and must be applied only after the brake has been set to ensure that the brake augments the action of the stopper for additional security. Fig. 36 shows the correct way to fit a stopper.

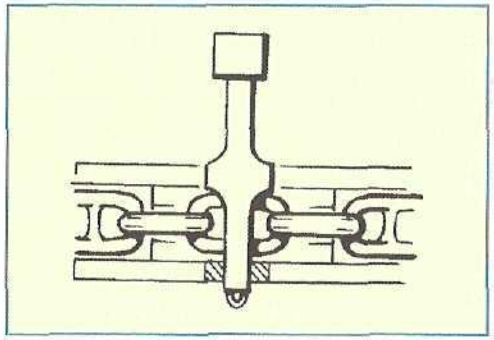


Fig. 36 Correct stopper fitting

Consideration may also be given to tying down the cable stopper whenever it is in use, in order to prevent it jumping when under a heavy load.

Cable stoppers must also be in position, together with the securing chains, when the anchor is "home" in the pipe.

Anchor cables

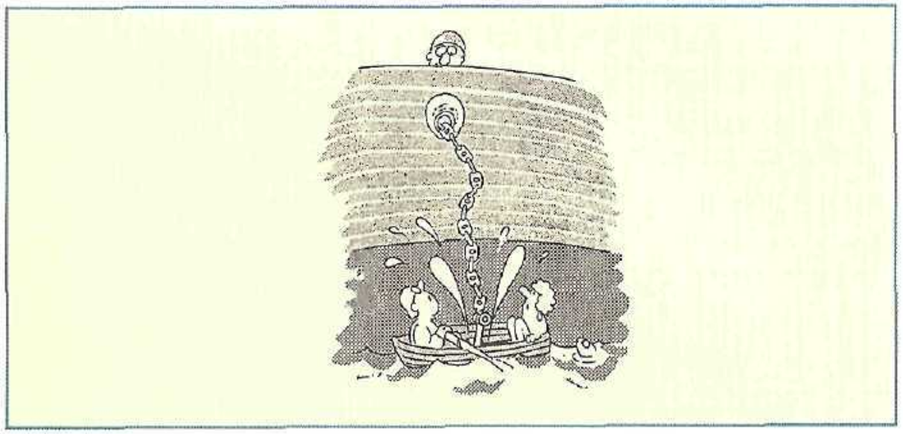
It is very important that anchor cable lengths are clearly marked with white paint and if possible, stainless steel bands, even when cable counters are fitted.

It is also advisable to paint the second shackle from the bitter end, in order to identify it. This will serve as a visual warning of the approach of the end of the anchor cable.

Communication

If you are charged with the duty of controlling the anchor during an anchoring operation, be sure that the bridge is aware of precisely what is happening or could happen, as the Master is, to a large degree, dependent upon your information. It is important to relay information to the bridge e.g. the direction and amount of cable paid out, and an estimation of whether there is for example light, moderate or heavy weight on it.

Before lowering the anchor or indeed, heaving in, check over the side for small boats, tugs, etc.



Maintenance of windlass brakes

Windlass brakes require careful attention with regard to greasing and adjustment.

Where linkages form part of the braking mechanism, it is important that the linkages are **free.**

Malfunction can cause the operator to believe that the brake is fully applied when, in fact, it is **not.**

It is also most important to inspect the tightness of 'bearing keep nuts' and 'cotter pins', especially after a refit, where it is known that work has been carried out on the assembly.

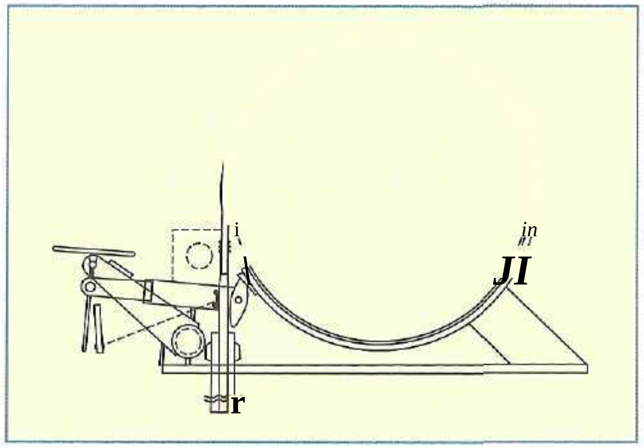


Fig. 37 Typical brake arrangement

Adjustments

Provision is sometimes made to compensate for brake lining wear. Consult the Manufacturer's instructions and make sure you are familiar with this facility.

If in doubt about the brake holding efficiency - REPORT IT!

Prolonged periods of non-use

After a long sea passage and a port call not requiring the use of either anchor, consideration should be given to a controlled walking-out (i.e. windlass in gear) of the anchors and cable to ensure that the system is still fully operational.

Greasing of bearings, brake linkages, etc, should be carried out during this operation.

SAFETY REMINDERS

Do not stand in line with the cable when it is under load or being "run out" or "hove in".

