Mooring Equipment Guidelines (MEG4)

Fourth Edition 2018

OCIMF

The Mooring Equipment Guidelines has been fully reviewed and updated for the fourth edition.

New chapters and key changes include:

- Enhanced guidance for the purchasing, condition monitoring, and retirement of mooring lines and tails.
- Enhanced guidance on documentation of mooring equipment.
- New chapter on the Human Factors in Mooring Design.
- New chapter on Jetty Design and Fittings.
- New chapter on Ship Shore Interface.
- New chapter on Alternative Technologies.

The updated guidance addresses the questions raised by reader since the third edition was published in 2008. We have reviewed not only the technical content, but also the language so that the information provided is clear and easy to understand.

The guidance within MEG is sure to enhance the safety of mooring from the design of mooring arrangements using a Human Centered Design approach and an increased focus on the use and understanding of mooring lines and tails.

1.1 - General

Mooring is the securing of a ship to a marine facility, terminal, berth or another ship using mooring lines. It is one of the most important and frequently undertaken activities on board any ship. For the purposes of this publication, mooring is considered to be an integrated system that factors in the role that each component in the system plays, resulting in a securely moored ship.

Most tankers are moored to conventional piers and sea islands. However, tankers may be moored to facilities that may not be connected to the shore, including Multi Buoy Moorings (MBMs), Single Point Moorings (SPMs), Floating (Production) Storage and Offloading units (F(P)SOs) and other offshore loading/discharging facilities.

Ships may engage in a broader range of mooring operations when undertaking emergency towing, tug handling, barge mooring, canal transit, Ship to Ship (STS) transfer and anchoring, some of which may require specialised fittings or equipment.

Anchoring equipment is covered by Classification Society rules and is not included in this publication.

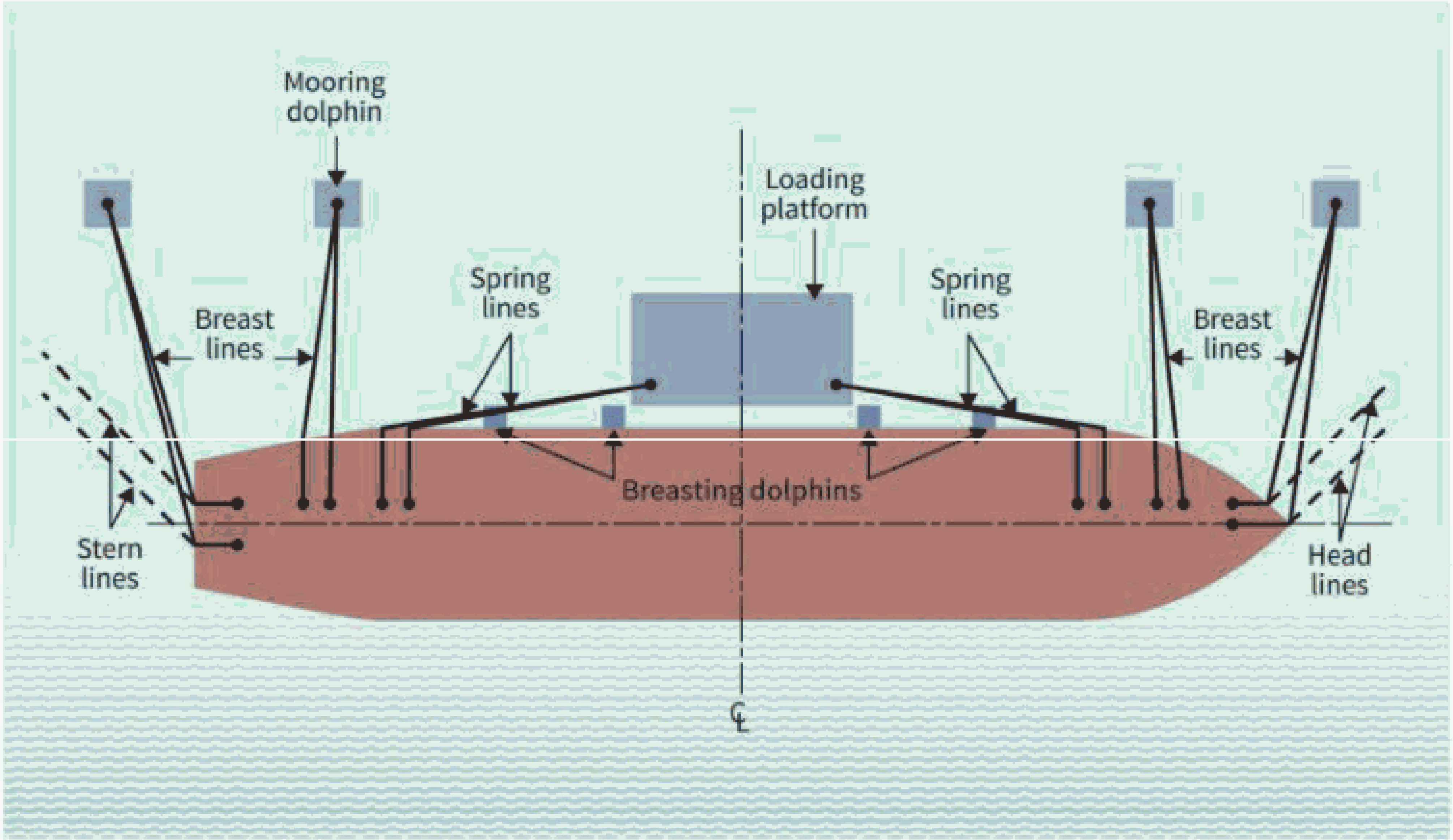


Figure 1.1: *A typical mooring pattern at a conventional tanker terminal*

The use of an effective mooring system is essential for the safety of the ship, its crew, the terminal and the environment. In order to know how to optimise the moorings so that they can resist the various forces that will act upon the ship (which may impact the effectiveness of the mooring system), the following three questions will need answers:

1. What are the forces applied on the ship?
2. What general factors determine how the applied forces are distributed to the mooring lines?
3. How can the answers to questions 1 and 2 be applied in establishing a good mooring system?

The most important principle of mooring is that no mooring arrangement has an unlimited capability. It will be necessary to understand precisely what the mooring system of the ship is expected to encounter, and then design and equip to achieve it.

1.2 - Objectives

Guidance in this section is intended for all stakeholders in the design and safe operation of a ship, including ship and equipment designers, ship builders, surveyors, ship operators/owners/managers, equipment manufacturers and suppliers, ship's personnel and marine terminal personnel.

It establishes the principles covering all aspects of the mooring system, from initial ship design and mooring equipment arrangements (including fixtures and fittings and associated ship structural strength), to the factors influencing the selection of mooring lines and their safe handling, maintenance and retirement.

Further guidance is provided on procedures for the safe operation and maintenance of the mooring system by ship's personnel, including the operational considerations and mooring management at the interface of the ship with the marine terminals that it visits.

This section also provides guidance on the requirements for the mooring system that are to be included in the ship's management system through a functioning Mooring System Management Plan (MSMP). An MSMP should cover all aspects of the mooring equipment, operation and maintenance (see section 1.9). These should be effectively managed from the ship's initial design through to end life.

1.3 - Forces acting on the ship

The moorings of a ship must resist the forces due to some, or possibly all, of the following factors:

- Wind.
- Current.
- Tides.
- Interaction from other ships.
- Waves/swell/seiche.
- Ice.
- Changes in draught, trim or list.

This section deals mainly with the development of a mooring system to resist standard environmental criteria (defined in section three) involving wind, current and tidal forces on a ship at a berth. If the mooring system is designed to accommodate maximum wind and current forces, reserve strength may be sufficient to resist other moderate forces that may arise. However, if significant surge, waves or ice conditions exist at a terminal, considerable additional loads can be developed in the ship's moorings. These forces are difficult to analyse except through model testing, field measurements or dynamic computer programs.

In planning for mooring at a terminal, consideration should be given to potential scenarios where the standard environmental criteria could be exceeded and deciding on what appropriate measures will need to be implemented to avoid causing injury to personnel, damage to the environment or to assets.

Forces on the moorings due to changes in ship elevation, from either tidal fluctuations or loading or discharging operations, must be addressed by diligent mooring line management.

1.3.1 Wind and current drag forces

The procedures for calculating wind and current drag forces are covered in appendix A. Calculations carried out on a range of ship sizes have shown that the wind and current drag coefficients are not significantly dependent on ship size. Consequently, the ship drag coefficients in appendix A may be used for bridge-aft ships with similar geometry, down to 16,000 DWT.

Figure 1.2 demonstrates how the resultant wind force on a ship varies with wind velocity and direction. For simplicity, wind forces acting on a ship can be broken down into two components: a longitudinal force acting parallel to the longitudinal axis of the ship and a transverse force acting perpendicular to the longitudinal axis. The transverse force generally produces a yawing moment.

Wind force on the ship also varies with the exposed area of the ship. Since a head wind only strikes a small portion of the total exposed area of the ship, the longitudinal force is relatively small. A beam wind, on the other hand, exerts a very large transverse force on the exposed side area of the ship. For a given wind velocity the maximum transverse wind force on a VLCC is about five times as great as the maximum longitudinal wind force. For a 50 knot wind on a ballasted 250,000 DWT tanker, the maximum transverse forces are about 300 tonnes (2,943kN), whereas the ahead longitudinal forces are about 60 tonnes (589kN).

Mean Draught (Metres)	**Astern** (Tonnes)	**Ahead** (Tonnes)	**Transverse** (Tonnes)
6	47.8	68	303
7	47.2	66.7	283
8	46.7	65.3	263
9	46.1	63.9	244

Table 1.1: *Maximum longitudinal and transverse wind forces on a 250,000 DWT tanker, 5m trim, 50 knot wind*

If the wind is from any quartering direction between the beam and ahead (or astern), it will exert both a transverse and longitudinal force since it is acting on both the bow (or stern) and the side of the ship. For any given wind velocity, both the transverse and longitudinal force components of a quartering wind will be smaller than the corresponding forces caused by the same wind acting abeam or head on.

Note the sign convention used in this section is aligned with the sign convention used by the scientific community, such as research establishments and designers, where a force from directly astern is considered to be from 0 degrees and the compass angles proceed in an anti-clockwise direction. This convention is also adopted in appendix A when discussing wind and current forces. (This is different to the normal interpretation used by mariners, whereby force from directly ahead is considered to be from 0 degrees and the compass angles proceed in a clockwise direction).

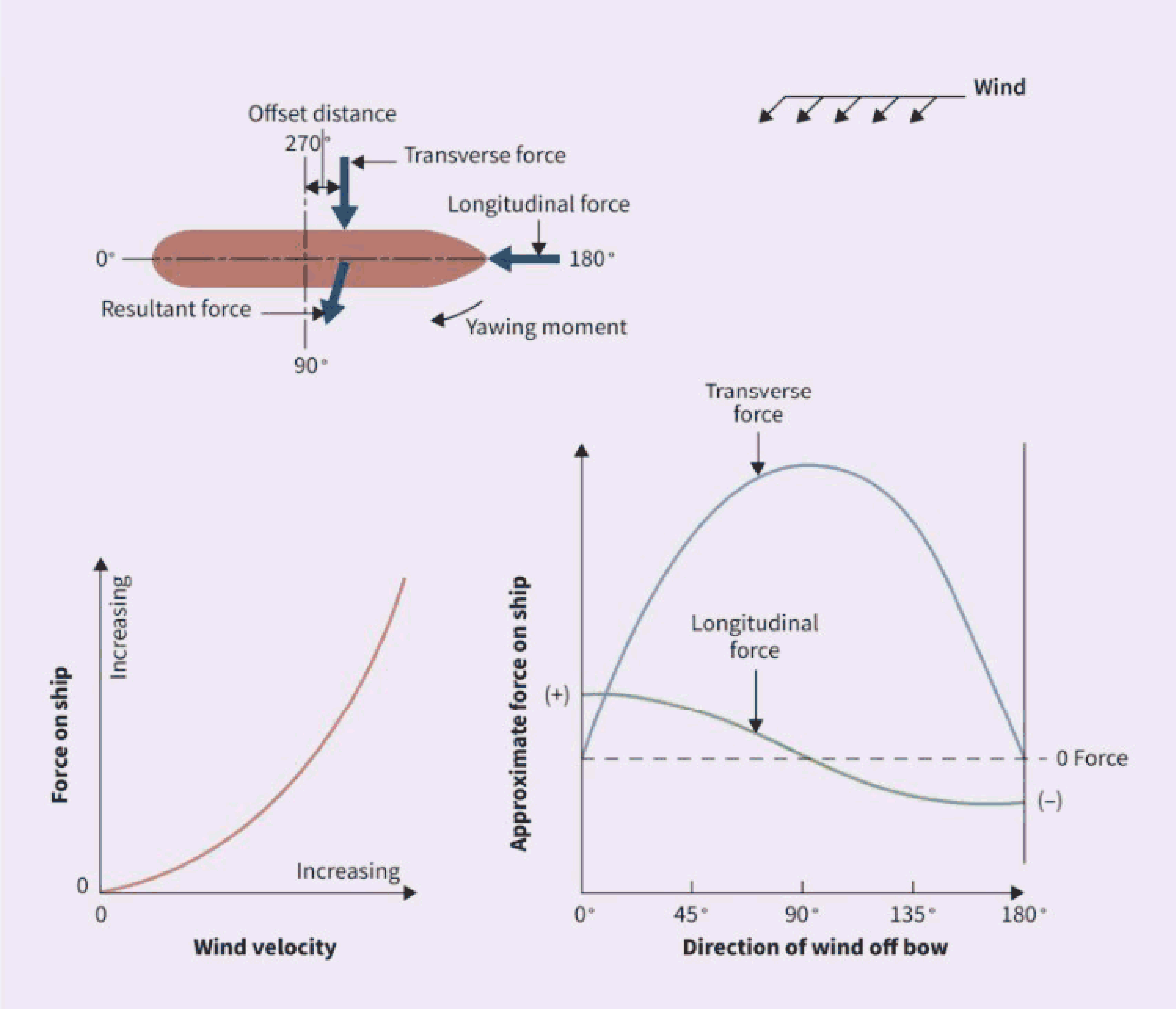


Figure 1.2: *Wind forces on a ship*

With the exception of wind that is dead ahead or astern or directly abeam, the resultant wind force does not have the same angular direction as the wind. For example, for a 250,000 DWT tanker, a wind 45 degrees off the bow leads to a resultant wind force of about 80 degrees off the bow. In this case, the point of application of the force is forward of the transverse centreline, producing a yawing moment on the ship.

Degree Off Stern	Force Direction	5 x Draught or More (Tonnes)	3 x Draught (Tonnes)	1.10 x Draught (Tonnes)	1.02 x Draught (Tonnes)
90	Longitudinal	8	9	20	37
	Lateral	221	427	788	1,171
150	Longitudinal	-10	1	142	-55
	Lateral	80	141	632	377
170	Longitudinal	-12	-6	-12	11
	Lateral	0	26	212	205

Table 1.2: *Example of the effect of under keel clearance versus draught (assuming 2 knot current)*

Current forces on the ship must also be considered when evaluating a mooring arrangement. In general, the variability of current forces on a ship due to current velocity and direction follows a pattern similar to that for wind forces. Current forces are further complicated by the significant effect of under keel clearance. Table 1.2 shows the impact on force due to reduced under keel clearance. The majority of terminals are orientated more or less parallel to the current, thereby minimising current forces. Nevertheless, even a current with a small angle (such as 5 degrees) off the ship's longitudinal axis can create a large transverse force and must be taken into consideration.

1.4 - Mooring system design principles

Once the forces acting on the ship have been calculated (using the standard environmental criteria), the ship designer, ship builder (if known at time of design/build) and the ship owner will need to decide what individual components of the mooring system to use to withstand these forces.

These components will comprise:

- Mooring equipment and arrangements.
- Mooring equipment strength.
- Mooring pattern.

While components will be discussed separately below, they are interlinked and must be considered jointly during the design phase of the ship. This will ensure the ship can both moor safely and achieve the design capacity to meet or exceed the requirements of the standard environmental criteria as defined in section 3.2.

1.4.1 Mooring equipment and arrangements

Early in the ship design process the selection and location of mooring equipment and their arrangement on the deck of the ship must be determined to ensure that the ship can moor safely alongside berths and meet the standard environmental criteria.

Areas that should be considered when designing mooring equipment and arrangements are outlined throughout this publication and take full account of the safety and exposure of personnel during mooring operations. They include:

- The need for sufficient deck space and equipment to enable effective oversight and supervision of operations, adequate lighting and avoidance of impairments that degrade communications capability, such as from machinery noise.
- The number, location and size of deck winches, mooring lines, bollards and fairleads to provide an effective, balanced mooring pattern.
- Industry requirements including applicable IMO regulations, recognised industry standards (e.g. IACS, ISO) and associated industry guidance and recommendations as they apply to mooring and towing equipment.
- The application of human factors in the design to ensure crews are not exposed to avoidable risks during mooring operations.

If a ship operator requests enhanced flexibility with ship mooring, which may be outside a standard mooring arrangement, the following may also be considered:

- Residual capacity to ensure the ship can berth, or remain berthed, in the event of unscheduled occurrences such as winches being out of service.
- Lines unable to be deployed from optimal locations due to incompatibility with berth facilities.
- Equipment redundancy, including critical equipment and spares.
- Other influencing factors, such as locations with peculiar environmental operating parameters, e.g.:
    - Exposed locations.
    - Operating envelope limits of loading arms at berth.
    - Extraordinary strong tide, current or other phenomena (tidal bore).

1.4.2 Mooring equipment strength

In considering the design of the mooring equipment and arrangements in section 1.4.1, this publication also establishes principles for equipment strength, many of which are interrelated and should also be taken into consideration. These include:

- System design will establish, from standard environmental criteria, the effective ship design MBL for each mooring line in the standard mooring pattern.
- System design will ensure that the mooring fittings and machinery, and the structure to which they are attached, do not suffer structural damage or failure before the mooring line; i.e. the SWL of fittings should be at least equal to or exceed the ship design MBL.
- Loads to which mooring lines are exposed do not exceed the stated WLL.

The relationship between SWL, WLL and ship design MBL of loose and permanent equipment is explored in figures 1.3 and 1.4.

All values are percentage values of the ship design MBL.

Ships					
Ship Mooring System Component	Double Bollard, Closed Chock, Pedestal Fairlead	Single Bollard, Recessed Bitt	Winch Foundation	Winch Drum, Shafts, Bearings	Winch Brake
Operational brake render					60
Max design brake render (ISO-Holding load)					80
Safe Working Load (SWL)	100	100	100	100	100
Ship design MBL	100	100	100	100	100
Max rated pull				33	
Design Basis Load (DBL)	200	100	100	100	100
Specified Minimum Yield Stress (SMYS)	250	125	118	111	118

Lines							
Mooring Line Type/ Component	Wire	Synthetic		HMSF	Polyamide (Nylon)	Synthetic Tail	Joining Shackle
Shackle SWL (synthetic)							50
Shackle SWL (wire)							55
Working Load Limit (WLL)	55	50		50	50		
Ship design MBL	100	100		100	100	100	100
Replace	75	75		75	75	75	
Line Design Break Force (LDBF)	100	100		100	100	125	
LDBF (Max)	105	105		105	105	130	

Shore/Terminal				
Shore Mooring Point Type	Single Hook/Bollard	2 Hook Mooring Point	3 Hook Mooring Point	4 Hook Mooring Point
EU - Mooring structure SWL, extreme loads benign locn	100	120	180	240
EU - Mooring structure SWL, extreme loads exposed locn	100	150	230	310
EU - Mooring structure SWL, accidental load condition	118	210	280	350
Max ship design MBL	100	100	100	100
US - Mooring structure SWL	118	160	220	280
Hooks	1	2	3	4

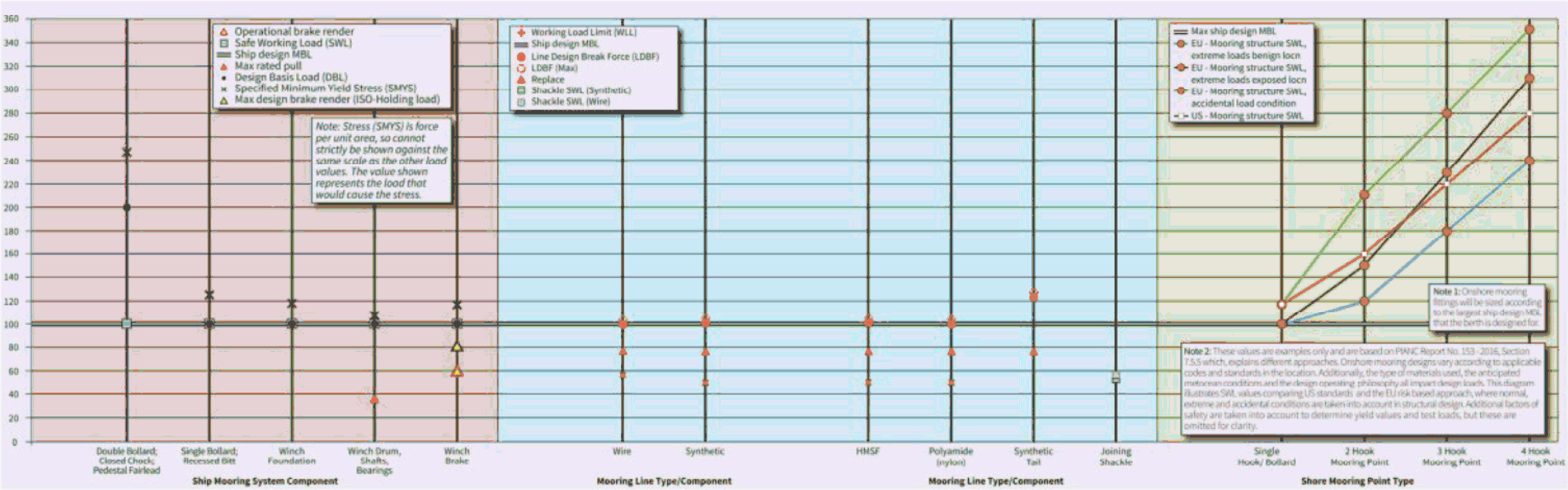


Figure 1.3: *Relative percentage values of mooring system components based on ship design MBL*