The anchoring party *MUST wear.*

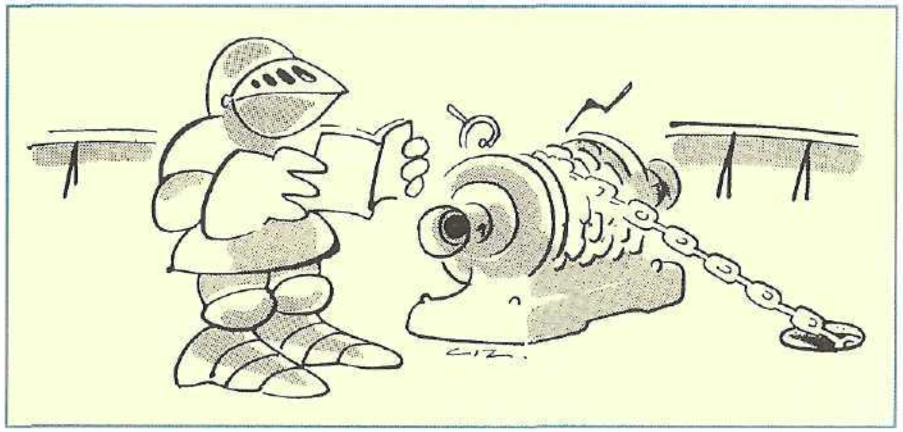
(1) Safety goggles; the windlass operator should remember that the wearing of safety goggles may reduce his field of vision, but nevertheless, they must be worn.

(2) Safety helmet.

(3) Safety shoes.

(4) A good pair of overalls with long sleeves.

Flying fragments can injure the operator. Minor injuries could distract him and set the scene for a more serious accident.



READ ANY GOVERNMENT NOTICES, COMPANY INSTRUCTIONS OR 'CODES OF PRACTICE' ON BOARD YOUR SHIP.

Chapter 7

Personal Safety

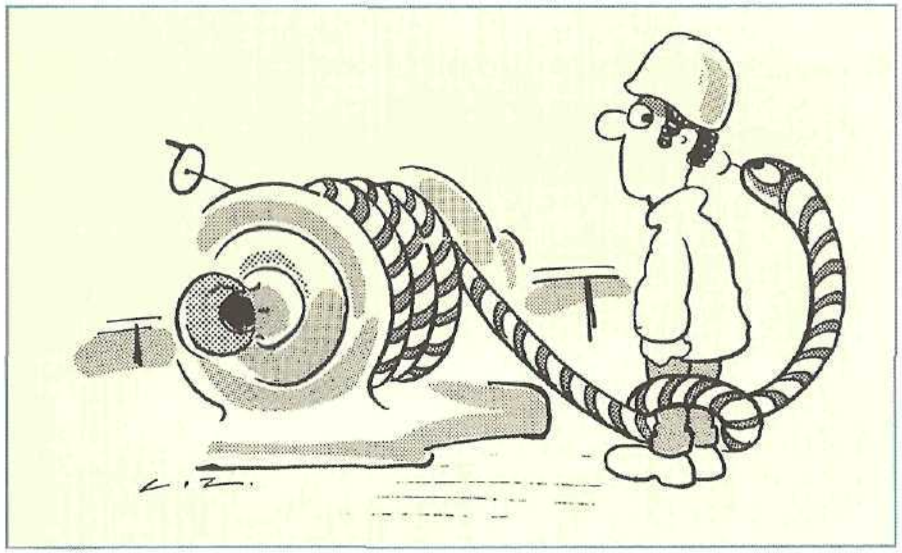
Handling of moorings

REMEMBER, you stand a greater risk of injuring yourself or a shipmate, during mooring and unmooring operations than at any other time.

STAND CLEAR of all wires and ropes under heavy loads even when not directly involved in their handling.

When paying out wires or ropes, watch that both your own and shipmate's feet are not in the coil or loop.

BEWARE THE BIGHT!



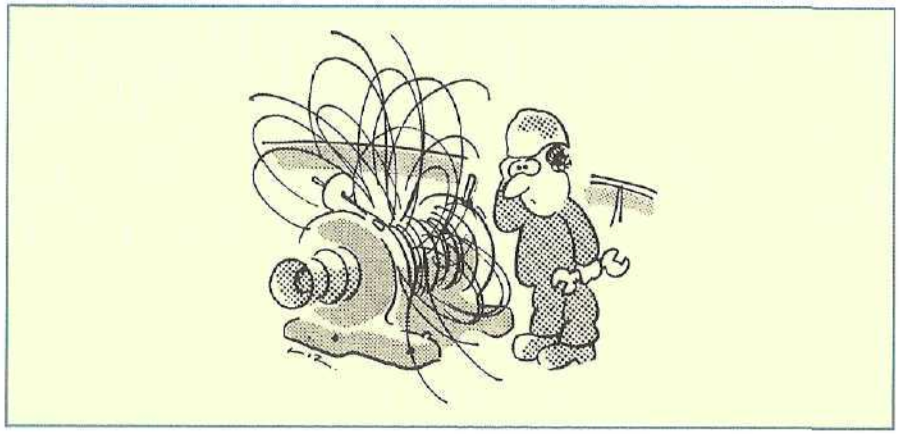
Beware the Bight!!