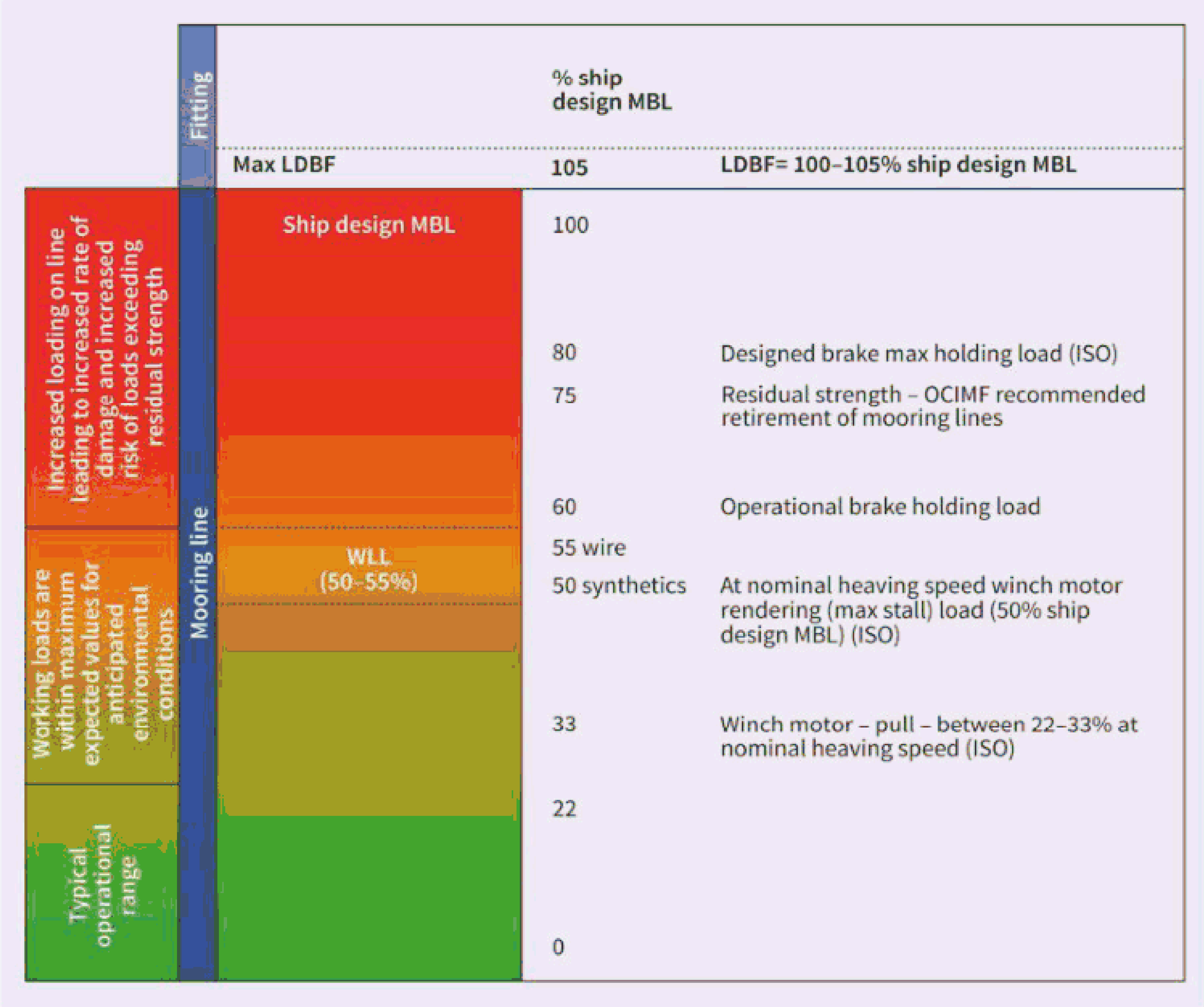


Figure 1.4: *Illustration of operational and limiting values for mooring lines*

1.4.3 Mooring pattern

The term mooring pattern refers to the geometric arrangement of mooring lines between the ship and the berth. Industry has previously standardised on the concept of a generic mooring pattern (see figure 1.1), taking into account standard environmental criteria. The generic mooring pattern is mainly applicable to a multi-directional environment and to the design of a ship's mooring system.

For ships regularly trading to terminals with a directional environment, a site-specific pattern (such as one including head and stern lines and/or extra breast and spring lines) may be more effective. Consideration may be given to the provision of additional or higher capacity mooring equipment.

The most efficient line lead for resisting any given environmental load is a line orientated in the same direction of the load. This would imply that, theoretically, mooring lines should all be orientated in the direction of the environmental forces and be attached at such a longitudinal location on the ship that the resultant load and restraint act through one location. Such a system would, however, be impractical since it has no flexibility to accommodate the different environmental load directions and mooring point locations encountered at various terminals.

For general applications, the mooring pattern must be able to cope with environmental forces from any direction. This can best be approached by splitting these forces into a longitudinal and a transverse component and then calculating how to most effectively resist them. It follows that some lines should be in a longitudinal direction (spring lines) and some lines in a transverse direction (breast lines). This is the guiding principle for an effective mooring pattern for general application, although the locations of the actual fittings at the terminal will not always allow it to be put into practice.

The decrease in efficiency caused by deviating from the optimum line lead is shown in figures 1.5 and 1.6 (compare with cases 1 and 3 in figure 1.7, where the maximum line load increases from 57 (559kN) to 88 tonnes (863kN)). However, for a 60 knot head wind the highest loaded line for the generic pattern is 39.5 tonnes, whereas it is 28.6 tonnes for the site-specific pattern. For terminals located where the environment forces are directional, the site-specific pattern is actually more effective. See sections 1.7, 1.8, 3.3 and 3.4 for further details.

Designers and operators must fully understand the basic difference between spring lines and breast lines:

- Spring lines restrain the ship in two directions (forward and aft).
- Breast lines are deployed perpendicular to the ship and restrain against transverse motion away from the berth.

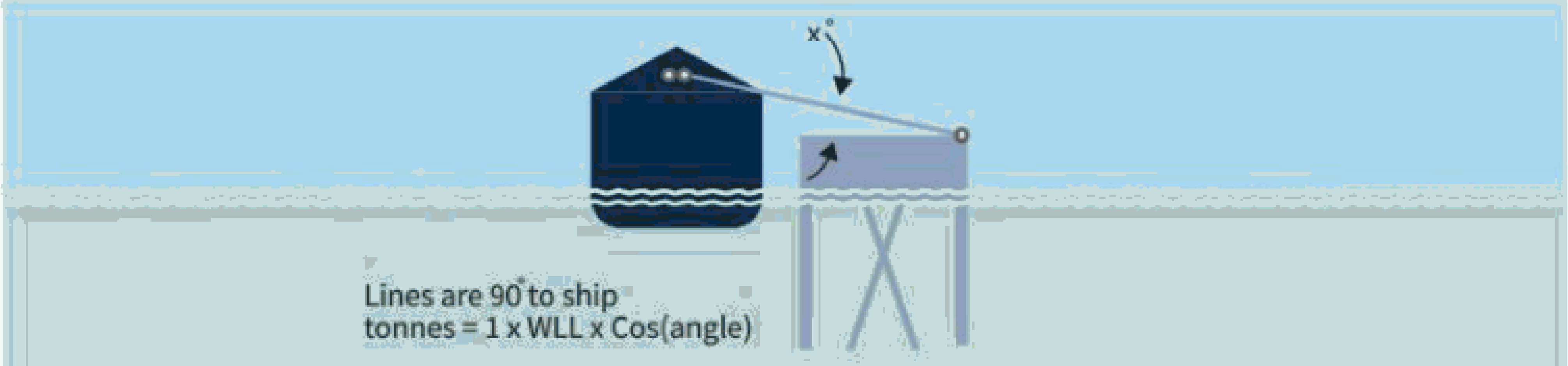
On-berth direction restraint is provided by the pier or facility through fenders, breasting dolphins or other restraint mechanism. Whereas all breast lines will be stressed under an off-berth environmental force, only the aft or the forward spring lines will generally be stressed depending on the direction of the force at a given time. Requirements for line tending therefore differ between spring and breast lines.

If spring lines are pre-tensioned, the effective longitudinal restraint is provided by the difference between the tension in the opposing spring lines. Too high a pre-tension can significantly reduce the effectiveness of the mooring system. Likewise, differences in vertical angles between forward and aft springs can lead to ship surge along the jetty.

Mooring patterns for a directional environment may incorporate head and stern lines that are orientated between a longitudinal and transverse direction. This optimises restraint for the longitudinal direction where the dominant environmental force acts, while maintaining some lateral restraint for the less dominant lateral environmental directions.

Another option for mooring patterns with dominant longitudinal forces is to add more spring lines.

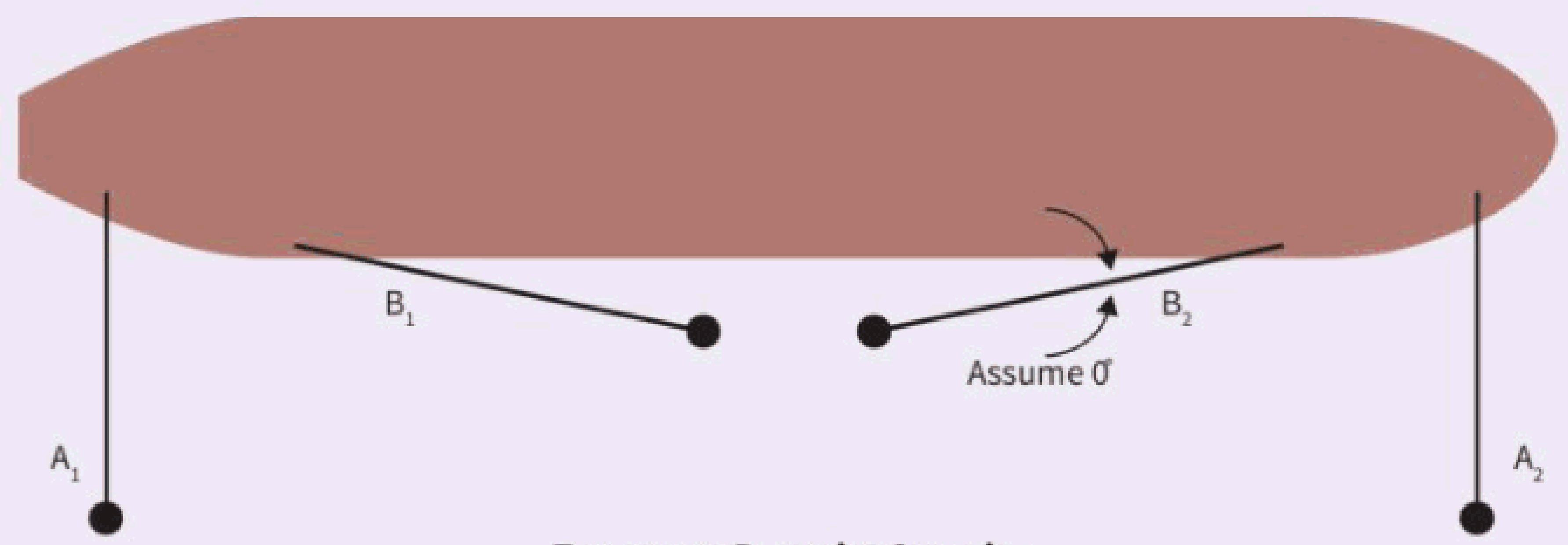
The effectiveness of a mooring line is influenced by two angles: the vertical angle the line forms with the pier deck and the horizontal angle the line forms with the parallel side of the ship. The steeper the orientation of a line, the less effective it is in resisting horizontal loads. As an example, a line orientated at a 45 degree vertical angle is only 75% as effective in restraining the ship as a line orientated at a 20 degree vertical angle. Similarly, the larger the horizontal angle between the parallel side of the ship and the line, the less effective the spring line is in resisting a longitudinal force.



Angle	Number of lines	WLL	Cos(angle)	Tonnes	% effective
20°	1	50	Cos(20)	47.0	94%
45°	1	50	Cos(45)	35.4	71%
60°	1	50	Cos(60)	25.0	50%

Figure 1.5: *Effect of vertical angle on transverse restraint*

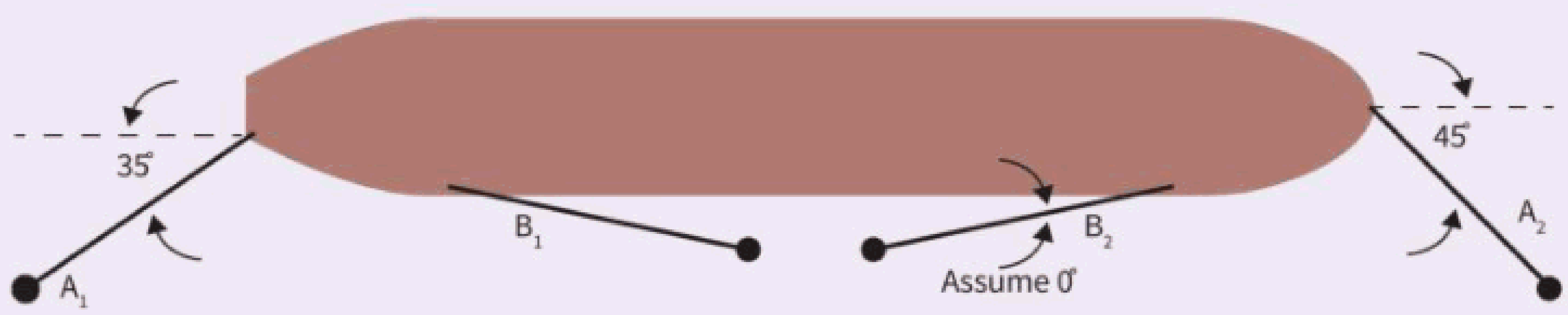
Simple 4 Line Mooring Pattern



Transverse Restraint Capacity

Line	WLL	$Sin_{(Angle)}$	Transverse restraint (t)
A_1	50	$Sin_{(90°)}$	50.0
A_2	50	$Sin_{(90°)}$	50.0
		Total	100.0

Simple 4 Line Mooring Pattern



Transverse Restraint Capacity

Line	WLL	$Sin_{(Angle)}$	Transverse restraint (t)
A_1	50	$Sin_{(35°)}$	28.7
A_2	50	$Sin_{(45°)}$	35.4
		Total	64.1

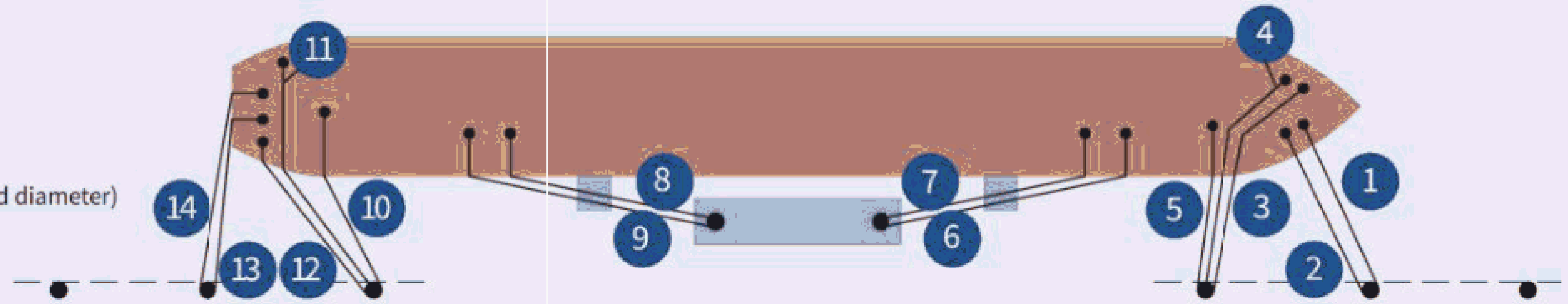
Figure 1.6: *Effect of horizontal angle on transverse restraint*

For the total effect of both horizontal and vertical angle on transverse restraint, further calculation is required to arrive at the resultant transverse restraint value.

All loads are in tonnes

✓ Recommended

CASE 1 Generic All Wire Mooring
(All wires the same construction and diameter)

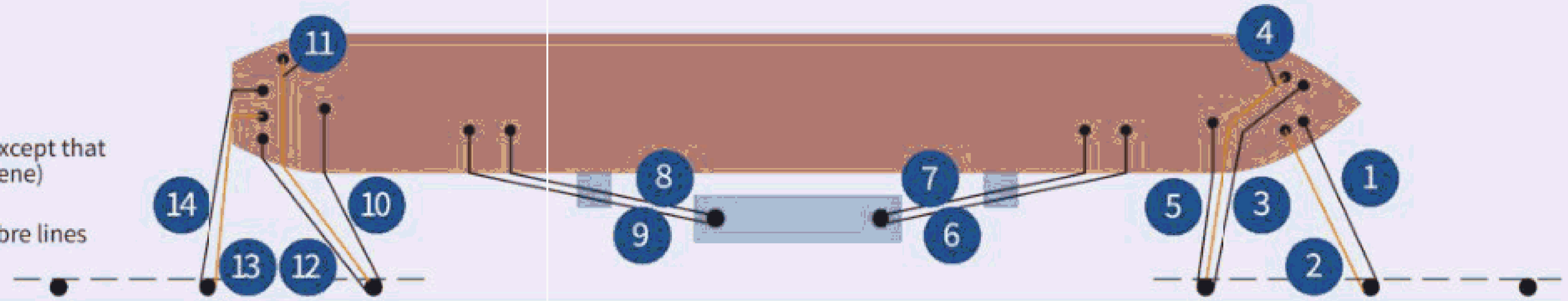


Line number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
60 knot head wind	8.6	11.3	0	0	0	0	0	39.0	39.5	0	0	0	0	0
60 knot wind 45° off bow	56.7	57.1	34.5	34.9	39.0	5.9	5.9	10.9	11.3	25.9	25.4	34.0	24.9	23.6
60 knot beam wind	56.7	56.7	39.5	39.9	44.9	13.2	13.2	6.3	6.3	43.5	42.6	57.1	51.2	47.6

× Not Recommended

CASE 2 Generic Mixed Moorings
(Mooring arrangements as above except that lines 2, 4, 11 and 13 are polypropylene)

Illustrates lack of contribution of fibre lines to overall mooring strength

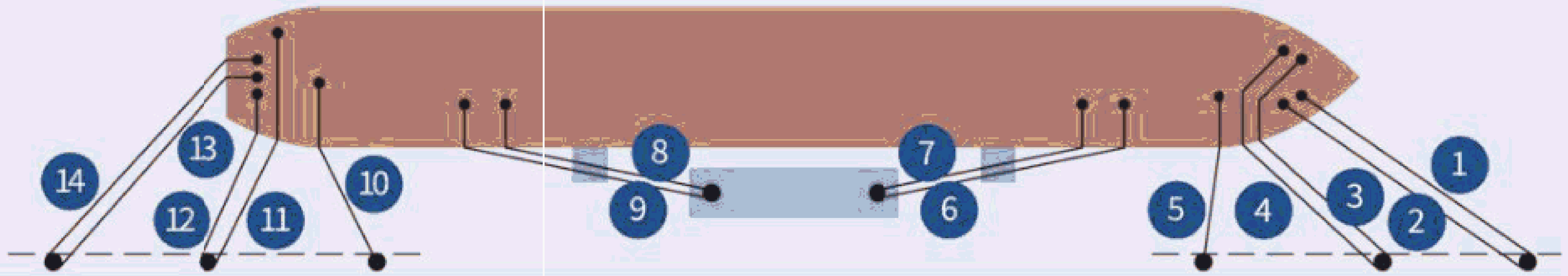


Line number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
60 knot head wind	15.9	5.0	0	4.1	0	0	0	39.4	39.4	0	3.6	0	2.7	0
60 knot wind 45° off bow	91.6	6.8	54.4	5.9	62.6	7.7	7.3	14.5	15.0	37.6	5.4	50.3	5.4	33.6
60 knot beam wind	91.2	6.8	61.2	5.9	69.8	17.2	16.8	9.5	9.5	67.1	5.9	88.0	6.3	73.0

• Non-ideal

CASE 3 Site-specific
(All wires the same construction and diameter)

Showing effect on line tensions as consequence of non-ideal leads



Line number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
60 knot head wind	10.4	11.8	5.4	8.2	0	0	0	28.6	28.6	0.9	0	0	0	0
60 knot wind 45° off bow	52.6	49.9	48.5	43.5	83.9	19.5	19.0	5.0	5.0	36.7	30.4	40.8	24.9	24.0
60 knot beam wind	56.2	54.0	53.1	48.1	88.4	17.7	17.2	11.8	12.2	70.3	49.9	70.3	46.3	45.8

Note: Computer program assumes line does not yield or break. Examples are based on ballasted 250,000 DWT ship. Loads are for conditions shown. Should the wind shift, lines without loads, as shown above, would assume some loadings, so all lines should be tended at all times

Figure 1.7: *Mooring pattern analysis (all the loads are in tonnes)*

A comparison of cases 1 and 3 in figure 1.7 demonstrates that, although the same number of lines is used in each situation, Case 1 results in a better load distribution, minimising the load in any single line. Therefore, ships will be most effectively moored using lines 'within the length' of the ship, through a combination of breast and spring lines, with:

- Breast lines orientated as perpendicular as possible to the longitudinal centreline of the ship and as far aft and forward as possible.
- Spring lines orientated as parallel as possible to the longitudinal centreline of the ship.

1.5 - Stiffness of lines

The stiffness of a mooring line is a measure of its ability to stretch under load. Under a given load, a low stiffness line will stretch more than a high stiffness line. Stiffness plays an important role in the mooring system. It is covered in greater detail in section five. This section deals with the role of stiffness in the mooring system. The stiffness of mooring lines can affect the mooring system in a number of ways, including:

- Low stiffness lines can absorb higher dynamic loads. For this reason, low stiffness is desirable for STS transfer operations, or at terminals subject to waves, swell or passing ship forces.
- Extremely low stiffness (such as all nylon lines) on a ship can also mean that the ship will move further in her berth and this could cause problems with marine loading arms or hoses and operating envelopes.
- Movement can also create additional energy in the mooring system. Stored energy in a low stiffness line, if released on sudden failure, will 'snap-back' unpredictably and can cause injury to personnel and/or damage to equipment.
- The different stiffness of multiple line materials may affect how forces are distributed into the mooring system.
- Ensuring properly tensioned lines will reduce line failures from dynamic effects, e.g. passing ship, seiche and wind gusting.

The simple four-line mooring pattern shown in the upper portion of figure 1.6 is insensitive to the stiffness of the lines and is only suitable for small ships such as tugs, small barges and coasters. Larger ships will require more lines resulting in more effective load sharing and interaction between lines. This becomes more complicated as the number of mooring lines increases.

Optimum restraint is generally accomplished when load sharing is achieved and breast lines are loaded equally to the same percentage of their breaking strength.

If, however, two parallel lines of different stiffness are connected to a ship at the same point, the stiffer one will always take a greater portion of the load (if the winch brake is set) even if the orientation is the same. This is because both lines must stretch an equal amount to ensure an even distribution of forces in each line and if not achieved, the stiffer line assumes a greater portion of the load. The relative difference between loads can be very large, and depends on the difference in line stiffness.

The stiffness of a mooring line primarily depends on the following factors:

- Material type.
- Construction.
- Length.

Figure 1.8 demonstrates the significance of material type, construction and length on load distribution. The most important points to note in this example are the appreciable difference in stiffness between wire and fibre lines and the effect of line length on stiffness.

- Case A shows an acceptable mooring where lines of the same size and material are used.
- Case B indicates the sharing of loads between lines of the same material but of different size and each line is equally stressed to approximately the same percentage of its breaking strength.
- Cases C and D are examples of mooring arrangements that should be avoided (mixed mooring materials and lines of different lengths).

Wire mooring lines are very stiff. Typical elongation of a wire line under load is about 1% of wire length. Under an equivalent load, a polypropylene rope may stretch ten times as much as a wire. Therefore, if a wire is run out parallel to a conventional fibre line, the wire will carry almost the entire load while the fibre line carries practically none.

There are many varieties of fibre lines in use, and new product developments are introduced all the time. These fibre lines include those made from High Modulus Synthetic Fibre (HMSF) which, like wire mooring lines, are also very stiff compared to conventional fibre moorings.

Stiffness also varies between different types of fibre lines and, although the difference is generally not as significant as that between fibre line and wire, the difference will affect load distribution. HMSF lines will, for example, have much higher stiffness than other synthetic fibre lines and would carry the majority of the load if run out parallel to conventional synthetic lines.

The effect of material on load distribution is, therefore, critical and the use of mixed moorings for similar service should be avoided.

Where mixed moorings are used for similar service the low stiffness fibre lines will carry almost no load while the high stiffness wires will be heavily loaded. The same could be true of mixed fibre lines of varying stiffness although the differences would generally not be as great unless the moorings also include HMSF lines.

The effects of mixing wire and synthetic fibre lines are shown in figure 1.7 by comparison of cases 1 and 2. Note the low loads in fibre lines 2, 4, 11 and 13 in case 2 and the subsequent increase in load in the wire at line 1 (56.7 tonnes) in both the 60 knot 45 degree off bow and beam wind to 91.6 and 91.2 tonnes respectively. Further, the load in the wire in line 12 also increases, from a high of 57.1 tonnes in the case 1 beam wind scenario to 88.0 tonnes in case 2.

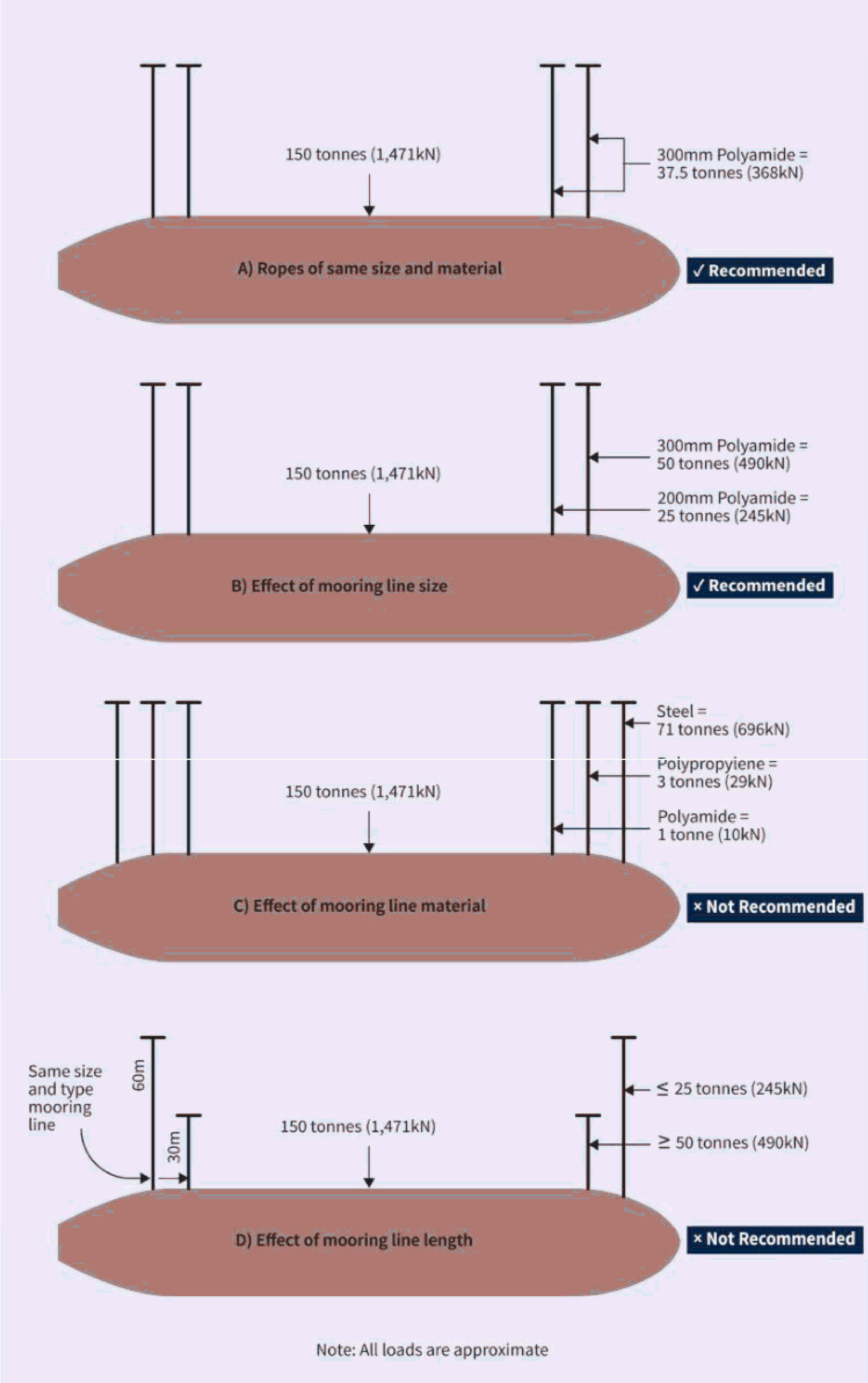


Figure 1.8: *Effect of mooring stiffness on restraint capacity*

The effect of line length (from securing point on board to shore bollard) on load distribution must also be considered. Line stiffness varies directly with line length and has a significant effect on line load. As shown in scenario D (figure 1.8), a line 60m long will assume only about half the load of a 30m parallel and adjacent line of the material type, construction and diameter.

For a similar line diameter and construction, age can also impact on line stiffness. Usually this factor is not an important consideration since the load relative to a line's strength is the governing factor rather than the absolute load.

Synthetic tails are often used on the ends of wire lines to permit easier handling and to decrease line stiffness. Tails may also be used to decrease the stiffness of low stretch ropes made from HMSF materials (see section 5.8).

If tails are used, the same size and type of tail should be used on all lines run out in the same service.

The effect of attaching 11m long tails, made from both polyester and polyamide, to steel wire and HMSF mooring lines is shown in figure 1.9. Longer tails will have a significant impact on the mooring system stiffness.

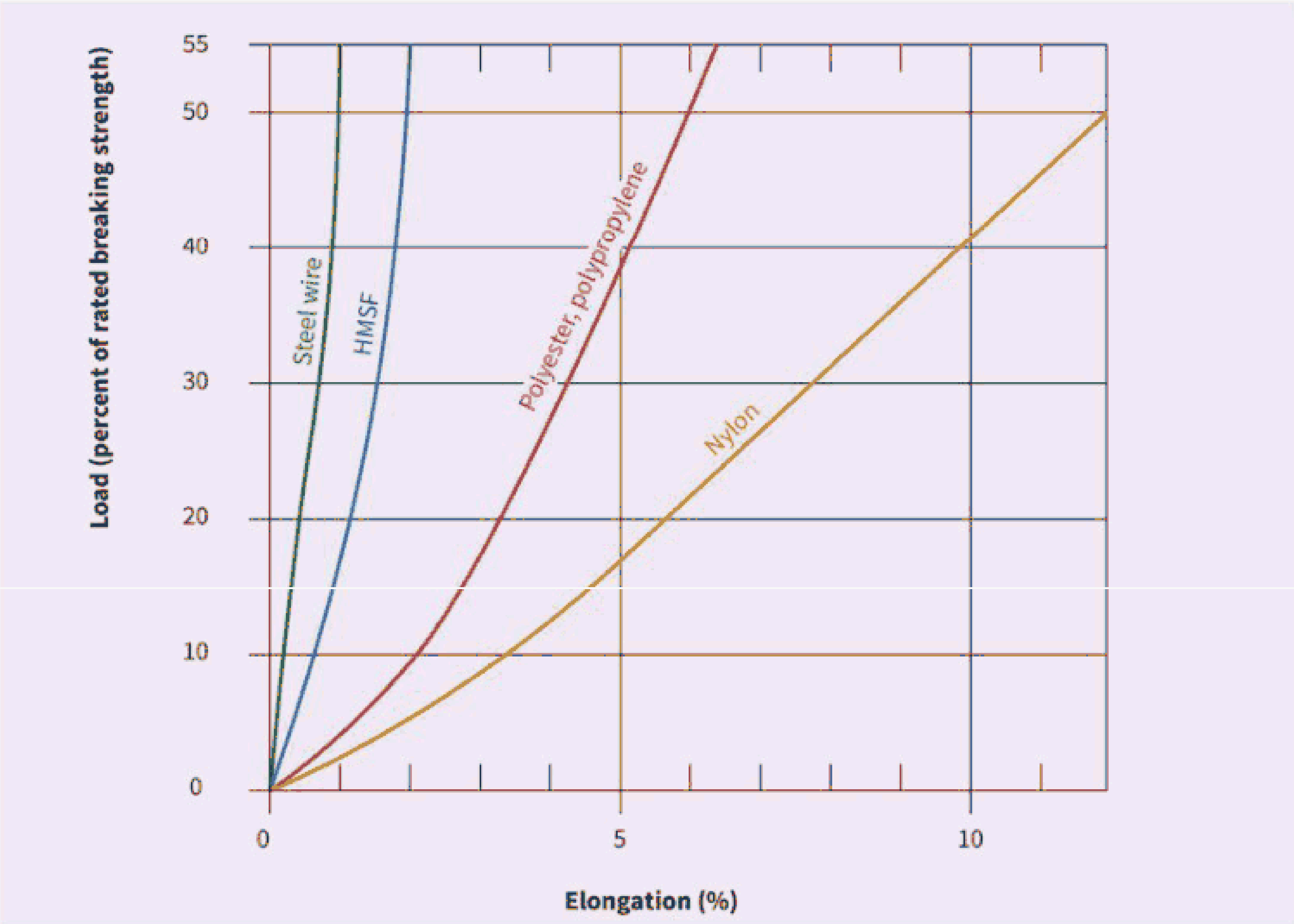


Figure 1.9: *Typical load/extension stiffness characteristics of wire and synthetic fibre lines up to 50% of LDBF and 55% LDBF for steel wire ropes*

1.6 - General mooring guidelines

1.6.1 Objectives

The objective of a good shipboard mooring arrangement is to provide and arrange equipment to accomplish the following:

- Provide for a safe and effective mooring pattern at conventional piers and sea islands.
- Facilitate safe and effective mooring, unmooring and line tending operations, including the handling of tug lines during harbour and escort towing operations, with minimum demand and risk to personnel.
- Enable safe and effective mooring at anticipated non-conventional terminals such as SPMs, MBMs and offshore terminals including F(P)SOs and Floating Storage and Offloading units (FSOs).
- Allow safe and effective operations at anticipated activities, such as STS transfers or canal transits.

The mooring equipment and arrangements should be designed to minimise the risk to those involved in the operation, taking account of human factors as laid out in section two and IMO resolution A947 (23).

1.6.2 Mooring line arrangements

These guidelines assume that the moored ship may be exposed to strong winds or current from any direction. Consideration of the principles of load distribution in figure 1.7 leads to the following mooring guidelines which should be considered when planning mooring line arrangements:

- Mooring lines should be arranged as symmetrically as possible about the midship point of the ship. A symmetrical arrangement is more likely to ensure a good load distribution than an asymmetrical arrangement.
- Head and stern lines alone have limited efficiency in restraining a ship in its berth, but when used the following should be considered:
  - Use of head and stern lines will require provision of additional mooring dolphins and decreases the overall restraining efficiency of a mooring pattern when the number of available lines is limited. This is due to their poor orientation, longer lengths and consequently lower stiffness.
  - Head and stern lines should only be used where required by the terminal operator and necessitated by surge forces, weather conditions or local pier geometry; e.g. small ships berthed in facilities designed for larger ships may require head and stern lines to be used because of the berth geometry.
  - Head and stern lines can sometimes be required for manoeuvring purposes, but that should not lead to their reliance when the ship is moored, when lines should be repositioned to form a more symmetrical arrangement.
- Mooring facilities with effective breast and spring lines alone will allow a ship to be moored securely within its own length.
- The vertical angle of the mooring line should be kept to a minimum. The flatter the mooring line angle, the more effective the line will be in resisting horizontally applied loads on the ship.
- Mooring lines of the same size and material should be used for all leads. If this is not possible, all lines in the same service, i.e. breast lines, spring lines, etc. should be the same size and type. For example, all spring lines could be wire and all breast lines synthetic.
- If used, mooring tails should be the same size and material.
- All lines in the same service should be about the same length between the ship's winch and the shore bollard. Line stiffness varies directly with line length and shorter lines will assume more load.

In practice, final selection of the mooring lines to achieve a mooring pattern for a given berth is not something a ship can assess in isolation. Consideration of local operational and weather conditions, pier geometry and ship design, will also need to be taken into account, and may often require input from local experts. For example:

- While it is normal for spring lines to be used for manoeuvring a ship out of a berth, some pilots may request head and stern lines to assist in this purpose.
- At berths where the mooring points are too close to the ship and effective breast lines cannot be provided, head and stern lines may be necessary.
- Where the location of bollards means that lines will have an excessive vertical angle in the light condition, these excessive angles would considerably reduce restraint capability, requiring extra lines to provide additional restraint capacity.

1.7 - Operational considerations

The primary consideration for the mooring arrangement is to optimise load distribution to the moorings, typically in a symmetrical mooring arrangement. However, in practice, final selection of the moorings and how they are arranged must also take into account other operational considerations. For example, high winds and currents from certain directions might make an asymmetrical mooring arrangement a more effective option.

Another factor to consider is the optimum length of mooring lines. In general, to avoid a large vertical angle, the horizontal distance to the shore mooring point should be at least twice the vertical elevation of the ship's fairlead above the berth. Vertical angles less than 25 degrees are preferred. For example, if the ship's fairlead location is 25m above the shore mooring point, the mooring point should be at least 50m horizontally from the fairlead taking into account draught and tide variations.

Long lines are advantageous both from a standpoint of load efficiency and line tending. However, where conventional fibre ropes are used, the decreased stiffness can be a disadvantage by allowing the ship to move excessively alongside the berth thereby risking excursions from the operating envelope of the marine loading arms/hoses. Figure 1.10 illustrates the effects of line lengths on line tending requirements.

1.7.1 Line management principles

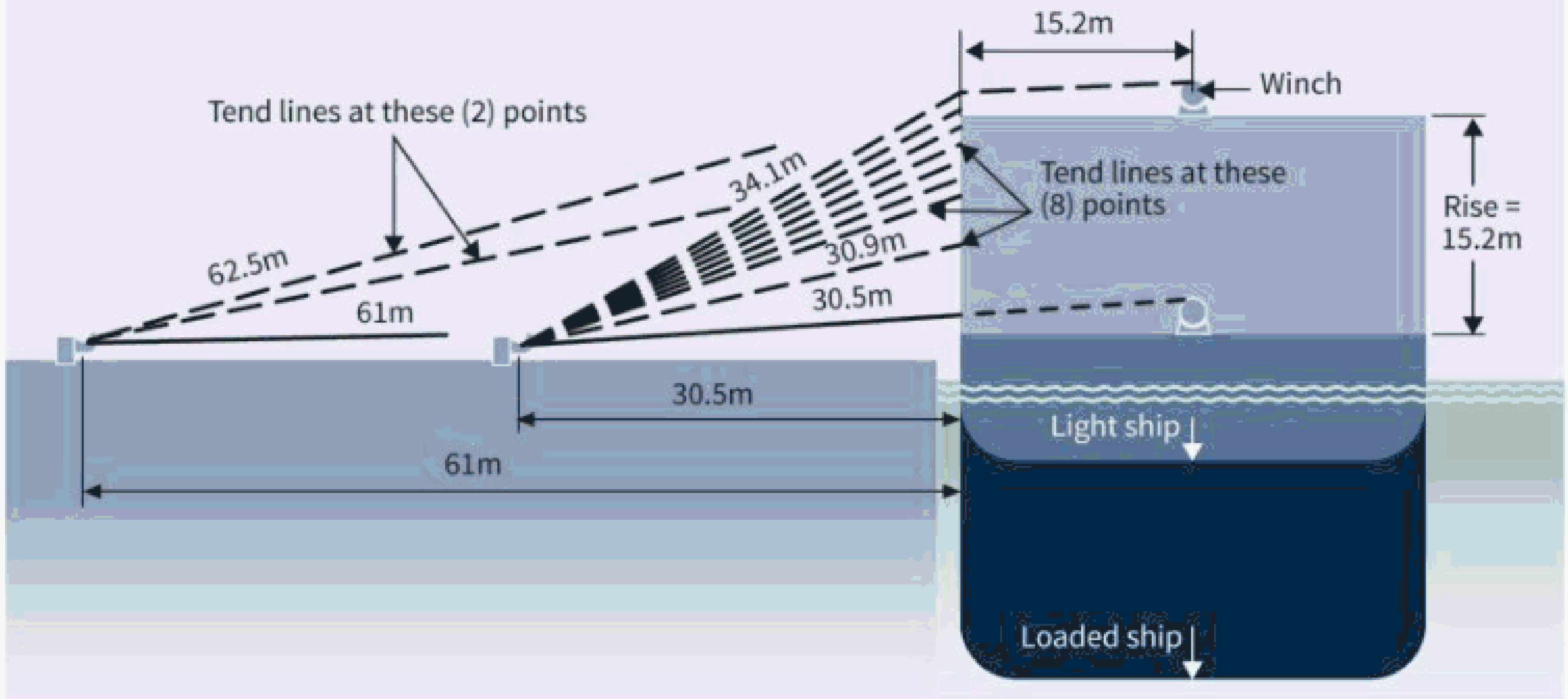
The objective of good line tending is to ensure that all lines share the load to the maximum extent possible and ship's movement is limited in the berth (off or along the berth face). Pre-tensioning of lines (i.e. loading a line with a winch prior to the application of environmental forces) reduces ship movement and improves the load distribution when lines of different lengths and stiffness are being used.

Tending head or stern lines can introduce a range of issues and they should be tended in a similar manner to either a spring or breast line depending on whether longitudinal or transverse restraint is more critical. For example, if a high longitudinal current on the bow is expected, the bow line should be pre-tensioned while the stern line is tensioned only to take up any slack.

To prevent excessive movement of the ship along the berth face it is very important to tend spring lines differently to breast lines.

The following general rules apply to line tending:

- Slack lines should be hauled in first. Slack lines may permit excessive movement of the ship when there is a sudden change in the environment.
- One line should be tended at a time. When a line is tended, it temporarily changes the load in other lines and may increase it. The simultaneous tending of two lines may allow unexpected ship movement in the berth, overload other lines and risk loss of mooring.
- Spring lines should be tended together, but not simultaneously. Caution should be taken to not cause excessive movement of the ship along the berth face to maintain position with marine loading arms or hoses.



Distance from bollard to ship's side	Minimum no. tendings Due to 15.2m ship rise
30.5m	8
45.7m	4
61.0m	2

Notes
- Assume wire lines. Yield strain = 1% Length = 0.46m for 45.7m mooring line
- Assume no slack in wires
- Assume lines tended before reaching WLL

Figure 1.10: *Effect of line length on tending requirements*

1.7.2 Warping of ships alongside berths

During mooring operations, warping a ship along a berth to position is not recommended. Instead, tugs, ship's engines or thrusters should be used to position the ship and the moorings tensioned to retain position.

If warping a ship along a berth when it is already berthed/moored is unavoidable, then the safest means must be verified by a risk assessment considering the following factors:

- Are the prevailing environmental conditions (weather, current and tide) sufficiently benign to ensure ship movement remains always under control?
- Are sufficient crew available to ensure supervisory and operational control of the operation?
- Is the warping operation to be supervised by a senior officer from a place of overall control, e.g. wheelhouse?
- Has the risk assessment fully considered the potential need for use of ship's engines or thrusters, or deployment of harbour tugs to assist with and/or control the operation?
- Should the cargo operation be stopped and/or cargo arms/hoses disconnected during the repositioning.
- What do the terminal or port authority regulations require prior to undertaking repositioning.

1.8 - Ship mooring management

Effective ship mooring management requires knowledge of good mooring principles and the ship's overall mooring capability. The mooring arrangement is to be considered the total system, from the mooring hook on the jetty to the onboard fixture to which it is restrained, whether that is a bollard or a mooring winch. It is also important to have an understanding of the associated risks and capabilities of the crews used to perform mooring operations safely.

This systems approach requires ship designers, operations management and ship's personnel to understand some or all of the following:

- Information about the original mooring equipment and design philosophy used to achieve the mooring system.
- Detailed list of mooring equipment installed on the ship.
- Proper inspection and maintenance of the equipment.
- How to identify the risks associated with the use of the equipment, as well as human element considerations to address these risks.
- Detailed operating procedures covering operations planning, supervision, line tending and training.
- Records and documentation covering all equipment including any changes to the original design basis.
- Applicable regulations, codes and industry recommendations and guidance pertaining to safe mooring.

It is a fundamental principle of safe mooring that all personnel involved in mooring operations should know the capabilities of the mooring equipment installed on their ship. Details of key factors such as winch brake settings, correct direction of line reeling on the winch drum, mooring line specifications and risk assessments should be readily available and fully understood.