Always endeavour to remain in control of the line.

Anticipate and prevent situations arising that may cause a line to run unchecked. **If the line does take charge, DO NOT attempt to stop it with your feet or hands as this can result in serious injury.**

Ensure that the "tail end" of the line is secured on board to prevent complete loss.

WHEN OPERATING A WINCH OR WINDLASS, ensure that the operator (or yourself} understands the controls and **CAN SEE** the officer or person in charge for instructions.



DO NOT leave winches and windlasses running unattended. DO NOT stand on the machinery itself to get a **better view.**

DO NOT use a wire direct from a stowage reel that has been designed only for stowing, but ***do make sure*** you have enough wire off the **reel** ***before*** you put it into use.

When using a Double Barrel Winch, ***ensure that the drum not in use is clear.***

Safe handling of tug lines

When tugs are used to assist manoeuvring the ship, additional care is required by the ship's crew.

The condition of the tug's lines is unknown, and the crew on mooring stations will not normally be aware of when the tug is actually heaving or what load is being applied to the line. ***It is therefore important to stay well clear of the towline at all times. Beware the snapback zone!***

When the tug is being secured or let go, the person in charge of the mooring should monitor the operation closely to ensure that no load comes onto the line before it is properly secured, or whilst it is being let go.

Never let a tug go until instructed to do so from the bridge; do not merely respond to directions from the tug's crew.

If the towline has an eye on it, heave this past the biLLs so that there is sufficient slack line to work with, stopper off the line, then put the eye on the bitts. Do not try to manhandle a line on to the bitt if there is insufficient slack line. If the line has no eye and is to be turned up on the bitts Ihen it should always be stoppered off, before handling it.

Do not try to hold a line in position by standing on it just because it is slack - if the tug moves away so will you!

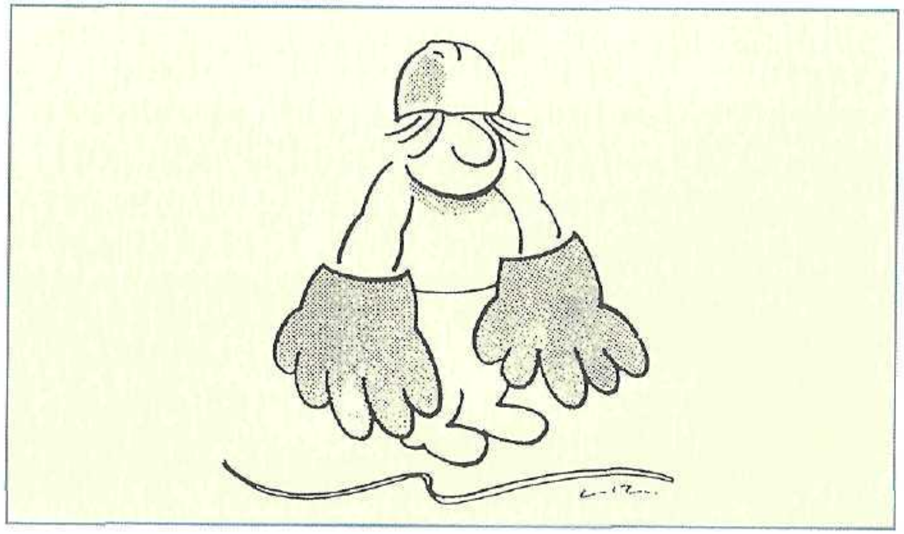
When letting go do not simply throw the line off the bitts and let it run out; always slack it back to the fairlead in a controlled manner, using a messenger line if necessary to avoid whiplash.

Gloves

Gloves protect the hands against abrasion and also give insulation against very hot or cold conditions, both of which could affect a person's handling of equipment.

Wire should not be handled without leather or similar heavy protective gloves. These can prevent wounds caused by "snags" (broken wire strands). Such wounds may become infected and may bring about medical complications.

Loose fitting gloves are more liable to become trapped between wires and other equipment such as drum ends *or* bollards and do not give the necessary degree of protection.



In any event, it must always be remembered lhat gloves cannot be relied upon to give complete protection against snags in the wire. Also, that such snags may cateh in the material and endanger life and limb through trapping.

Such an event can be prevented by attention to the good practices described in this book.

SAFETY REMINDERS

Do not attempt to handle a wire or rope on a drum end, UNLESS a second person is available to remove or feed the slack rope to you. Someone should be able to stop the winch immediately in the event of a problem.

Do not work too close to the drum when handling wires and ropes. The wire or rope could "jump" and trap your hand.

Always wear safety helmets with chinstraps properly tightened during mooring operations.

Gear wheels and other moving parts must be protectively covered. If any guards are missing:

Report it!

Have them replaced as soon as possible.

Keep your distance