1.9 - Mooring System Management Plan

Introduction

Throughout this section the emphasis has been on ensuring that the ship's mooring system is properly designed and effectively operated against a range of fundamental mooring principles. As many components of the mooring system may be critical to the ship, it is recommended that the necessary information is readily available and kept as part of the ship's management system to ensure ship's staff gain a complete understanding of the mooring system.

The Mooring System Management Plan (MSMP) has been created to help operators ensure the mooring system is inspected, maintained and operated in accordance with the original design basis. It will contain information that can be available to anyone on the ship who needs to review it.

The guidance builds upon a goal-based approach typically used by the IMO to provide consistency of approach and methodology. Through this process, a series of goals and functional requirements are provided that will enable ship operators to align with the process.

Ship operators are recommended to develop their own MSMP using this approach, and it is further recommended that it be incorporated as a component of the ship's Safety Management System (SMS) and, where necessary, records be retained with the ship for its complete lifecycle.

1.9.1 Objective

The objective for the MSMP is to ensure that all assessed risks are effectively managed through the design and operation of the mooring system. Its aim is to ensure that during mooring operations, no harm comes to ship or terminal staff or damage to the ship or terminal/facility it is interfacing with and that the mooring system meets applicable regulations, codes and recommended practice.

All stakeholders should ensure the MSMP is appropriately created. Ship operators and ship builders should collaborate from the earliest stage in the ship's design to ensure risks are reduced through mooring design and risk reviews.

A structure for an MSMP is proposed in this section and contains details of items that may be ship or operator specific (e.g. parts of the operator's SMS), and guidance on items that should be retained in a Mooring System Management Plan Register (MSMPR) that stays with the ship throughout its lifecycle. An outline of what may be contained within an MSMPR template is provided below.

While all new ships should be able to achieve all parts of the proposed MSMP structure, existing ships may experience limitations particularly in accessing original design information. It is recommended that existing ships undertake the necessary due diligence to collate required information or align their operating practices with these fundamental safe mooring principles, so far as it is possible and practicable.

Notwithstanding the above, in achieving the objective for the MSMP, it is not intended that the structure should create a duplication of information, procedures, or plans that may exist elsewhere in the ship's management system. However, in seeking not to replicate this material, it should instead be cross-referenced to ensure the overriding principle of the MSMP is achieved and that every effort is made to follow this guidance to ensure the safety of ship and crew.

1.9.2 Mooring System Management Plan structure

The MSMP information will be outlined in individual parts that each cover a key component of the ship's mooring system.

Each part will establish:

- The overall goal for that section.
- Functional requirements to achieve the goal.
- Where detailed information may be found to provide additional guidance or clarify to assist in achieving the goal.

Collectively the parts will achieve the objective of the MSMP through establishing:

- Records of mooring equipment, including all permanent and loose items and its 'as built' design basis, to be retained by the ship throughout its lifecycle (the MSMPR).
- Information required to be maintained as an up-to-date record of the ship's mooring equipment technical status.
- Operating procedures and risk assessments that ensure the safety and occupational health and wellbeing of the ship's staff when using mooring equipment or operating in the mooring workspace.

It is intended to be a complementary component of the SMS, which facilitates updates, internal and external compliance verifications, induction and training, communication with manufacturers and transition to a new ship operator. The contents of the MSMP may include information in both electronic and hard copy.

The format of the MSMP may therefore vary from a complete standalone approach, to an integrated system that uses links and/or references to existing systems. However, in all cases it should be easy for the mooring system users to access the MSMP information, whether that be a physical location (e.g. documented manual) or a virtual location such as an online library.

Mooring System Management Plan

The MSMP will consist of the following:

Part A – General ship particulars

Part B – Mooring equipment design philosophy

Part C – Detailed list of mooring equipment

Part D – Inspection, maintenance and retirement strategies/principles

Part E – Risk and change management, safety of personnel and human factors

Part F – Records and documentation

Part G – Mooring System Management Plan Register

1.9.2.1 Part A – General ship particulars

Goal:

Maintain a detailed, continuous and up-to-date record of the ship's ownership history.

Functional requirements:

The MSMP records should, as a minimum, match those required under the IMO International Ship and Port Security (ISPS) Code's continuous synopsis record.

As a minimum, the MSMP should contain, or be linked to, information on:

A.1. Ship details including name, date of build, registration, IMO number, Flag/Class.

A.2. Current owners, operators/technical managers, including (where applicable) bareboat owners.

A.3. All changes to the above including details of dates of transfer of owners, operators/technical managers, Flag, Class, registration, etc.

To assist in record keeping it is recommended that a detailed SIRE Vessel Particulars Questionnaire (VPQ) is maintained.

1.9.2.2 Part B – Mooring equipment design philosophy

Goal:

Provide comprehensive details of the ship's original design philosophy and show how the philosophy demonstrates that the ship can be effectively and safely moored against standard environmental criteria.

Functional requirements:

The MSMPR records should, as a minimum, contain information that details the requirements for:

B.1. Design considerations to achieve the ship's optimal mooring pattern including information on the siting of mooring winches and fairleads to provide for direct leads and minimal lines across open decks.

B.2. Mooring force calculations against the standard environmental criteria.

B.3. Mooring restraint calculations to determine the strength and number of mooring lines and winches to balance the forces calculated.

B.4. Design loads, safety factors and strength for required mooring lines and fixed equipment.

B.5. Assumptions on the standard mooring pattern and considerations for redundancy provisions, including sub-optimal line distribution to cover unpredicted events (e.g. storm surges, shore mooring hooks out of service).

B.6. Initial mooring line selection inputs, including assumptions, methodology and supplier(s) and information on the agreed rope commissioning process.

B.7. Determining the original mooring line service life expectations, including supporting evidence used to determine criterion. This can be achieved through various means:
- OEM guidance and recommendations.
- References from other operating companies on similar trades.
- Empirical data from similar fleets.
- Historical data related to that type of rope, ship and service, etc.

B.8. Alternate mooring patterns to meet the standard environmental criteria assessment and designed-in options when the optimal mooring pattern is unachievable in some real-world scenarios (e.g. hooks, dolphins or mooring winches out of service, breast lines not in an optimal perpendicular lead, etc.).

B.9. Limitations and exclusions for initial mooring philosophy, and provisions for modifications.

1.9.2.3 Part C – Detailed list of mooring equipment

Goal:

Provide detailed information on all of the ship's mooring equipment.

Functional requirements:

Documents should contain information that details the ship-specific mooring capabilities and limitations for the following equipment where fitted:

C.1. Permanent fittings (mooring fittings, rollers, fairleads, etc.).

C.2. Permanent machinery installations (winch motors/drives, etc.).

C.3. Loose equipment (mooring lines, tails, pennants, joining shackles, etc.).

C.4. Critical and specialist equipment (e.g. winch brake testing equipment) including tools to undertake maintenance and repairs of this equipment.

C.5. Performance standards/requirements for above equipment.

C.6. Details of ship structure and under deck strengthening.

In addition, a mooring arrangement plan complementing the above equipment list should be available that clearly indicates the following:

C.7. Location of all permanent/fixed equipment. This should as a minimum include winches and their direct leads and any alternative arrangements. This arrangement plan can be combined with records for part B.

a. Location of hazardous mooring zones including higher risk areas, protective locations, optimal viewing and sight lines for supervisors and other human element considerations included in part E.

b. For ease of use, consideration should be given to marking the plan with basic functional information; e.g. ship design MBL, winch brake holding capacity, mooring line WLL/LDBF, SWL of mooring bitts, minimum yield load for bow mooring equipment, location of extra strength bitts for tugs and towing, etc.

c. Any changes to mooring equipment.

1.9.2.4 Part D – Inspection, maintenance and retirement strategies/principles

Goal:

Provide detailed information on the requirements for inspecting and maintaining all loose and permanent mooring equipment, as well as the management strategies to test, retire and replace equipment and interface with the OEM.

Functional requirements:

Information should as a minimum cover all items of loose or permanent mooring equipment used or deployed by the ship to achieve safe mooring. The information should complement that held in the onboard planned maintenance scheme and ship's SMS. (See part F of the MSMP for further information):

D.1. Detailed list of mandatory and recommended survey requirements for all equipment, including any specific OEM requirements.

D.2. Inspection and planned maintenance schedules including, where necessary, requirements for use of specialist contractors, e.g. OEM representatives.

D.3. Critical and specialist equipment should be clearly identified in the inspection and maintenance system, along with any required training and competency requirements for maintenance on this equipment.

D.4. A mooring Line Management Plan (LMP) covering all mooring ropes and wires in use, including ancillary equipment, e.g. mooring line tails and joining shackles. See section five.

D.5. Certificates and documents detailing onboard equipment and spares maintenance, e.g. winch brake test records.

1.9.2.5 Part E – Risk and change management, safety of personnel and human factors

Goal:

Provide detailed information on the requirements for identification and management of hazards and risks arising from the mooring system.

Functional requirements:

Information should be readily available covering health, safety and requirements that ensure as a minimum, the safety, health and wellbeing of all personnel in or around the mooring workspace.

Requirements should also cover personnel handling or operating loose or permanent mooring equipment used or deployed by the ship and methods to ensure safe mooring operations, including:

E.1. An assessment of safety should be undertaken including, but not limited to:

- Reviews undertaken during design or to assess effectiveness of the original design basis of mooring equipment and pattern.
- Operations interfaces and exposures for personnel in or around the mooring workspace (also see E.4.).
- Measures taken, or required to be taken, to eliminate risks or mitigate harm to personnel and/or damage to equipment.

E.2. Critical equipment including any required additional control measures.

E.3. Manning and training

- Safe manning levels including minimum required by Class, Flag and/or the ship's SMS.
- Manufacturer's instructions and standard operating procedures.
- Outline competency requirements for undertaking mooring operations and operating mooring machinery (operator and/or industry).
- Induction, familiarisation and training requirements necessary before personnel undertake mooring operations, including any ship-specific requirements and periodic refresher training.

E.4. Human factors and personnel risk management

- A human factors integration plan that establishes the methods by which Human-Centred Design (HCD) has collectively addressed risks to personnel through a hierarchy of elimination, substitution, isolation or mitigation of risk at source, technical or engineering controls and organisational measures.
- Hazard identification techniques used to determine opportunities to eliminate or mitigate to ALARP risks to personnel through design or engineering controls.
- Residual risks of injury and occupational health for all personnel in or around the mooring workspace should be clearly identified.
- Ergonomic assessments to further consider engineering or operational control measures that will enhance the safety and wellbeing of all personnel operating mooring equipment.
- Assessment and identification of all areas of increased or higher risk in the mooring work space, including snap-back danger zones.
- Protected locations including clear lines of sight for personnel when operating deck machinery or supervising mooring operations.
- Considerations around managing stress, fatigue and hours of rest.
- Considerations for managing exposure to extreme environmental conditions.

E.5. Mooring operations plans and procedures

- Risk based mooring operations plans and procedures should be detailed and include pre-arrival briefings, ship/shore mooring arrangements, safety and occupational health issues and required crew resources.

- Contingency plans for mooring operations with appropriate control measures and operational procedures.
- Requirements for operations supervision at each mooring work space and overall control of mooring operations (e.g. Master/Pilot) are to be detailed.
- Communications methods both primary and secondary should form a part of the operations plans.

E.6. Change management

- The change management process and procedures and lines of authority should be detailed to control and record:
    - Where changes occur to operations, procedures or ship mooring equipment.
    - Where changes may impact personnel safety.
    - Steps to manage changes to mooring plans during operations.
    - Control equipment change out.
    - Changes to the design philosophy, e.g. due to change of owner, trading pattern or ship design.
    - Risk assessments undertaken to manage the impacts of the proposed change.
- The change management process should also detail information to be retained for the ship lifecycle.

1.9.2.6 Part F – Records and documentation

Goal:

Part F provides records of detailed maintenance information on the ship's mooring equipment system, and requirements for documentation management. This may also include upgrades or modifications to mooring equipment. This information should form the historical record of the mooring equipment which should be transferred with the ship.

Functional requirements:

Documentation covering equipment and operational requirements that ensure, as a minimum, the safety, health and wellbeing of all personnel in or around the mooring workspace, should be available:

F.1. OEM books, operating and maintenance guides, e.g.:

- Inspection, survey, maintenance and retirement records, e.g.:
    - Retired equipment records to be maintained with ship throughout lifecycle along with the background/reason for retirement/change.
- Survey and test certificates.

F.2. Records of all associated management of change reviews should be retained, throughout the ship lifecycle, to ensure successive owners can fully re-evaluate design and operational changes.

1.9.2.7 Part G – Mooring System Management Plan Register

Goal:

Part G provides details of the records that should be retained by the ship throughout its lifecycle from original design to disposal. They should be in a form that enables transfer when ship ownership changes.

Functional requirements:

The relevant information identified in the MSMP covering the mooring equipment system, should be retained on board every ship. It should be maintained as an accurate and up-to-date record, and be readily available for inspection.

How this information is kept will vary by ship. It is recommended that the information required by part G is kept in a single file or folder for ease of reference. Its location on board, and the person responsible for maintaining the information or up-to-date record, should be clearly identified in the MSMPR.

Table 1.3 is an example of how the central MSMPR may be used to list the information needed to achieve the functional requirement.

Mooring system management plan register

It is recommended that the MSMPR is available to ship's staff and others authorised to review or monitor the equipment status. All stakeholders have a responsibility in collaborating to ensure the MSMPR is properly created. Ship operators and ship builders should work together to ensure risks during operation and maintenance are reduced through mooring design.

An example template, table 1.3, is provided below and sets out as follows:

- Part C is shown, but the MSMPR would have a representative table for each MSMP part.
- Each table will be formed of:
  1. MSMP part: References the relevant MSMP part from section one. (In this example part C).
  2. Functional requirement scope: Outline scope of the functional requirement.
  3. Location: Example of where the relevant information may be kept. Each ship is encouraged to use this column to both identify where the information is kept, and who is responsible for maintaining those records.
  4. Items: Lists the information that could be considered for the MSMPR record. It is recommended that information is recorded as Temporary (T) if that information is only for the current ship operations, or Permanent (P) where it is intended to remain with the ship for its lifecycle. The ship owner will assign their respective designation within this column.
  5. Comments: Provide additional guidance on the types of information that may be required. It is recommended this is annotated where it is not intended that the information will be handed over with changes of ship operators.

It is recommended that the MSMPR is kept as an up-to-date record of the mooring system, and any amendments undertaken with minimal delay. The MSMPR should be integrated into the ship's document control system, be subject to change management controls to ensure a complete history is established for the benefit of future ship staff and operators.

It is further recommended that a backup copy is of the MSMPR is kept separate from the ship in case of damage or loss and that shore-side responsibility is identified to maintain these records along with the relevant ship's continuous synopsis record.

Part C: Detailed list of mooring equipment

MSMP Part	Functional Requirement Scope	Location	Items	Comments
C.1	Permanent equipment	This column should be used to record where this information is held on board and who is responsible for keeping the information up to date, e.g.: • Company SMS or PMS. • A Class approved shipyard mooring equipment design document. • OEM information.	This should list the permanent equipment on board. It is recommended that the list is checked regularly in accordance with the company's SMS/PMS requirements and that a record of any changes and their dates is kept. Examples of the permanent equipment could include: • Anchor windlass and mooring winches. • Bitts, cleats and stopper eye-bolts. • Bollards. • Fairleads and roller leads. • Bow chain stoppers. • High strength towing bitts. • Emergency towing arrangements, etc. • Winch brake test records. • Special mooring equipment (bitts/bollards) for STS and bow/stern operations.	The MSMPR should list all permanently installed mooring related equipment, fixtures and fittings (bitts and bollards, etc.), winches, rollers, fairleads, etc. Permanent equipment records should always be updated alongside other documents such as a mooring arrangement plan, or an OCIMF Vessel Particulars Questionnaire (VPQ). If multiple onboard records exist, the comments section should record which is the official up-to-date record.
C.2	Machinery installations			Includes all winch motors and drives (hydraulic, electric, etc.) and any required ancillary equipment.
C.3	Loose (non-permanent) mooring equipment		• Line certificates.	Include all mooring lines, tails, pennants and joining shackles (where fitted), and chains/ropes used for stoppers, heaving lines, etc. Information should align with the LMP and include relevant information such as manufacture and in service dates.

MSMP Part	Functional Requirement Scope	Location	Items	Comments
C.4	Critical or specialist equipment		• Winch brake testing equipment.	Included items will typically require trained specialists for maintenance and repair using dedicated tools. For critical equipment, lists should include reference to any equipment spares and stock levels required to be carried to ensure integrity.
C.5	Performance standards and requirements			Include up-to-date references to applicable codes and standards, and any additional requirements.
C.6	Ship structure			Identify where information relating to the ships structure and mooring equipment (e.g. winch under deck strengthening) is kept. Include any routine test requirements, e.g. Class surveys.
C.7 a. b. c.	Mooring equipment and arrangement plan of the deck complimenting the above lists where appropriate		• Mooring equipment and arrangement plan.	The mooring equipment and arrangement plan should include the location of all permanent/fixed equipment, including all bitts/bollards (including extra strength towing arrangements), winches and their direct leads. Consider annotating any designed-in alternative arrangements/leads (if this does not clutter the plan) or noting where alternate arrangement diagrams are kept.

Table 1.3: *Example of part C: Detailed list of mooring equipment*

Some of the information required by the MSMPR will already be required by authorities to comply with statutory requirements (e.g. ISPS Code Continuous Synopsis Record) or as a part of the ship's Planned Maintenance System (PMS) or SMS.

The MSMPR should complement these requirements and contribute to the overall safety of the ship and crew by providing an enhanced awareness and understanding of the status of the ship's mooring system and should not create an administrative burden.

Most of the information required to complete and maintain the MSMPR is not statutory. Keeping information, including design considerations, deck layout, equipment plans and equipment manufacturer's operating manuals with the ship is, however, recommended.

The overall objective of the MSMPR is to ensure that, where possible, a complete and up-to-date record is maintained throughout the ship's lifecycle. In order to provide the maximum benefit to both current and future crews, the full cooperation of the ship's owners/operators is needed, as well as the most transparent record keeping possible to contribute fully to the wider safety objective.

Section two

Human factors

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2.1 - Introduction

2.1.1 Objective

How people behave and work with equipment while doing a job is known as human factors. The guidance in this section describes the human factors considerations for improving safety through design and the design impact on the operation and maintenance of mooring systems.

2.1.2 Context

Humans make mistakes and such human failure can have grave safety implications as well as impact the availability of the ship.

There are two types of human failure, namely human error and non-compliance (violation).

Human error is an unintentional unsafe behaviour such as failing to see a signal, forgetting a piece of information, making a poor decision or pressing the wrong button. For example, operating a winch in the wrong direction, or not engaging a winch gear correctly.

Non-compliance is an intentional unsafe behaviour and may be a result of trying to save time or effort.

These can both result from human interaction with the designed system, inadequate management systems, poor procedures, insufficient training and the working environment. Human factors must, therefore, be taken into consideration for the design, operation and maintenance of mooring equipment. Human factors is a complex subject and specific subject matter expertise will be required to implement human factors controls that complement existing design and procedural controls.

Human factors should be considered throughout the full lifecycle of a ship, from initial design until the ship is scrapped, and when making changes to design or operational processes on existing ships.

2.1.3 Principles

To effectively identify human factors controls a typical programme would include:

- The implementation of a safety critical task analysis.
- Use of a human reliability analysis tool to identify performance shaping factors and determine competence standards.

These concepts may not be common in the maritime industry, but they are an essential element of determining human factors controls in other high risk industries. The concepts are further explained in section 2.2.

Having completed these analyses, suitable human factors controls can then be determined. Examples include designing out (removing the task altogether), automating (having a machine do the work and therefore removing the need for people to be put at risk) or procedural controls (clear step-by-step instructions on how to minimise risks to ship personnel, etc.).

For new-build ships when designing mooring systems, a Human-Centred Design (HCD) process (see section 2.3) should be considered that draws on the safety critical task analysis to produce a human factors integration plan to list, track and assist with the implementation of human factors controls.

The Maritime Labour Convention 2006, Regulation 4.3 stipulates that the work environment in which seafarers operate should promote occupational safety and health. To achieve this, seafarers should be provided with the necessary protection while living and working on board ships. To ensure compliance with this regulatory framework, it is necessary to carefully design mooring equipment to prevent accidents and injuries. This should begin early in the planning stages. Risk assessments should be completed for the mooring layout design and use of equipment and machinery. The operating environment in which the seafarer is required to work also needs to be considered.

Preventive measures should be considered to address the risk as early as possible in the process through effective design of the workplace and equipment. Prevention should take priority over protective equipment. The International Labour Organization (ILO) publication *A 5 Step Guide for Employers, Workers and their Representatives on Conducting Workplace Risk Assessments* presents a preferred sequence, or hierarchy, of risk control measures. The following list is based on the ILO sequence:

1. Elimination, e.g. alternative method of mooring may eliminate mooring lines and their associated risks.
2. Substitution, e.g. a new or superior type of winch may be used to substitute existing winches.
3. Isolation of the risk at the source, e.g. protective cages for personnel.
4. Technical or engineering controls, e.g. positioning of operating controls away from hazardous locations.
5. Organisational measures, e.g. permits, procedures, training, etc.

It is necessary to understand the human factors risks before selecting the appropriate controls from the risk control hierarchy. An issue that is safety critical, for example, should prioritise the control measures at the top of the hierarchy, e.g. elimination or substitution. Safety critical tasks are explained further in section 2.2.

Substitution controls or engineering control measures could include automation, semi-automation, remote operation and monitoring, Closed Circuit Television (CCTV), closed protection systems and barriers around the mooring area workplace. Automated systems can fail and may not achieve optimal system performance, given that the human contributes to overall system performance. Automation may, for example:

- Simplify or eradicate one task, but increase the number and complexity of tasks elsewhere in the system, e.g. maintenance tasks.
- Reduce situational awareness as the operator becomes more remote from the operation of the system.
- Lead to a reduction in manual skills and an inability to effectively manage the operation when automation fails.
- Excessively reduce workload leading to boredom and lack of engagement in the task.
- Trigger over-reliance and complacency.
- Lead to lost opportunities from the human contribution.

Humans may be better than machines for several reasons, mostly related to dealing with unusual/unexpected circumstances. In general:

- People reach conclusions and make decisions based on little data.
- Skilled people do not usually make many errors but often complement the design and make it work in practice.
- Designers cannot foresee all future situations and conditions.

When viewing the mooring system as a whole, i.e. the design, layout, operation, maintenance and individual behaviours, the picture can be complex and risks may not be easy to predict. Therefore, a balanced approach to selecting control measures is required.

Organisational measures could include separating the mooring workplace from other workplaces (e.g. removing general walkways from mooring areas), conducting appropriate maintenance of equipment, providing special instructions and limiting working time on a job.

2.1.4 Overview

Designers of mooring equipment and layout arrangements can improve the safety of mooring operations. The important aspects are:

- Understanding and focusing on safety critical tasks (section 2.2).
- Considering human factors during design and throughout the life of a ship, incorporating an HCD philosophy (section 2.3) to ensure that human factors are thoroughly considered at each of the stages within a mooring design project.
- Considering human factors issues during operation and maintenance (section 2.4).
- Considering competence and training, including the lessons from safety critical task analyses and use of a competency management system (section 2.5).
- Considering health and wellbeing, including the effects of fatigue and stress, and where design considerations can assist (section 2.6).

If these issues are considered by project design teams, the potential benefit will be significantly safer mooring operations. Figure 2.1 portrays how human factors can be considered in the design phase and how it links through to operations.

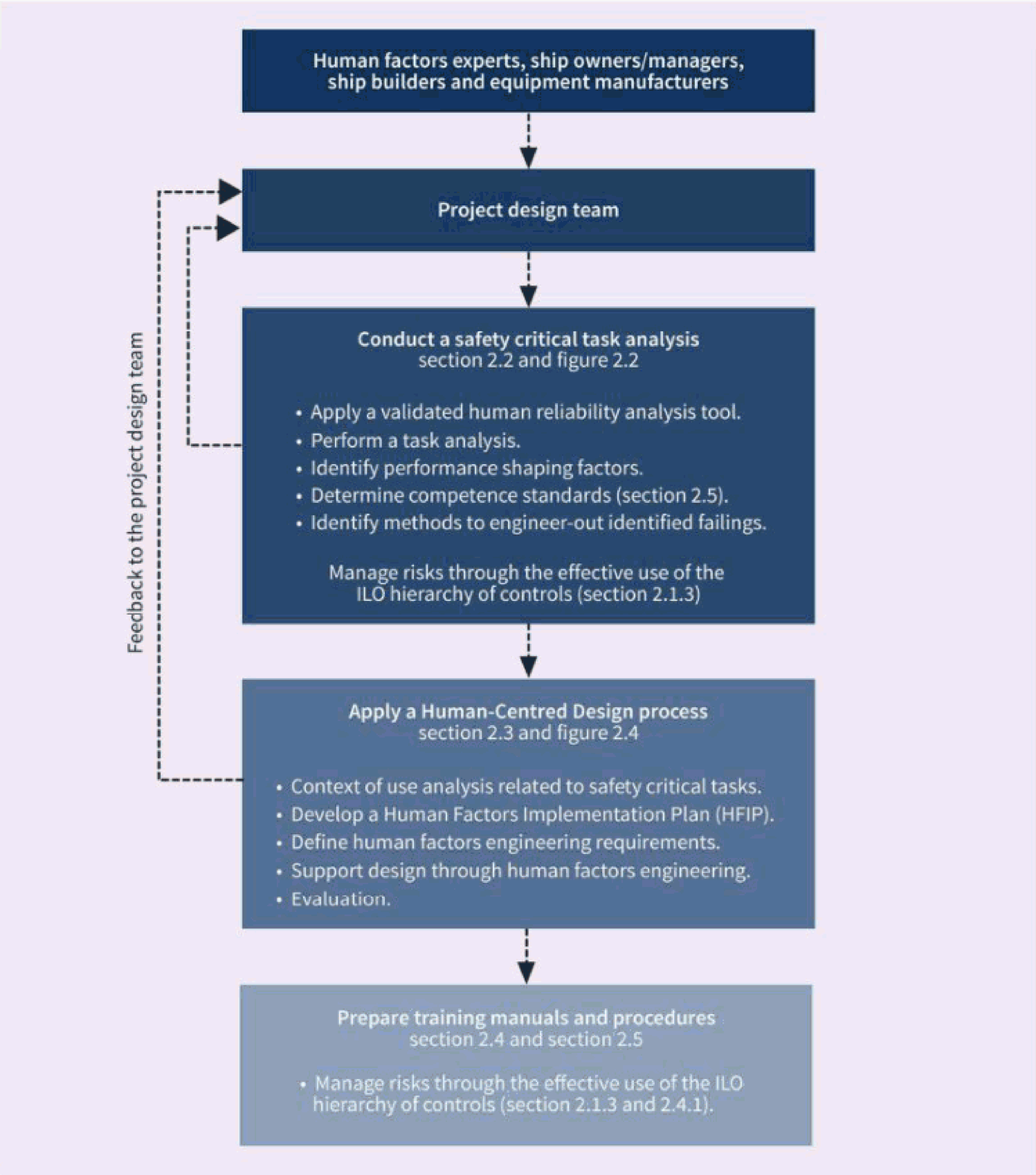

Figure 2.1: *Human factors flowchart*

The boxes within the flowchart in figure 2.1 are further investigated in sections 2.2 to 2.5.

2.2 - Safety critical task analysis

A safety critical task is a task related to the ship's main hazards where humans may cause or fail to avoid a major incident, such as injury, health or environmental impacts.

The objectives of a safety critical task analysis are to:

- Identify which tasks are safety critical.
- Understand how human behaviour might make a failure more likely or more serious.
- Identify barriers for these safety critical tasks to reduce the likelihood or consequence of human failure.

This description is based on the Energy Institute's *Guidance on Human Factors Safety Critical Task Analysis*. A safety critical task analysis process is shown in figure 2.2, and can be used during design or to assess existing operational activities.

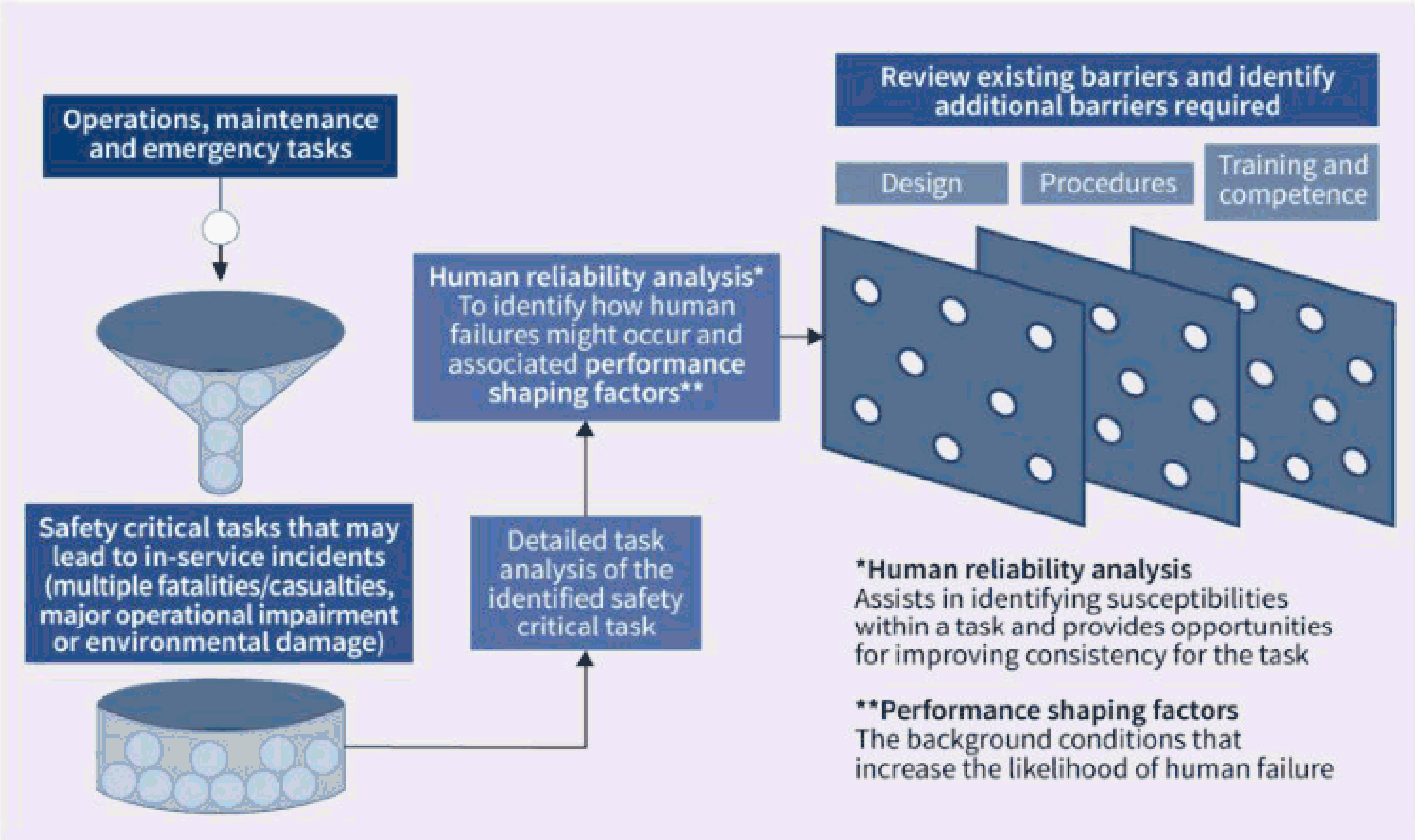

Figure 2.2: *A typical safety critical task analysis process*

The safety critical task analysis should involve personnel with recent operational and maintenance experience of mooring equipment and engineers with a good understanding of the design of the equipment. Human factors subject matter experts can facilitate the process and support judgements of human behaviour, capabilities and limitations (see figure 2.3).

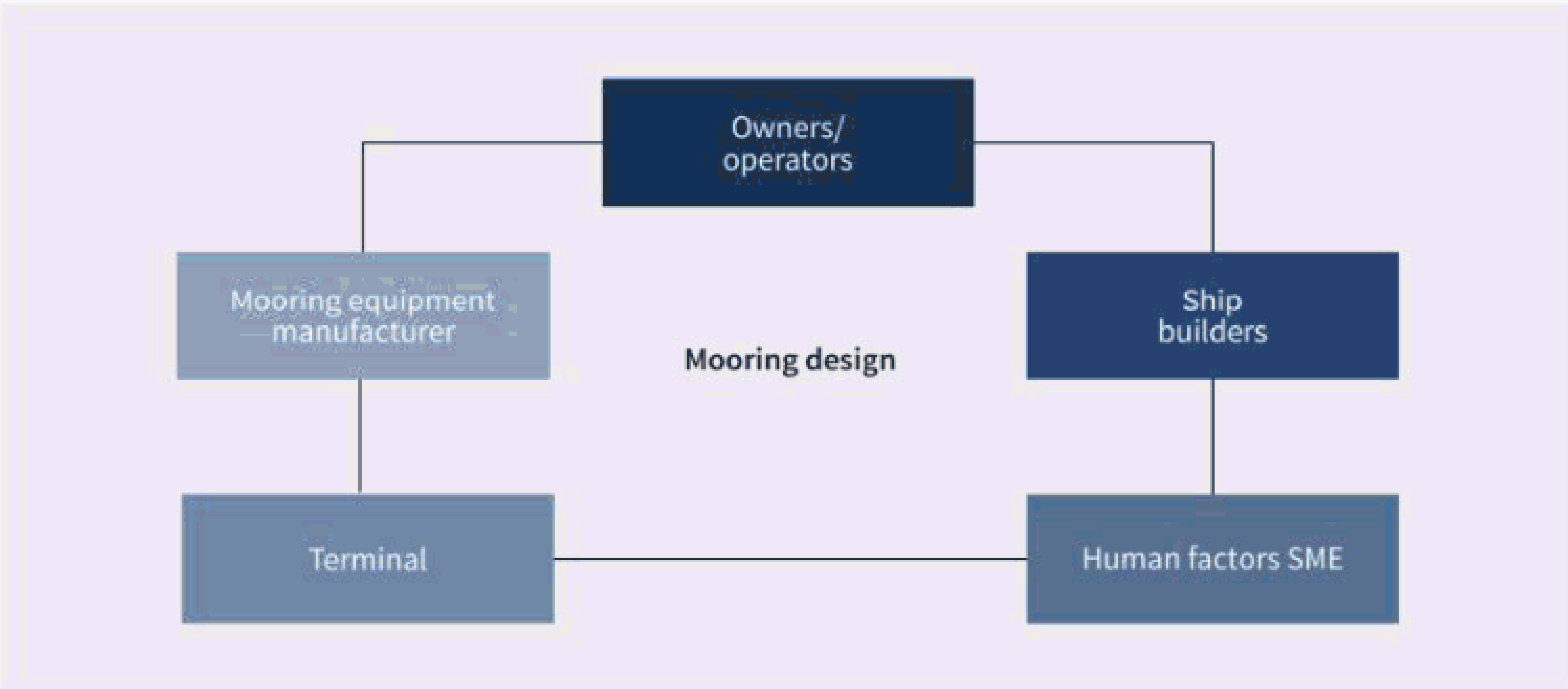

Figure 2.3: *Adequate engagement for mooring assessment in mooring design and layout*

The key steps within any safety critical task analysis may include:

- Listing the tasks associated with a safe mooring operation, including operations, maintenance and emergency related tasks.

- Determining the criticality of these tasks.
- Applying a validated human reliability analysis tool to understand the potential for human failure. When applying the tool, the following should be considered:
  1. Equipment facilitated errors and previous operational/incident data and root causes.
  2. Identifying how human failures might occur, their consequences and identifying opportunities for improvements in the safety management system.
  3. Identifying performance shaping factors that are the background conditions of the task that make failures more likely. Example performance shaping factors are given in table 2.1.
- Exploring opportunities to improve the design of the mooring system to minimise the chance of human errors happening.
- Defining the competence requirements for each critical task, indicating the minimum required knowledge, skills and testing for individuals performing the tasks.

Performance Shaping Factor	Explanation/Examples
Task	Task factors may include high (or low) workload, working under time pressure, difficult tasks demanding high levels of concentration, tasks which are very repetitive, situations with many distractions, interruptions or divided attention, or non-routine activities.
Communication	Communication can be verbal, non-verbal or written and can be affected by high volume, poor phrasing or low communication standards, language differences and heavy accents, the level of technical content, the quality and method of communication and the reliability/quality of communications equipment.
Procedures	Procedures or work instructions can make errors more likely through being incomplete, inaccurate, poorly presented, or over complex and unclear.
Environment	The environment can present significant challenges to performance and may include the weather, temperature, lighting, noise, air quality and the presence of health hazards.
Training and experience	Task performance can be affected by a lack of understanding, not enough time, poor training, a lack of training or a time gap between training and doing the task, and a lack of opportunity to develop sufficient competence.
Human machine interaction	The equipment, its condition or the workspace that people work in can cause error. There are several examples, including poorly presented information or a lack of information, too much automation (causing low situational awareness), poor quality alarms or alarm overload, poor equipment positioning, poor quality or reliability of equipment, inappropriate work tools for the task, unclear signs and signals, inadequate workplace access or workspace arrangement or factors that make the task more difficult, such as the use of personal protective equipment.
Personal	Personal factors may include stress, low morale, boredom, under or over confidence, complacency, poor fitness, poor mental or physical health, age, or being under the influence of drugs or alcohol. It also includes being affected by chronic or acute fatigue.
Social and team	Social and team factors may include poor relationships, team dynamics, coordination and communication, or a lack of team maturity. It can also include poorly defined roles and responsibilities, poor work scheduling, inadequate staffing levels and poor shift handover, as well as poor supervision and poor safety culture.

Table 2.1: *Performance shaping factors*

Having identified the critical tasks, they should be analysed answering different types of question, such as:

Questions	Application
What are the task frequencies and sequences, durations and possible difficulties during mooring?	Used to support the design and layout of equipment.
What are the human performance standards for each specific task?	Used to support operating procedures and training requirements.
What workload is imposed on the mooring personnel during a mooring operation, considering the resources available to successfully complete the task?	Enables an assessment of the ability of personnel to cope, and the potential areas which may affect performance.

Table 2.2: *Example of questions for critical task analysis*

The outputs of the analysis should be used for:

- The design, including the ergonomics of equipment arrangement and layout. Consideration for the operator's field of vision and the ability to access, operate and maintain machinery that may be hazardous or moving (safety guards, interlocks, etc.).
- Control equipment and instrumentation including primary controls, remote controls, display panels and alarm consoles.
- Work environment including lighting, noise, heat/cold controls and safe location identification.
- Labelling and signs that are easy to read and understand, highly visible and appropriately located on the machinery. This can include simplified visual guidance such as arrows for rotation, heave and payout on controls.
- Communication appropriate for the noise and light conditions. The reliability of primary devices/methods and secondary methods, including visibility, lines of sight and established protocols.

It is recommended that ongoing evaluations are conducted on the mooring design, operations and maintenance, for ships and terminals in service, to validate or improve the human factors controls based on in-service learnings.

2.3 - Human-Centred Design

2.3.1 Background

HCD addresses how the design of the ship can improve the operation and maintenance of equipment and reduce the risk of human failures that may cause personnel injuries or impact the operational life of the ship.

Design project teams should have access to qualified human factors resources and personnel with recent hands-on experience of operating and maintaining mooring equipment. The design project team should include equipment manufacturer representatives, where known, at the design stage.

The responsibility and subsequent roles of personnel involved in HCD must be agreed between the shipyard and ship operator before detailed design commences.

A human factors integration plan should define a structured approach to identify the full range of human factors issues that need to be addressed during the design process.

2.3.2 Human-Centred Design process

2.3.2.1 Overview of Human-Centred Design

The HCD process broadly outlined in figure 2.4 is based on ISO 9241:210 *Human-Centred Design for Interactive Systems*, and provides a useful and simple definition of the key processes within design. Another useful reference is the International Oil and Gas Producers' *Human Factors Engineering in Projects*.

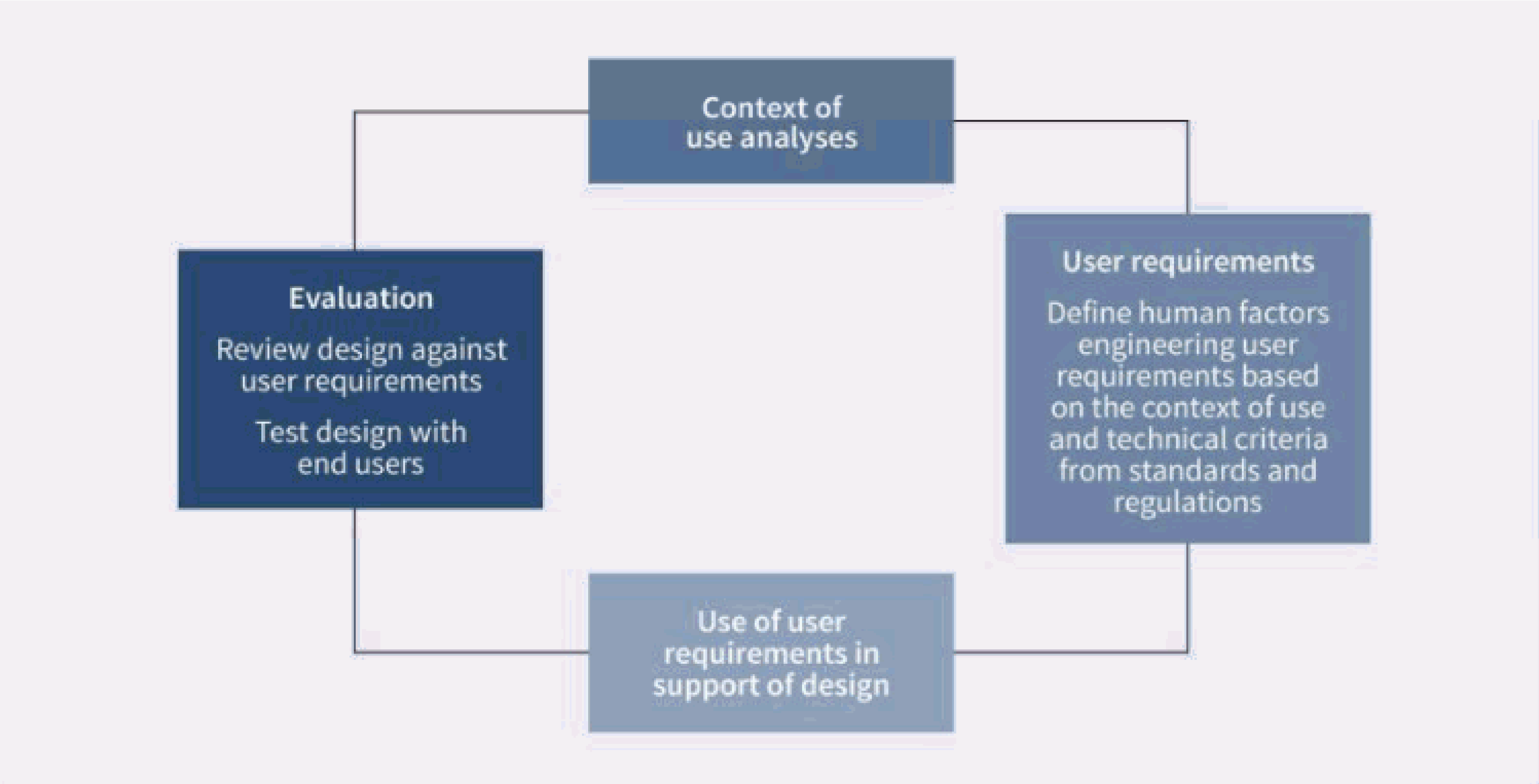

Figure 2.4: *HCD process*

The stages in the HCD process are intended to be repeated and matured throughout the design process, ideally starting at the earliest opportunity to enable the outputs to positively influence the design. The process is intended to ensure that:

- The end user's needs have been considered within design.
- The design meets design criteria from standards and regulations.
- The HCD process has been adequately conducted.
- The end result is a well-designed mooring arrangement that can be safely and efficiently used to moor and unmoor ships.

The stages are explained in more detail in the following subsections.

2.3.2.2 Context of use analysis

A context of use analysis identifies the real conditions in normal day to day operations in which the equipment will be used.

There are many tools and techniques used to understand end user tasks which factor into the working environment. The methods used are normally defined within a human factors integration plan. The two main reasons for a context of use analysis are to identify:

- Specific end user needs to be captured within the design criteria.
- Potential human failures which could occur and need to be considered within design, e.g. incorporating lessons learned from incidents.

2.3.2.3 User requirements

User requirements form the baseline of the HCD process. They are based on what has been learnt from the context of use analysis and human factors standards, guidance and regulations. This information is translated into design criteria relevant to the scope of the project. For example, the Human Factors Engineering (HFE) design criteria might state that two switches need to be within reach at the same time based on how the task needs to be undertaken (derived from the context of use analysis). This might be supplemented with requirements from standards, such as the height at which the switches should be mounted, what type of switch is required and what size it needs to be.

There are several HFE standards available, including:

- American Bureau of Shipping (ABS) *2013 Guidance Notes on the Application of Ergonomics to Marine Systems*.
- ASTM International: F1166, 2007 (Reapproved 2013) *Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities*.
- EEMUA 191 (3rd Edition, 2013) *Alarm Systems – A Guide to Design, Management and Procurement*.

2.3.2.4 Design support and evaluation of design

The user requirements are intended to support and drive design. They will also be used to evaluate the final design, i.e. does the design meet criteria set within the user requirements?

Early in the design stage, it is usual to meet only some of the HFE design requirements. This provides an opportunity to understand how the design needs to be modified. It can also be used to define the boundaries when design trade-offs need to be made. Where user requirements are not met, further analysis or review (including more detailed calculations) may be needed to fully understand the implications of a non, or partial conformance of established criteria. Additionally, designers and users will be able to judge whether the design is acceptable or not and whether other mitigations are required.

2.3.2.5 HCD programme management

The degree of management or control of the HCD process is dependent on the size and criticality of the project. Projects with a smaller scope may not need a formal process, but the principles of the HCD process should still be followed.

2.3.3 Current design challenges

When designing mooring equipment and layout the areas outlined in this section have presented operational challenges in the past. Because of this, they should be considered as a part of the HCD.

2.3.3.1 Position of winches and associated equipment

Winches are often located near the centreline of the ship to reduce the number of winches required, i.e. the same winch can be used for deploying moorings to either side of the ship. This may result in:

- Fairleads and pedestal rollers being located in less than ideal positions for a direct lead to the ship's side.
    - Due to space restriction, some mooring lines may need to be routed via one or more pedestal rollers to exit the deck edge. This complicates the snap-back reaction if the mooring line fails, increasing the area of higher risk and, by increasing the number of bends around rollers, the potential damage to mooring lines.
- Mooring lines being led across the deck and needing to clear external structures, piping and supports.
- Reduction in strength of mooring lines.
- Mooring arrangements that do not provide for a direct line of sight between the winch and the ship's side fairlead.
    - Requires an intermediate signaller with a direct 'line of sight' between the winch operator and the shipside fairlead position. In some cases, more than one signaller is required which increases the risk of human error and the potential for injury.

If winches are sited near the deck edge or too close to rollers or fairleads, adjustment of the mooring line on the drum can be problematic and cause issues for ship's personnel when retrieving lines.

It is recommended that designers account for the various risks associated with each location being considered for winch placement.

2.3.3.2 Operation of winches

Where the winch is manually operated, the winch operator's view of the ship's side or the signaller may be limited. Conversely, where winches are operated remotely, the operator may not be able to see the winch drum nor personnel around the winch. Consideration should be given to the remote operator's location and should ensure that operators are not positioned in the danger area of any mooring line.

Lighting should be provided that adequately illuminates winch controls, gauges, clutches and operator platforms. Poor illumination can cause areas of deep shadow and is often given little consideration during design. The result is that it is often not possible to engage a clutch at night without the use of a flashlight. It is recommended that appropriate fixed lighting should be provided so that all mooring operations can be conducted without the need for supplemental lighting.

2.3.3.3 Mooring line load monitoring

There is often no facility, either ashore or on board, to monitor mooring line loads during mooring or during the ship's stay alongside the berth, with the consequence that mooring lines can become slack or over-tensioned when unattended. It is recommended that remote load monitoring is included in the mooring design.

2.3.3.4 Number of people involved

The safe operation of winches and the handling of mooring lines is a manpower intensive and complex task. The demand on human resources is increased when there is a requirement to handle more than one mooring line simultaneously. Lack of manpower may encourage poor practice and/or risk-taking such as operating two winches simultaneously, combining incompatible tasks, or short-cutting controls, etc.

Communications between winch operator, ship's side, signaller, bridge (Master and docking pilot) and shore mooring team can be challenging due to the number of people involved, language barriers and obstructions in the line of sight. The design process should consider the number of personnel who will be available to use the equipment. If this is not known, then an assumption on number of personnel should be taken and recorded in the human factors design documentation.

Addressing these common performance shaping factors (see section 2.2) will reduce errors and make the operation safer.

2.3.4 Further design considerations

Ship and jetty designers should analyse and understand their specific requirements and consider alternative designs that meet their requirements and mitigate relevant safety issues. The following examples related to mooring arrangements and layouts are presented for consideration during the design stage to reduce risks to personnel during operations and maintenance. The list is not exhaustive and designers may wish to consider other aspects of the mooring system:

Type of mooring system

- Conventional mooring system (e.g. winches and mooring lines).
- Alternative/innovative mooring system (other than winches and mooring lines).

Simplification of mooring line handling

- Elimination or reduction of number of changes in direction for mooring lines.

Prevention of mooring line breakage

- Protection for mooring lines of fairleads and pedestal rollers.
- Suitable bend radius of fairlead/pedestal.
- Provision to monitor loads on winches/mooring lines.

Physical removal of personnel from danger areas

- Remote operation of winches.
- Use of CCTV.
- Use of other technical aids.
- Provision of protected or elevated areas to provide safer oversight.
- Indication of danger areas, for example signage.

Awareness of dangers

- Sufficient lighting levels around mooring equipment and fittings, or during mooring activities.
- Distractions/noise levels from other machinery.

- Lack of clarity in communications between ship's personnel, among shore personnel and in the ship/shore interface.
- Line of sight.

When considering the above, automation needs to be balanced to ensure that human performance is not impaired, the task does not become more complex and situational awareness is not reduced. It should be considered as part of the HCD process.

2.4 - Operations and maintenance

2.4.1 Operations

Human factors risks in mooring can be reduced by using a human factors approach to the design and carrying forward further controls into operational procedures. The residual risk during operations should be managed using risk assessments, toolbox talks, briefings and training. The management and control of risks should be based on the ILO hierarchy of controls, as discussed in section 2.1.3.

2.4.1.1 Shipboard procedures

Shipboard procedures are in addition to engineering design specifications and training requirements and include the step by step instructions that should be implemented by competent personnel when conducting mooring operations. There are two elements to ensure the effectiveness of mooring procedures:

- The development process.
- The presentation of the procedures to the end user.

An effective mooring procedure is only as good as the team that developed it. Greater operational accuracy and consistency is reached when procedures are developed using input from subject matter experts with current or recent operational experience. The procedures should not only highlight the key physical safety critical issues and hazards but also areas where human error may occur.

There is guidance available to improve the presentation of procedures to make them easier to use and less likely to cause human error, such as ASM Consortium's *Effective Procedural Practices* (2010).

2.4.1.2 Risk assessments and toolbox talks

Risk assessments and toolbox talks are key to safe mooring operations and maintenance. They should identify potential risks and capture mitigation steps to reduce or remove them.

Potential human failures that should be included in risk assessments are categorised as:

- Action errors, such as:
  - Operating the winch in the wrong direction.
  - Forgetting to engage the brake.
- Checking errors, such as:
  - Failure to confirm that personnel are clear of mooring lines before heaving.
  - Failure to de-energise/shut down equipment at completion.
- Communication errors, such as:
  - Signalling 'heave' instead of 'slack out'.
  - Radio does not work.
- Selection errors, such as:
  - Selecting the wrong equipment or mooring line size.
  - Selecting the wrong switch.
- Planning errors, such as:
  - Failing to plan the steps in order.

  - Not enough personnel.
  - Not following maintenance intervals.
  - Not identifying danger zones/risk areas.
- Violations, such as:
  - Intentionally taking a short-cut.
  - Walking over tensioned mooring lines.
  - Modifying or adjusting equipment or settings without approval as defined by a Management of Change (MOC) process.

There should be positive reinforcement of safe behaviours, including stop work authorisation. Risk assessments should be reviewed periodically and updated to capture any new risks or modifications to equipment, shared lessons from industry incidents and/or near misses, etc.

2.4.2 Maintenance

The maintenance of mooring equipment can be either planned or unplanned (break down). Mooring equipment manufacturers normally give recommendations and guidance on the maintenance that is required for the equipment, e.g. inspections schedules, lubricating oil changes, greasing routine, recommended grease, etc. These recommendations are technical in nature but should also cover human factors. Maintenance can present significant safety risks, especially if safety systems are inhibited.

2.4.2.1 Shipboard Planned Maintenance Systems

It is important that work descriptions in the PMS include human factors safety precautions. When detailing a maintenance routine in the PMS, each task within the job should be assessed for potential human failure which should then be captured in the work description, e.g. standing positions, blind sectors, lock-out tag-out systems, competency requirements, etc.

Lessons learnt while carrying out the task should also be captured for future use.

2.5 - Competence and training

2.5.1 Competence and training

To ensure a safe and efficient mooring operation, all involved personnel should be trained and verified as competent. The competence of the mooring personnel onshore cannot always be assessed or controlled by ship's personnel and vice versa. Therefore, both parties should accommodate the potential limitations of the other party during the mooring operation.

Competence is the ability to perform a task to a recognised standard consistently on a regular basis. It involves a combination of practical and mental skills, experience and knowledge, and a willingness to undertake the work activity in accordance with agreed standards, rules and procedures.

It is recommended that ship operators have a competence management system to assure and develop competence. This should include the following:

- The underpinning knowledge of the job, e.g. awareness and familiarity of mooring operations.
- Technical competencies, which are task related and enable the job to be completed safely. They are typically job or occupation specific and the objective is to meet minimum standards of performance, e.g. ship or ship operator specifics regarding each piece of mooring equipment.
- Non-technical competencies, which are behaviours that contribute to good performance and require knowledge and skill during the job. Examples include the ability to plan effectively, work well with other team members, coach or motivate others and communicate well.

Competent people can, and do, make mistakes. Understanding the range of human factors that impact performance will allow a design that can be operated and maintained effectively.

Processes should be developed to assess competence and assure the effectiveness of training.

Safety critical task analysis provides an essential input to competence management (see figures 2.2 and 2.3).

Training and/or qualifications alone will not necessarily mean that a person is competent, but they are likely to result in a basic level of competence. A Training Needs Analysis (TNA) is a structured approach for assessing training requirements and should be employed to identify the best means to meet competence requirements. It includes three stages: task analysis, training gap analysis and training options analysis to identify the best means to meet any skills gap. On-the-job development, refresher training, coaching and mentoring are also significant elements for developing and continuing to develop competence.

Training should not be limited to the use of mooring equipment. It should include the correct maintenance, testing and routine care of the equipment. This should be done in accordance with manufacturer's guidelines and industry norms and should be incorporated in the ship's PMS. Ship operators are also encouraged to regularly carry out safe mooring campaigns. These should include human safety and shared learning from near misses and accidents in the fleet.

2.6 - Health and wellbeing

All ship operators, Masters and personnel have a responsibility for the health and wellbeing of themselves and their work colleagues. It is a responsibility that should be delivered through a strong safety culture within the organisation and on the ships.

Regulations and industry guidance have been developed to provide a structure to support this principle and inform people of the risks.

Investigations of some incidents and accidents on ships have identified that measures to protect the health and wellbeing of ship's personnel were not fully implemented. This includes a failure to fully implement appropriate design or procedural measures. Additionally, opportunities to enhance the operation through improvements in equipment design, improved controls or safety management procedures were not realised.

There are many issues that fall under the general topic of health and wellbeing. Two specific human factors that can have a direct bearing on the safety of mooring operations are fatigue and stress, both of which are frequently connected in their causes and effects.

It is not the purpose of this guidance to explore in detail the complex issues that include these two factors, but it is important that ship operators fully consider them in the overall project. The HCD approach and the human factors integration plan should include measures that combat fatigue and stress.

2.6.1 Fatigue

Fatigue can lead to mental, physical and emotional impairment. It is caused by an inadequate amount of sleep, poor quality sleep or being awake for too long. Sleep deprivation can arise from a lack of onboard staffing, not following work/rest periods and extended mooring operations. The latter may arise, for example, from lengthy river passages/port approaches. The planning and risk management of mooring operations should include consideration of the following:

- Work hours, to ensure there is sufficient opportunity for sleep.
- Ensuring that adequate sleep has been achieved.
- Monitoring fatigue symptoms.
- Understanding and safeguarding tasks vulnerable to fatigue error.
- Investigating fatigue related causes of accidents, incidents and near misses.

Fatigue can be made worse by excessive workload and adverse working conditions. Workload management challenges can be caused by extended in-port operations, but can also be from poor operations planning and equipment/tools that have not benefitted from a design that minimises the workload for personnel, e.g. manual handling of mooring lines on bitts and drums.

Extreme environments, hot or cold, or where personnel are exposed to poor lighting, noise and inclement weather can also cause fatigue.

Improvements in ship and equipment design, such as self-stowing winches, noise reduction on winches and their drive motors, deck shelters to protect from extreme weather conditions and good lighting can be among physical design measures that can significantly mitigate the impact of fatigue on personnel.

2.6.2 Stress

Stress is caused when the demands on personnel (whether perceived or actual) consistently exceed their ability to meet them. It can arise from shipboard situations including workload or social isolation, but can also arise from off-ship issues such as domestic or employment concerns. Personnel under stress may become increasingly unpredictable and more likely to make mistakes that could impact their safety and the safety of other personnel.

A distinction can be made between acute and chronic stress. Acute stress is caused by a particularly stressful but temporary event (such as an accident). Chronic stress is experienced when a person feels under sustained pressure, repeatedly finding themselves in situations they feel they cannot cope with and cannot see a way out of.

Acute stress leads to a range of physical changes in the moment that can have either positive or negative effects on performance, including an increased heart rate and muscle tension (the fight or flight response). Recovery from acute stress is normally rapid, taking anything from an hour to a few days and rarely requires professional help, however in a particularly traumatic event it can lead to post-traumatic stress disorder.

Chronic stress leads to strain on the body due to experiencing an ongoing state of acute stress, including a range of psychological and physical consequences, with associated changes in behaviour. Exposure to chronic stress for lengthy periods of time can lead to serious physical and psychological ill health. Recovering from chronic stress is a slow process and can require medical and psychological professional support.

Stress, similarly to fatigue, can be mitigated most effectively during design. There should be access to competent human factors resources that can provide qualified input to, and verify the effectiveness of, design and operational elements. This should be complemented by operational personnel with recent hands-on experience of operating and maintaining mooring equipment.

When designing mooring deck arrangements it is imperative to factor in the capabilities, limitations and requirements of the ship's personnel who are required to operate safely in the workspace. Many studies have been done on the topic of stress. Frequently these demonstrate that investing in the right design upfront can significantly enhance the health and wellbeing of personnel in the short term and save the cost of solving a problem later.

Section three

Mooring forces and environmental criteria

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3.1 - Introduction

This section provides information on calculating the number and strength of mooring lines required to secure a ship at a berth using a set of standard environmental conditions to provide the reference mooring loads. The calculation of this ship-specific mooring line strength value, known as the ship design MBL, is the fundamental factor used to ensure that all other parts of the mooring system are correctly specified, as noted in the relevant following sections.

3.1.1 Objectives

The objective of this section is to provide guidance on assessing the mooring constraints required to control ship motions, taking into account:

1. The environmental forces that a ship may be exposed to at a berth.
2. The calculation of consequent ship motions and restraint requirements.
3. The calculation of the ship design MBL.
4. The calculation of forces on a jetty.

The wind and current drag coefficient data needed are detailed in appendix A.

3.1.2 Context

This section, through the calculation of the ship design MBL, provides the foundation on which subsequent sections are built.

3.1.3 Standard and site-specific environmental criteria

This section considers two cases, the standard case used for ship design and the site-specific case used in the design of terminals to reflect the impact of the local environmental conditions:

Standard environmental criteria

Ships are designed for worldwide trading and must be able to cope with mooring in a wide range of environmental conditions. To this end, OCIMF have adopted standard environmental criteria (see section 3.2). Environmental conditions that are greater than the standard environmental criteria will need to be managed operationally (see section nine).

The standard environmental criteria are used to calculate the restraining forces needed to secure the ship and to determine the ship design MBL for the mooring lines on which the ship's mooring system capability and equipment are based. This is explained in sections 3.3 and 3.4.

Site-specific environmental criteria

The site-specific environmental criteria are used by port and jetty designers to design the jetty and select its fittings. This data is used in conjunction with the standard environmental criteria derived mooring line strengths (ship design MBL) for the range of ship sizes expected to use the jetty.

These local environmental conditions may be determined by metocean studies or by operating experience (as described in section 3.5). They will also be used to determine the operating limits at the jetty and actions to be taken when such limits may be exceeded. Further guidance can be found in section nine.

3.2 - Standard environmental criteria

3.2.1 General

Standard environmental criteria is used as the basis for calculating the mooring needs of new ships, including the number and strength of mooring lines, equipment and fittings.

The updated recommendations in this publication highlight past inconsistencies with other sources such as Classification Society Equipment Number (EN) and local shipyard practices.

The standard environmental criteria outlined in this publication are different to those used by Classification Societies in the EN calculations/tables for mooring equipment. Although the IACS EN tables were upgraded in December 2016. For larger tankers there remains a difference in mooring line strength results (between EN and this publication), as well as a difference in the number of mooring lines that each method suggests. The inconsistency is primarily due to the lower environmental limits used by Classification Societies in the EN calculations.

OCIMF recommends that the standard environmental criteria in this publication should be specified to shipyards for use in ship design mooring analysis and subsequent shipboard mooring equipment configuration and not the EN derived mooring equipment configuration.

3.2.2 Standard environmental criteria

For all ships above 16,000 DWT intended for general worldwide trading, the mooring restraint available on board the ship as fixed equipment should be sufficient to satisfy the following conditions:

60 knot wind (defined below) from any direction simultaneously with:

3 knots current at 0 degrees or 180 degrees

or

2 knots current at 10 degrees or 170 degrees

or

0.75 knots from the direction of maximum beam loading

For oil tankers, water depth to draught ratios (Wd/T) for these conditions are to be taken as 1.05 when loaded and 3.0 when in ballast. For gas tankers above 150m in length the Wd/T should be taken as 1.05 for all conditions, since the draught of a gas carrier changes little during normal cargo transfer operations.

Table 3.1 shows that the drag forces do not change significantly with low under keel clearance values, so a Wd/T value of 1.05 is adequate for general use. While a number of terminals have a minimum Wd/T ratio alongside the berth of 1.02, this ratio will tend to occur around low slack water when average current velocities would be less than when the water level is at a Wd/T of 1.05. It is therefore recommended that the average velocities suggested in the standard criteria be used with the 1.05 ratio.

The worst-case conditions to be used for calculating the range of extreme values are:

- Ship ballasted, highest astronomical tide.
- Ship loaded, lowest astronomical tide.

UKC (Metres)	**Water Depth** (Metres)	**Draught** (Metres)	**Wd/T**	**Direction**	**Longitudinal X Force** (Tonnes)	**Lateral Y Force** (Tonnes)
0.4	22.7	22.3	1.02	10 off bow	10.8	204.9
0.5	22.8	22.3	1.024	10 off bow	11.6	213.9
1.1	23.4	22.3	1.05	10 off bow	16.8	272.5
2.2	24.5	22.3	1.1	10 off bow	-12.0	211.7
44.6	66.9	22.3	3	10 off bow	-6.0	25.6

Table 3.1: *Loaded 250,000 DWT tanker low under keel clearance current drag forces*

When a terminal designer reviews the need for shore augmentation, e.g. secondary mooring lines, calculations will need to be more precise. Actual site data and an appropriate range of ship data should be used for calculations as described in section 3.2.3.

Wind velocity is the velocity measured at the standard height of 10m above ground or water surface and is representative of a 30 second average mean velocity. The selection of the

30 second wind is based on the time it takes the forces in a mooring system to respond to wind velocity changes (30 seconds is a typical value for a large tanker). Smaller ships will respond more quickly than a fully laden VLCC, which may require longer to respond. However, for consistency a 30 second average period has proven to be an effective and uniform standard for all ship sizes and loading conditions. Many engineering standards (for fixed structures) use a one-minute average. Conversion factors from one-minute average mean velocity data records are defined in British Standards Institution (BSI) BS 6349-1-1 *Maritime Works. General. Code of Practice for Planning and Design for Operations* and DNV RP C205 *Environmental Conditions and Environmental Loads*.

The current velocity is the average velocity over the draught of the ship.

3.2.3 Practical considerations

The criteria in this section cover conditions that could be encountered on general worldwide trade. They do not cover the environmental conditions of every terminal worldwide.

Exposed terminals can be subject to more extreme environmental forces. Visiting ships may need to enhance the mooring equipment and/or supplement the mooring restraints with appropriate shore based equipment which may include additional mooring lines run from shore to ship's bitts. Further guidance on calculating likely loads, including dynamic forces (not included in the above), can be found in section 3.5.2.

The terminal should ensure that if the shore moorings are augmented, the site-specific design information and calculations are available to visiting ships. In some circumstances augmented moorings may not be practicable or may not be able to address the full environmental range. In such circumstances, terminal operators may need to set restrictive operational parameters and/or set procedures in place to stop operations and hold the ship with tugs or move the ship to a safe location prior to limitations being reached.

Companies may wish to design ships using this data if the intention is for the ship to be used for dedicated trade or in specific environments.

All ship design/operational information should be maintained with the ship (see section one) to ensure that the limitations of the mooring arrangements are highlighted if the ship changes trade or is sold.

3.3 - Calculation of forces

Computer programs are widely available to calculate mooring forces for any combination of wind and current speeds and angles. Example wind forces using first principle formulae are detailed in appendix A.

Any program should use the appropriate wind and current drag coefficients for the ship. Unless ship specific data is available, the generic wind and current drag coefficient data in appendix A should be used.

It is recommended that dynamic force calculations (including first order ship motions) are conducted alongside static analysis to calculate and size ship equipment. See section 3.5 for more on the use of dynamic forces for terminal design and operational parameters.

3.4 - Mooring restraint requirements

Once the environmental forces acting on the ship are known the strength and number of mooring lines required to balance them can be calculated.

To calculate mooring restraint, the following must be used:

- The three-dimensional coordinates of all ship and terminal mooring points (known or assumed).
- The stiffness of the mooring lines and compression of fenders. When calculating mooring line stiffness, the full length of line from winch to shore bollard should be used.

The structural characteristics of mooring and breasting dolphins may need to be accounted for if these structures are flexible.

Computer simulations/calculations are the most effective way to test the mooring system of an existing or planned ship at a terminal known to have unusual environmental conditions or mooring layout.

3.4.1 Basic principles of mooring calculations

A ship at a jetty or sea island is held at the berth by a combination of mooring lines and breasting dolphins that resist the environmental forces applied to the ship. There are multiple mooring lines that connect from several locations on the ship to several mooring points on the jetty or sea island. The ship's mooring lines and the breasting dolphins together may be considered as a complete mooring system, such that when a force is applied to the ship the ship will move a small but determinable amount. By determining the amount of movement of the ship, the forces in the mooring lines and breasting dolphins can be calculated using the principle of static equilibrium. However, it may not be assumed that the system geometry remains fixed under the application of forces and the solution must also account for any elongation of each mooring line due to stiffness of the components.

3.4.1.1 The principle of static equilibrium

If the environmental forces on the ship are fully balanced in all directions (ahead/astern/port/starboard and yaw) by the mooring line and breasting dolphin restraints so that there is no movement, the ship is in a state of static equilibrium.

3.4.1.2 The stiffness of each mooring line and the deflection of the breasting dolphin

For each mooring line and breasting dolphin, there is a relationship between stiffness (for mooring lines under load) or deflection (for breasting dolphins in compression) and the force applied to it.

For mooring lines, the stiffness is dependent on the material and construction of the line, its diameter and the loaded length, i.e. from the ship winch to the mooring point on the jetty or sea island. Mooring lines become stiffer (less stretch for a given load) with use and the stiffness of used lines should be employed for calculating loads, rather than the stiffness of a new line. The stiffness values can be obtained from mooring line manufacturers or suppliers.

For breasting dolphins, the stiffness values of manufactured fender units are available from the manufacturer. Deflection of the dolphin structure, if significant, can be calculated from the properties of the structure. However, this stiffness should not be considered in assessing mooring line stiffness. It can be included in the fender stiffness but note that stiff concrete capped piled systems are very stiff and have little effect. Monopiles are quite soft in deflection and can significantly reduce the composite fender/dolphin stiffness.

3.4.1.3 The geometrical relationship between the parts of the system

The change in length of each mooring line (and the deflection of each fender on the breasting dolphin) can be calculated from the amount of surge, sway and yaw at the centre of the ship. Since the ship is essentially a rigid element, each fairlead through which a mooring line passes moves in relation to the mooring point, effectively changing the distance between the fairlead and the mooring point on the jetty or sea island.

Using the above principles or system characteristics, the forces in the mooring lines for wind and current forces should be calculated with software that uses the general procedure outlined in the steps below:

1. Calculate the applied forces in the fore/aft and beam directions, and the yaw moment for wind and current.
2. Determine the stiffness of the entire mooring system from the load/deflection characteristics of each component and the geometry of the system. The stiffness of the system is expressed in terms of amount of surge, sway and yaw per unit force in each principal direction and per unit yaw moment.

3. Calculate the total amount of surge, sway and yaw at the centre of the ship by multiplying the amount per unit force and moment determined in step 2 by the applied forces and moment calculated in step 1. This provides a new ship position from which the positions of every mooring line, fairlead and fender contact point can be calculated relative to fixed shore points.
4. Determine the force in each mooring line and breasting fender by calculating the stretch in the line (or compression of the fender) that is compatible with the new ship position, allowing for any line pre-tensions.
5. Finally, calculate the resultant mooring restraint forces in the fore/aft and beam directions and the yaw moment and compare to the applied forces from step 1. It may be necessary to make several iterations of steps 2 to 5 before converging onto the equilibrium position of the ship where the mooring restraint forces exactly balance the applied wind and current forces.

3.4.2 Standard restraint requirements

To obtain a uniform standard of mooring equipment for ships not designed for a specific trade or terminal, it is recommended that the ship designer:

- Follows the principles provided in section 4 regarding the placement of winches and fairleads.
- Assumes breast mooring lines to be at an angle of 15 degrees to the perpendicular axis of the ship. A horizontal angle of 10 degrees to the side of the ship should be assumed for spring mooring lines. Maximum vertical angles of 25 degrees should be assumed for the lightest ballasted condition. These criteria therefore determine the position of mooring points for a generic mooring line layout, as illustrated in figure 3.1.
- Calculates the number of breast mooring lines and spring mooring lines that would be required for the standard environmental criteria and for the generic mooring layout in figure 3.1.

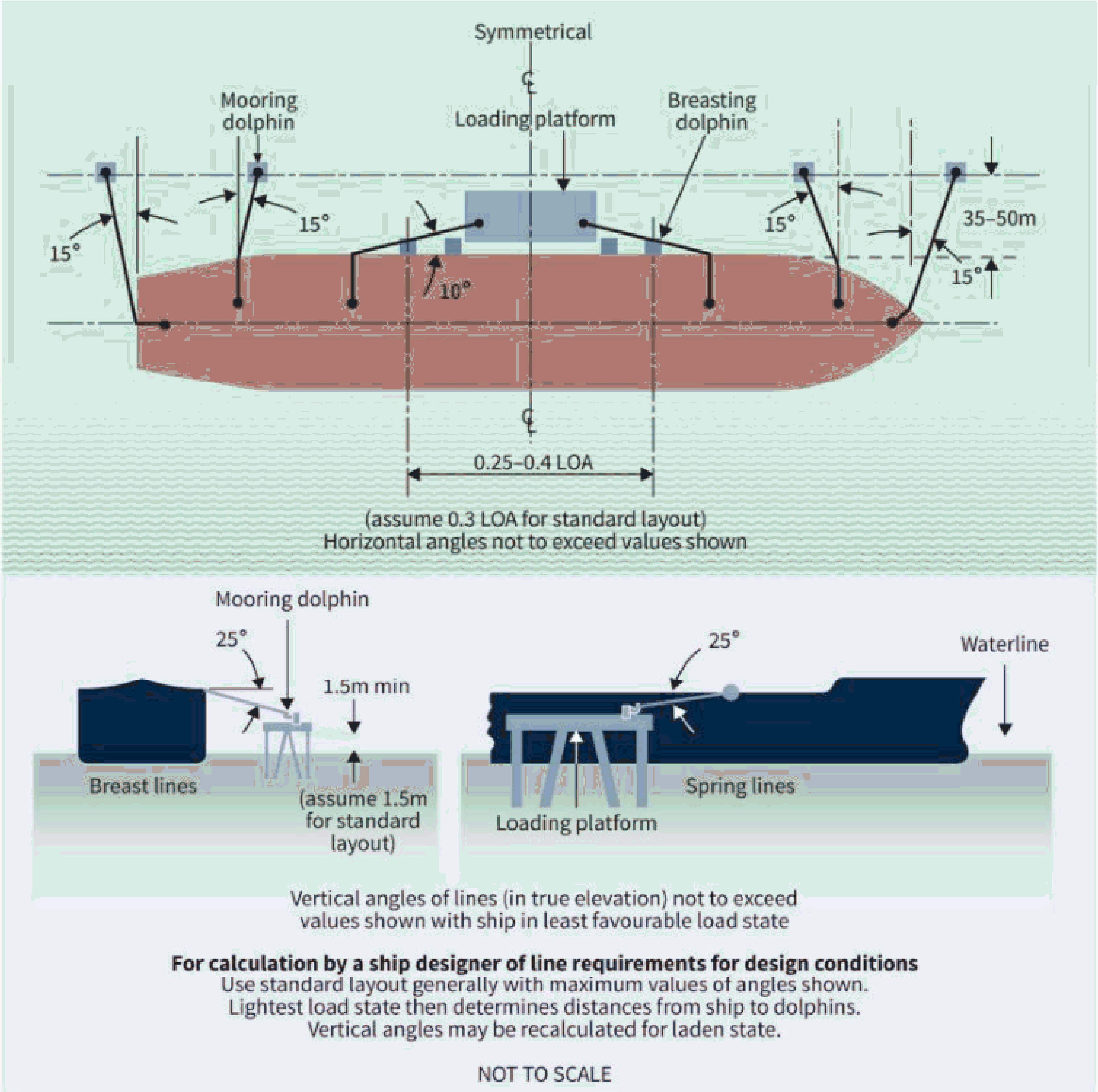

Figure 3.1: *Generic mooring layout used for computational purposes*

3.4.3 Calculating the ship design MBL

The figure below shows the process by which the ship design MBL is calculated.

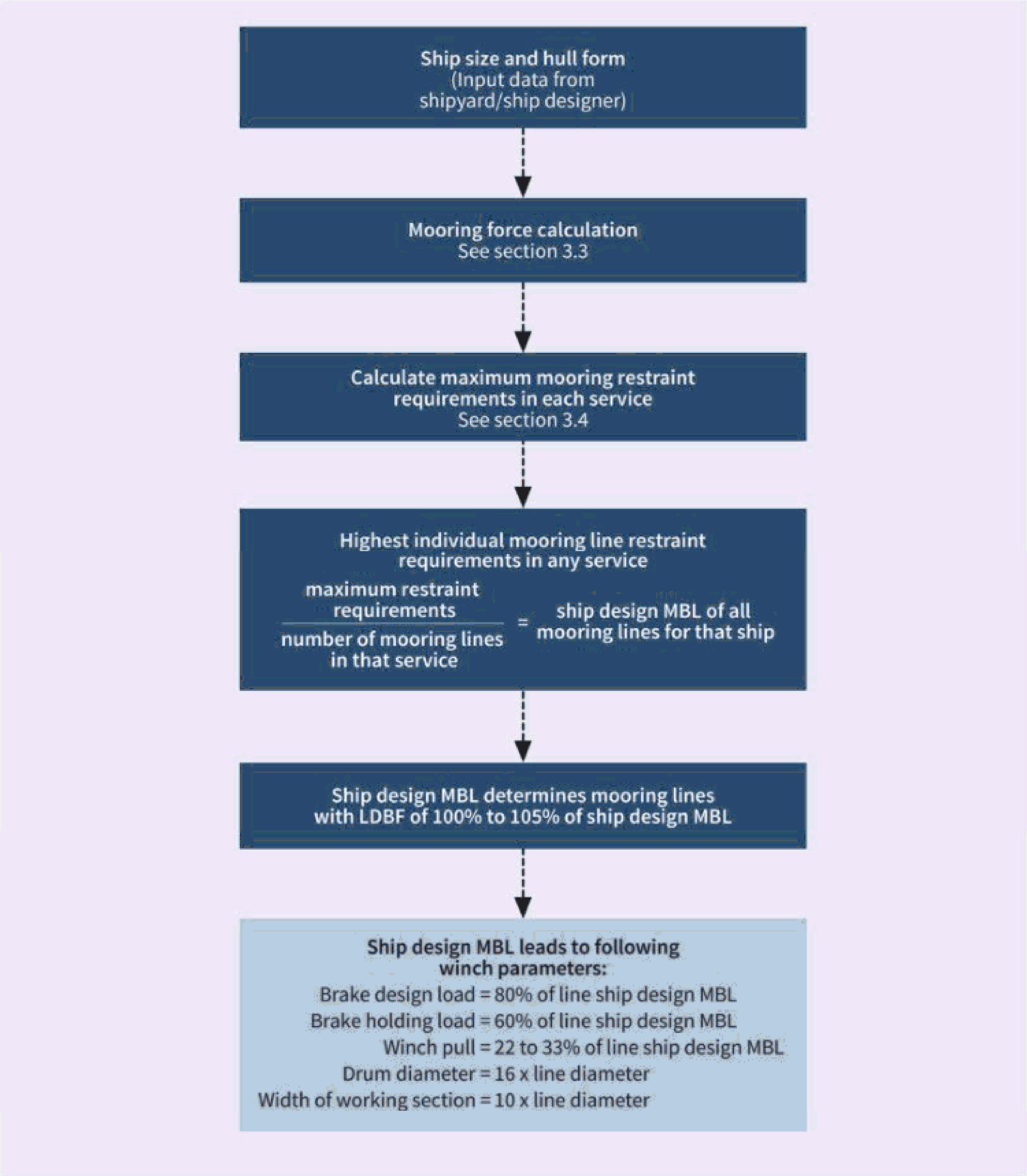

Figure 3.2: *Calculating the ship design MBL*

3.5 - Site-specific environmental data and mooring line loads

3.5.1 General

This section aims, with section nine, to help terminal designers and operators ensure that the design parameters are appropriate for the environmental conditions expected at a specific terminal. It will also help ship operators planning the mooring lines and deck equipment arrangements for ships calling at potentially exposed terminals, when agreeing the ship design with the shipyard.

While industry standard environmental conditions exist for offshore moorings, there are limited universal standard environmental conditions for typical jetty berth moorings. Local standards and established practices/requirements of port authorities or other administration agents may be available to provide guidance on optimum design parameters to be used and potential operational controls.

Determination of the design environmental conditions for a terminal requires an understanding of the maximum site-specific environmental conditions. This requires an understanding of the maximum forces generated by the combination of different parameters such as wind, tide, current and waves. The reliability of any environmental data used needs to be taken into account.

Likely terminal operations, and the time taken to carry them out, should be taken into account. These may include the need to:

- Safely berth the ship.
- Hold the ship alongside during cargo operations.
- Safely unberth the ship.
- Move the ship to a place of safety should conditions become marginal.

Historical environmental data, also known as hindcast data, may be available. Condensed data, with extended sampling periods that filter out many of the peak forces and rate of change information cannot accurately assess the forces acting on a ship. Ideally, data sampling records should be approximately one per second.

3.5.2 Environmental conditions

The primary categories of environmental effects to be considered are:

- Static forces, which tend to make the ship settle in position between the environment and mooring restraints. Static forces include:
  - Steady wind speed.
  - Short period wave drift forces.
  - Steady current.
- Dynamic forces, which create a continuously variable equilibrium between the environment and the mooring restraints that result in the ship being moved directly and immediately with the forces encountered. The degree of position change depends upon the rate of change of the combined factors and the design of the mooring restraint system. Dynamic forces include:
  - Gusting winds.
  - Longer period induced drift forces from swell waves and from other larger waves, e.g. with significant wave height of one metre or more.
  - Variable wave form and random combination effects of multi-modal wave trains and wave focussing.
  - Hydrodynamic effects from passing ships.
  - Effects of sudden mooring line failures.
  - Rapid change of current at turn of tide.
  - Local current eddies.
  - Tsunamis, and in some cases infragravity wave remnants.

3.5.3 Port layout and structures

The design of the port and its structures may influence the environmental conditions and consequently affect the forces exerted on the ship.

Buildings and stacked cargoes may provide shelter from winds or focus the wind effects more strongly. Similarly, breakwaters or other structures may reduce the influence of currents and wind waves in a port. However, in some cases the effects of swell waves are worsened by reflection patterns and wave focussing.

Water depth and under keel clearance also affect the environmental forces acting on the ship. See section 3.2.2.

3.5.4 Ship motions due to environmental forces

The ship's responses to waves are normally separated into two fundamental components:

First order	The ship moves directly and immediately with the impact from each wave encountered.
Second order	The ship moves under the action of steady or changing drift forces created by wave reflections off the hull and other structures, including complex refraction effects.

First order wave motions are directly proportional to the wave height, period and form. Such motions can normally be treated as independent of the mooring properties when in very sheltered locations. It is recommended that model tests, computer simulation tests, and/or measured movement of actual ship motions are used to estimate the forces in the worst local wave conditions expected at a particular berth. Solid piers and harbour walls can have a significant influence on reflecting waves and cause second order multi-modal wave interactions. Berths constructed on piles tend to have a lesser effect and, in some cases, are almost transparent to waves. However, such transparency in one wave direction can become a lack of shelter in the opposite direction.

Although low frequency ship motions due to varying wave drift forces are an important factor for offshore and deep water moorings, they may also need to be considered in more exposed shallow water moorings. They are not usually significant for larger ships at typical jetty moorings in very sheltered locations where the drift force induced wave motions may be small enough to be treated as a steady force, like wind and current. Such drift forces are generally proportional to the wave height squared, particularly with steep fronted wave forms (primarily wind driven) tending to move the ship horizontally rather than imparting vertical/rotational movement with a buoyancy change.

The properties of local wind-blown waves, as opposed to swell waves emanating from past wind action or from a distant wave disturbance, are generally different and independent. However, the combination of the two (or more) wave trains interacting in a multi-modal pattern can only be effectively calculated in model tests or computer simulations. These should also incorporate the possibility of wave focussing or other aspects of combined wave forms now known to occur in what can appear to be a random manner.

Wave motions should be allowed for when calculating the mooring line forces by first analysing the mooring response without any wave motion, then adding the ship motion factors on each fender and mooring line, taking into account its position and orientation. The resulting additional mooring line loads and fender reactions should be calculated from their stiffness.

Static and dynamic computer programs are available for the initial wave-free analysis. Static analysis may be suitable in cases where the environmental conditions are primarily benign and the timescale of variations in the forces due to wind and current is slow enough for the mooring system to respond in a quasi-static manner.

However, in most cases, dynamic analysis simulation will be necessary to effectively assess the rapid rate of change in forces that typically affect ships worldwide. Such changes include:

- Gusting of wind, passing of squalls or weather fronts.
- Changes in current speed/direction, tidal changes, local eddies.
- Movement after a sudden failure of one or more mooring lines.
- Hydrodynamic effects of passing ships.
- Seiche or harbour oscillation.

For those moorings generally exposed to wave action, the additional mooring line loads due to wave motions are calculated by superimposing these motions onto the equilibrium position calculated in the initial wave-free analysis. A frequency domain approach may be suited to the static analysis for benign environmental conditions, or compatibility studies. For detailed design or more rigorous analysis, extensive dynamic analysis simulating individual wave motions in the time domain is recommended to ensure that all factors of the wave motions are addressed.

Worst case loads for mooring line and fender loads should be based on:

- Ship ballasted at highest astronomical tide.
- Ship loaded at lowest astronomical tide.

In the event that this produces excessive mooring line and/or fender forces then, as highest astronomical tide and lowest astronomical tide are very rare events, mean high water springs and mean low water springs may be substituted.

In some locations very high current, wind or wave (or other) forces likely to act on the ship may require operational limits to be very stringent. In such circumstances, it may be necessary to consider alternative arrangements to supplement normal mooring equipment. Such arrangements can range from supplementary shore mooring lines to the new innovative mooring systems under development, or to operational restraints at the berth.

3.5.5 Calculation methods for mooring forces and ship motion

There are various methods to calculate mooring forces and the dynamic effects of ship movement. These range from simple calculations to sophisticated computer modelling. The appropriate methodology should be used based on the guidelines in this section.

A simple static mooring analysis can be suitable where variations in the forces due to wind and current are slow enough for the mooring system to respond in a quasi-static manner, e.g. berths in docks and in very sheltered harbours with mild environment and slow-moving ship traffic conditions.

Dynamic mooring analysis should be used for all other berth mooring analysis where the forces change relatively rapidly, last longer than it takes for the mooring system to initially respond or where the moored ship can settle to new positions with the changing environmental conditions.

The computer simulation programs for dynamic mooring analysis need to be relatively complex in order to address all likely inputs. However, if some of the older less complex computer analysis models are used, model tests or measured observations of actual motions of ships, fender and mooring line combinations may provide insight and guidance on the behaviour of ships at a particular berth and may be necessary to help validate the calculated result.

Dynamic mooring simulations should take the following into account:

- Environmental conditions.
- Rate of change of environmental conditions.
- Effects from passing ships.
- The physical properties of the fendering.
- The type and size of the mooring lines and their tails.

Section four

Mooring arrangements and layouts

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4.1 - Introduction

This section provides guidance on the various requirements that influence the mooring arrangement on board a ship at different installations and for different operations. The objective is for the mooring equipment to be designed with a flexible arrangement that will allow a ship to moor safely at a wide range of berths.

Guidance on individual equipment recommendations can be found in sections four, five, six, seven and eight.

The installations and operations considered are:

- Piers and sea islands.
- Bow mooring at offshore terminals.
- Multi Buoy Moorings (MBMs).
- Harbour towing.
- Emergency towing, escorting and pullback.
- Canal transit.
- Emergency tow-off pennants.
- Barge and small ship mooring.
- Ship to Ship (STS) transfer.
- Mooring augmentation.

The section follows the above order.

4.1.1 General design considerations for mooring arrangements

When designing the best mooring arrangement, a number of recommendations should be taken into account:

- The aim should be to have the simplest arrangement that services all requirements.
- Leads from winches to shipside fittings should be as direct as possible.
- The use of pedestal rollers should be minimised as they indicate a complex mooring arrangement and can reduce the mooring line's strength.
- If a fitting is used for more than one purpose the strength of the fitting should be based on the highest strength requirement.
- The aim should be to have all mooring lines stored on winches.
- Winch motors should not drive more than two winch drums. Doing so reduces the redundancy of the winch and increases the complexity of the mooring arrangement in both normal and emergency operating modes.
- Where different types of mooring line may be used, e.g. chain, steel wire or HMSF, the aim should be for each type of mooring line to have its own fairlead so there are no chafing issues.
- Extra care needs to be taken for HMSF mooring lines, including:
    - HMSF mooring lines should not be used in fairleads designed for steel wire ropes or chains without using an insert.
    - Stainless steel inserts, polymer type inserts or chafe sleeves can be used to smooth the surface of fairleads so they can be used with HMSF mooring lines while minimising chafe damage. Care should be taken when selecting polymer type inserts, however, as some types can transfer heat into HMSF mooring lines.
    - If inserts have been fitted to fairleads, steel wire ropes and chains should not be run through them because they can damage the smooth surface. If steel wire ropes and chains are run through, the inserts will need to be faired/replaced or suitable protection put in place before being used for HMSF mooring lines again.

4.2 - Piers and sea islands

The primary concern in the shipboard mooring arrangement is suitability for mooring at conventional piers and sea islands, since this is the requirement most commonly encountered. The principles for an efficient and safe mooring operation at these terminals are covered in section one. These principles apply to ships of all sizes and can be summarised as follows:

- Mooring arrangements should be as symmetrical as possible about the mid-length of the ship.
- For multi-directional environments, breast mooring lines should be as perpendicular as possible to the longitudinal centreline of the ship.
- For directional environments (see section 1.4.3), site-specific mooring arrangements may be considered to enhance lateral and/or longitudinal restraint.
- Spring mooring lines should be as parallel as possible to the longitudinal centreline of the ship.
- Mooring lines in the same service should have about the same length between the securing point on board and the jetty mooring points. They should be of the same size and material.

In addition to these principles, general guidelines for the mooring arrangement are as follows:

- Keep mooring areas as clear as possible.
- Avoid tensioned mooring lines crossing areas where personnel are normally working.
- Locate mooring operations as far forward and aft as possible.
- Locate bow and stern fairleads as far forward and aft and as low as possible.
- Locate spring mooring line fairleads as far forward and aft on the main deck as possible to provide adequate line lengths to spring mooring points on the berth.
- Correctly align fairleads and winch drums, both horizontally and vertically, to avoid the need for pedestal rollers. If winches are located above deck level (such as on some Liquefied Natural Gas (LNG) carriers and many externally framed ships), fairleads and bitts may have to be raised to ensure proper alignment. Horizontal horns or bars attached to the bitts, or cruciform bitts at deck level (to help keep the mooring lines close to the bitts), should not be fitted or used. Such multi-level arrangements are not recommended.
- Locate winch control positions to ensure the officer in charge of mooring has a clear view of the operation to minimise the risk of injury.
- All mooring lines should be capable of being run without numerous changes of direction.

4.2.1 Number, size and material of mooring lines

Before any mooring arrangement can be considered, the number, size and material of mooring lines should be determined; this is best done by computer analysis. The following factors should be considered.

4.2.1.1 Number and size of mooring lines

- There are practical minimums for the number of mooring lines (see final bullet point below). Operators should select the ship design MBL, as determined by analysis.
- To provide a symmetrical arrangement about midships, breast and spring mooring lines should be of an even number. A practical minimum should be two spring lines in each direction (two leading forward and two leading aft) plus two breast lines at each of the bow and the stern. If an uneven number of breast mooring lines is used, the decision on whether to deploy the extra line or lines from the bow or the stern should be determined by on-site analysis.

- The largest mooring lines that can be safely handled by ship and terminal personnel should be taken into account in the selection process. For steel wire mooring ropes, 44mm diameter is considered a practical maximum based on operator experience. For conventional fibre mooring lines, 80mm diameter is considered a practical maximum. HMSF mooring lines are normally a similar size to steel wire mooring ropes and have a similar ship design MBL, but they are much lighter to handle. In general, the larger a mooring line is, the less susceptible it will be to reduction of service life due to wear.
- For exposed locations that experience first order ship motions, using more mooring lines or mooring lines with higher ship design MBL values may result in increased individual line loads. Less stiffness is required to keep loads reasonable and will not generally result in increased excursions.

4.2.1.2 Material of mooring lines

- Maximum flexibility is provided if all mooring lines in the same service are of the same size and material (see sections 1.5 and 1.6).
- Select the most appropriate material on the basis of strength, stiffness, durability and handling characteristics. Section five provides guidelines for the selection of mooring line materials and line construction.
- Mooring lines with high stiffness are recommended for larger ships as they limit movement at the berth. HMSF mooring lines are considered a viable alternative to steel wire mooring ropes.
- Mooring lines with low stiffness are not recommended for large ships, as they can allow excessive movement at the berth.
- On smaller ships a combination of high and low stiffness mooring lines may be more appropriate, e.g. low stiffness for breast mooring lines and high stiffness for spring mooring lines. Where dynamic loading on moorings can be caused by swell conditions or by the close passing of other ships, synthetic tails at the end of steel wire rope or HMSF mooring lines should be used to reduce stiffness and associated loads in the lines (see section five).

The considerations above assume that mooring lines can be deployed from either the port or starboard side of the ship. If the arrangement of winches and fairleads does not allow this, or the terminal or trading pattern dictates otherwise, additional mooring lines and winches may be required.

To meet the considerations above and the equipment and fittings line-up recommendations in section 4.13, OCIMF recommends that all ship mooring lines are deployed from winch drums.

In addition to the guidance above, the designer and the ship operator should consider the terminal's mooring equipment requirements. Terminal requirements are sometimes based on past experience with inefficient mooring equipment (such as mixed material moorings) and the terminal may demand more mooring lines than are needed for a ship with efficient and well-maintained mooring equipment. If ship operators can show that they comply with the recommendations in this publication, the terminal might feel more confident that the ship mooring system is safe for specific conditions. The terminal might also then consider alternatives to their equipment requirements. A copy of the mooring analysis could be shown to the terminal to demonstrate the suitability of the mooring arrangement.

4.2.2 Head and stern mooring lines

Head and stern mooring lines are not as efficient as breast and spring mooring lines. For most berths, additional breast and spring mooring lines should be used instead. Head and stern mooring lines should only be considered if additional breast and spring mooring lines cannot be used to accommodate the local environmental conditions, e.g. in rivers with high currents that might push the ship bow or stern off the berth.

4.2.3 Arrangements for breast mooring lines

Breast mooring lines are effective in holding the ship against transverse forces. They are particularly effective in restraining the yawing tendency of the ship. To be most effective in restraining the yawing tendency, shipside fairleads for breast mooring lines should be as far forward and as far aft as possible. The lead from the winch drum to the shipside fairlead should be as direct as possible, preferably avoiding the use of pedestal fairleads. If pedestal fairleads are used, the change in mooring line direction should be kept to a minimum to reduce the loss of strength in the mooring lines and reduce introduction of complex snap-back trajectories. If deck space is limited, winches can be placed in a diagonal or transverse arrangement.

The arrangements shown in figures 4.1 to 4.7 of various typical mooring arrangements generally provide adequate flexibility in accommodating different shore mooring point locations.

4.2.4 Arrangements for spring mooring lines

Spring mooring lines should be as parallel as possible to the longitudinal centreline of the ship and are effective in holding the ship against longitudinal forces. To provide an efficient lead to the terminal mooring fittings, spring mooring line shipside fairleads should be as far forward and as far aft as possible. To avoid mooring line chafing on the shipside hull plating, the shipside fairleads must also be within the parallel mid-body.

In practical terms this means that the shipside fairleads serving the forward springs should be at the point where the upper deck starts to taper into the bow area. The shipside fairleads serving the aft springs are normally just forward of the aft deck house, where a direct lead to the winch can be provided. This arrangement results in the aft spring winches and the aft breast winches being some distance apart, which can lead to manning problems during mooring operations. The sequence of the mooring operations may need to be adjusted to cope with any manning issues, e.g. using tugs to help hold the ship in position while the moorings are secured. In some cases it may be necessary to locate the aft spring winches on the aft deck. However, this configuration with the fairleads aft of the parallel mid-body area will lead to difficulties with line of sight and a substantial risk of mooring line chafing issues. A better alternative is shown in figure 4.7, where the fairleads are positioned so that mooring line chafing on the hull plating does not occur and the line lead remains straight from shipside fairlead to shore.

Figure 4.1 shows the conventional manner for handling spring mooring lines, with mooring winches placed in line with the respective fairleads. Since the ship centreline is generally obstructed by deck piping, main deck winches can be moved to the side. In the figure, the main deck winches face to the port side with the mooring line leading from the bottom of the drum to the port side and from the top of the drum to the starboard side. When docking to starboard, the mooring line is led over the deck piping and over horizontal overhead rollers or pipe guards on the starboard side to the shipside fairlead.

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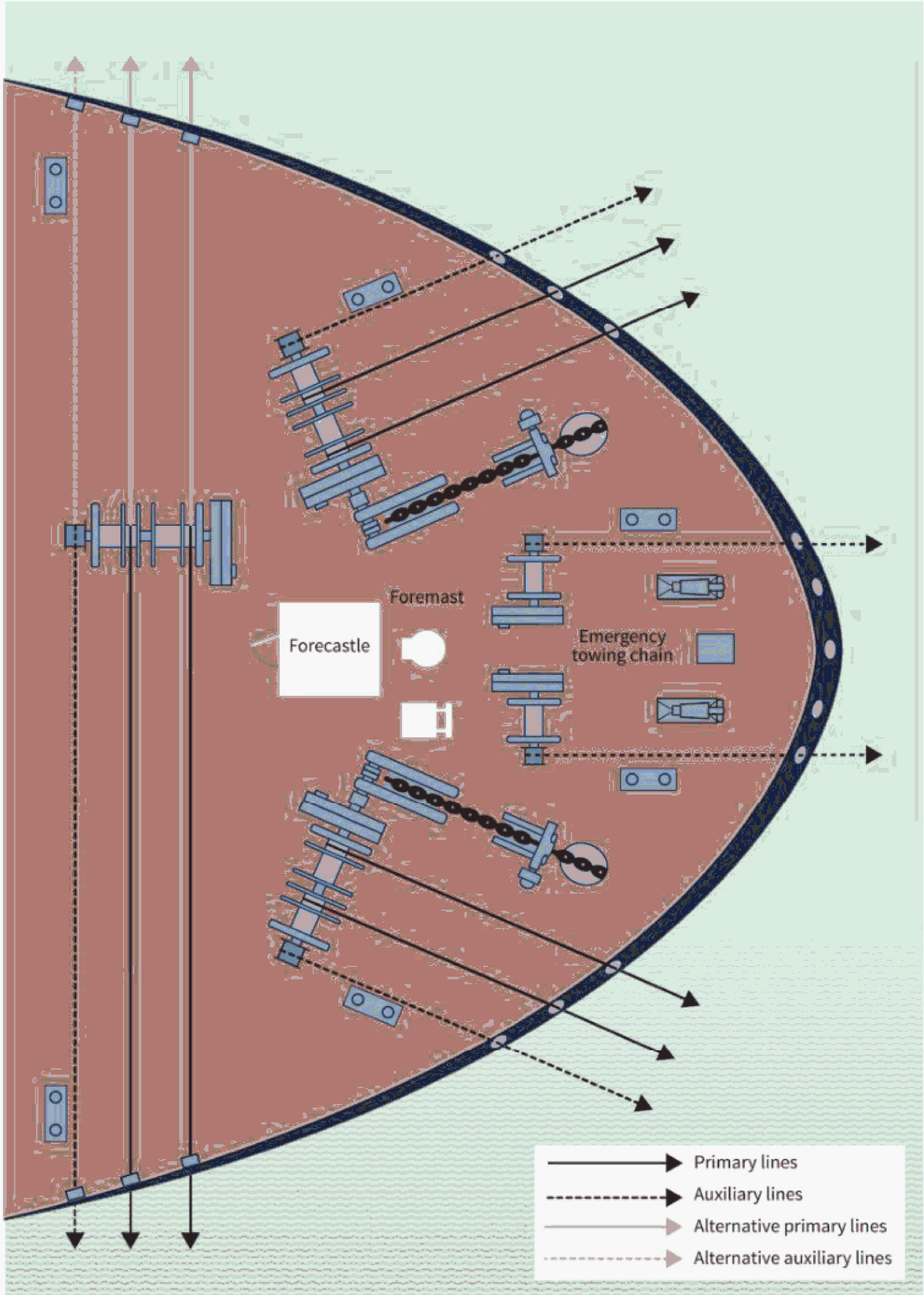

Figure 4.2: *Tanker mooring arrangement on the forward deck*

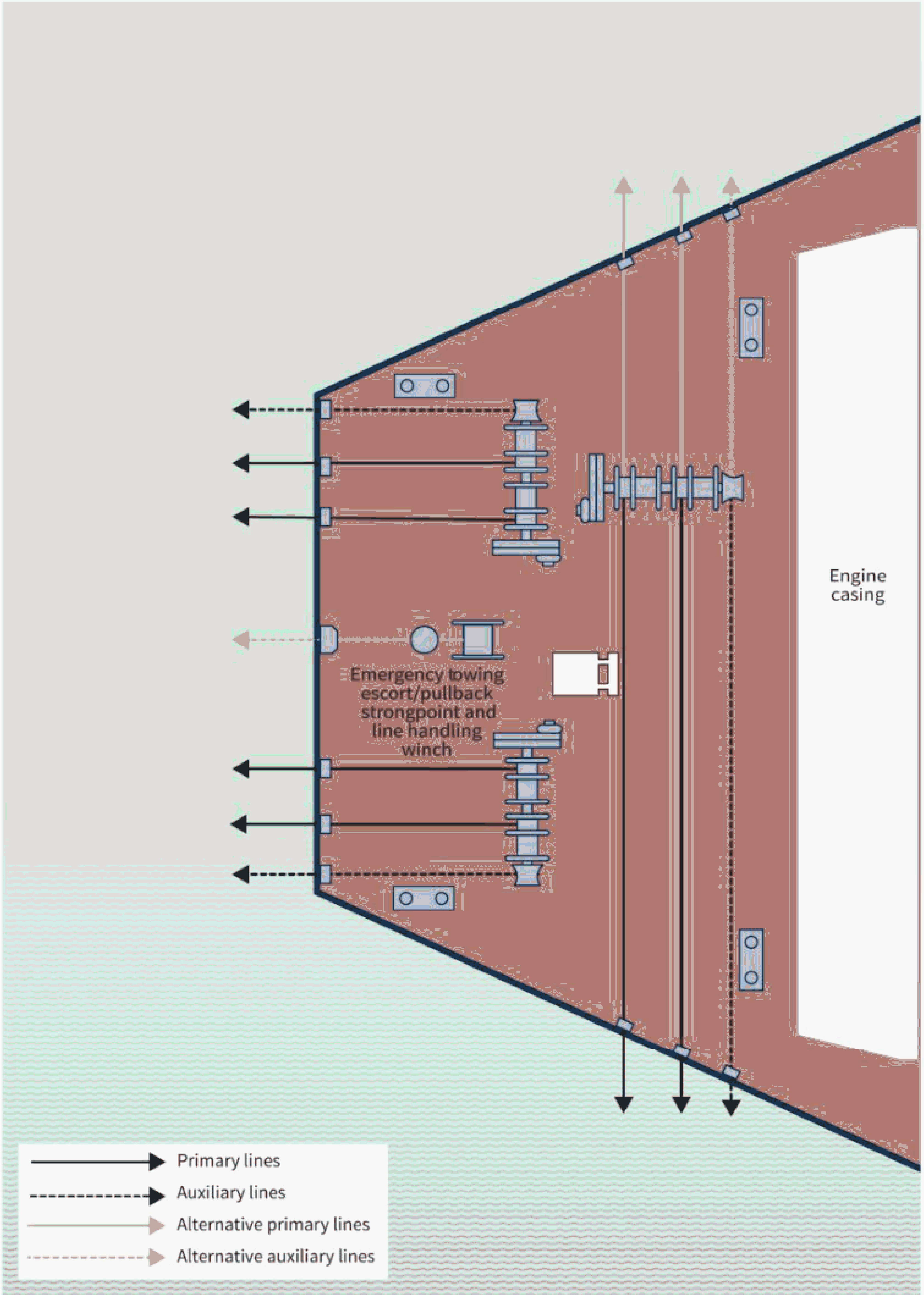

Figure 4.3: *Tanker mooring arrangement of the aft deck*

The lack of main deck winches on spherical tank LNG carriers and lobe/cylindrical tank LPG carriers can mean that capstans are required for handling tug lines. If provided, the capstans should be sized appropriately to the lines being hoisted. It is also common practice on LNG and LPG carriers to use towing bitts recessed into the side shell at appropriate heights for easy handling of the line from the tug.

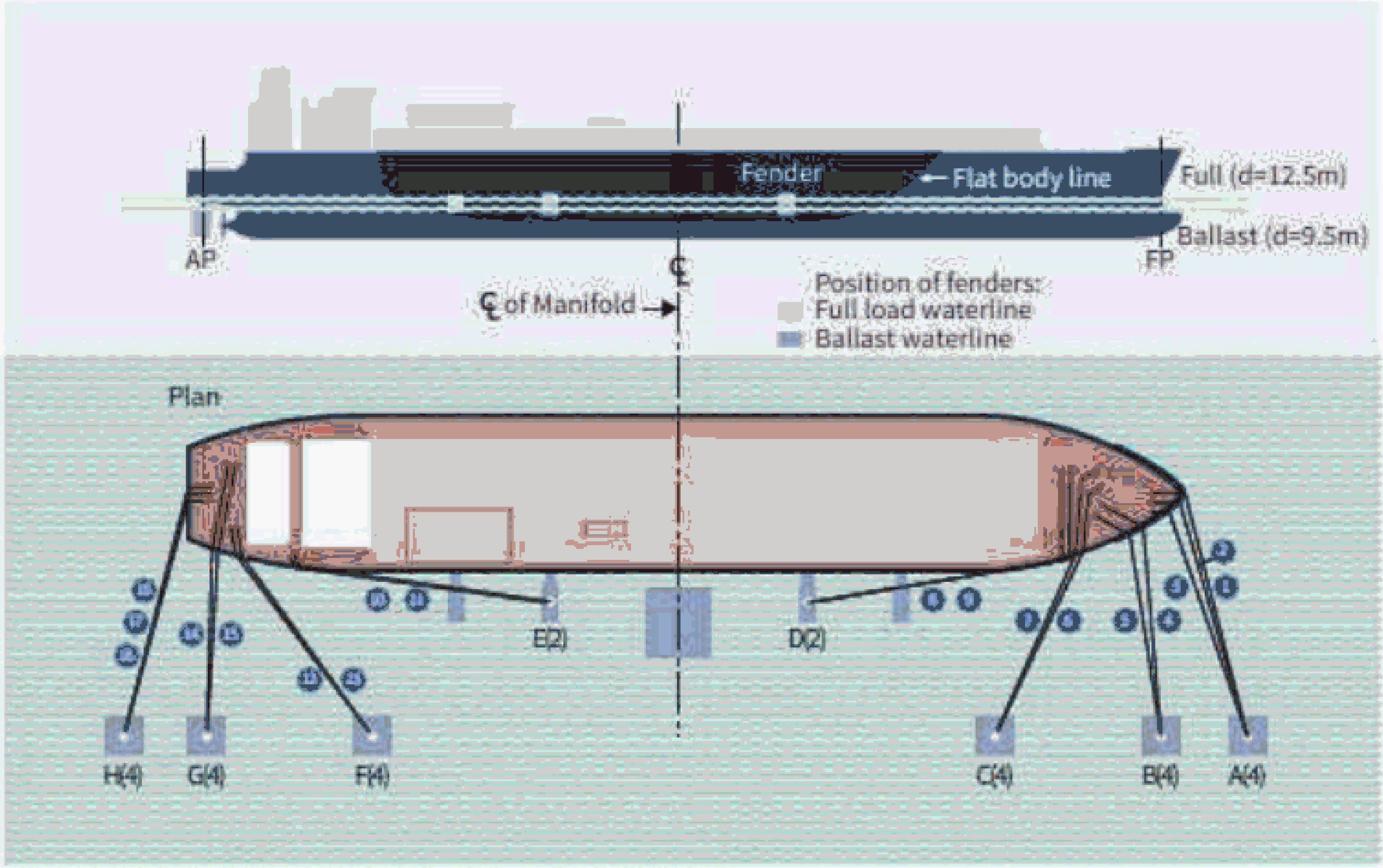

Figure 4.5: *Typical mooring arrangement of a large LNG carrier*

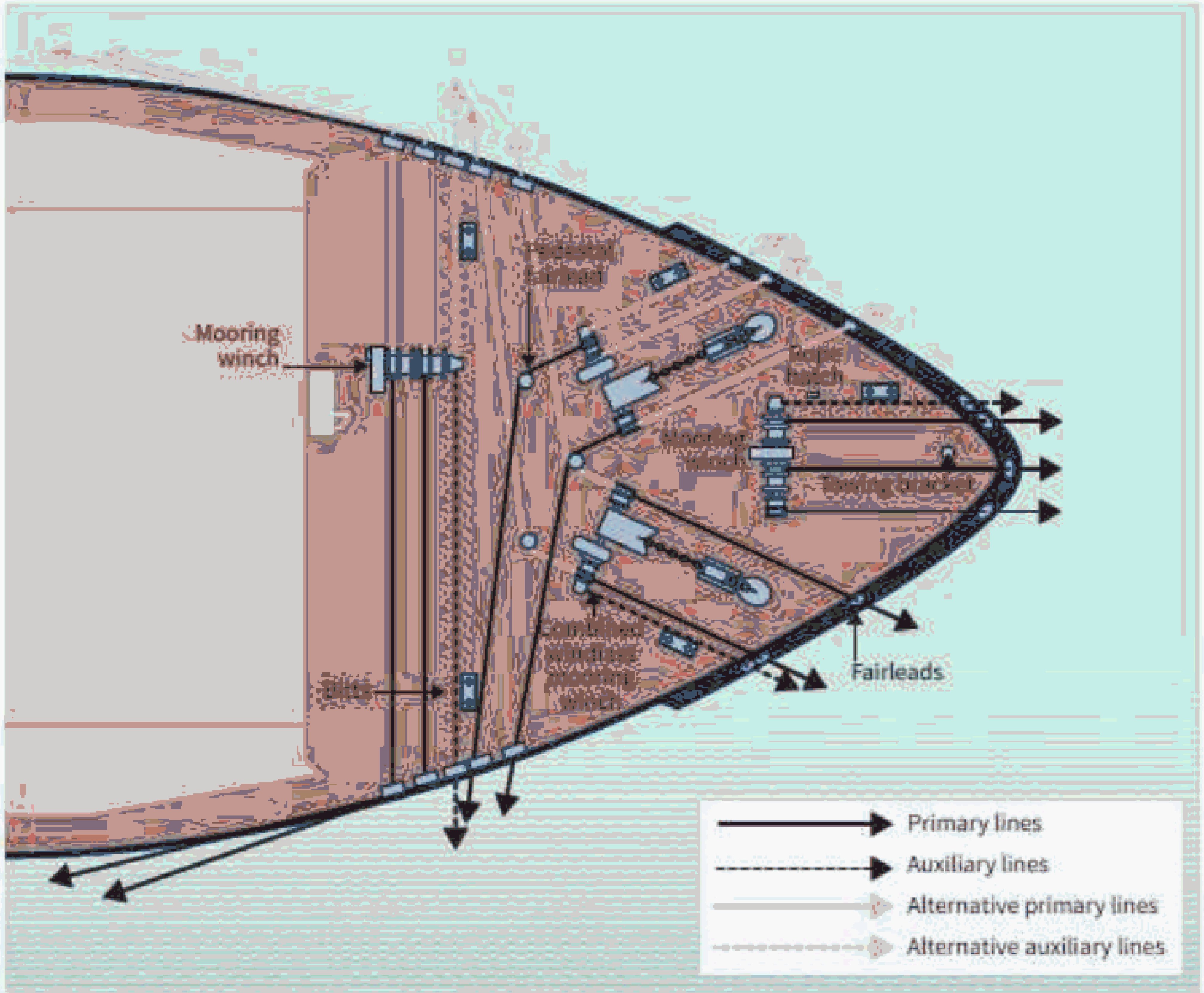

Figure 4.6: *Mooring arrangement on the forward deck of a large LNG carrier*

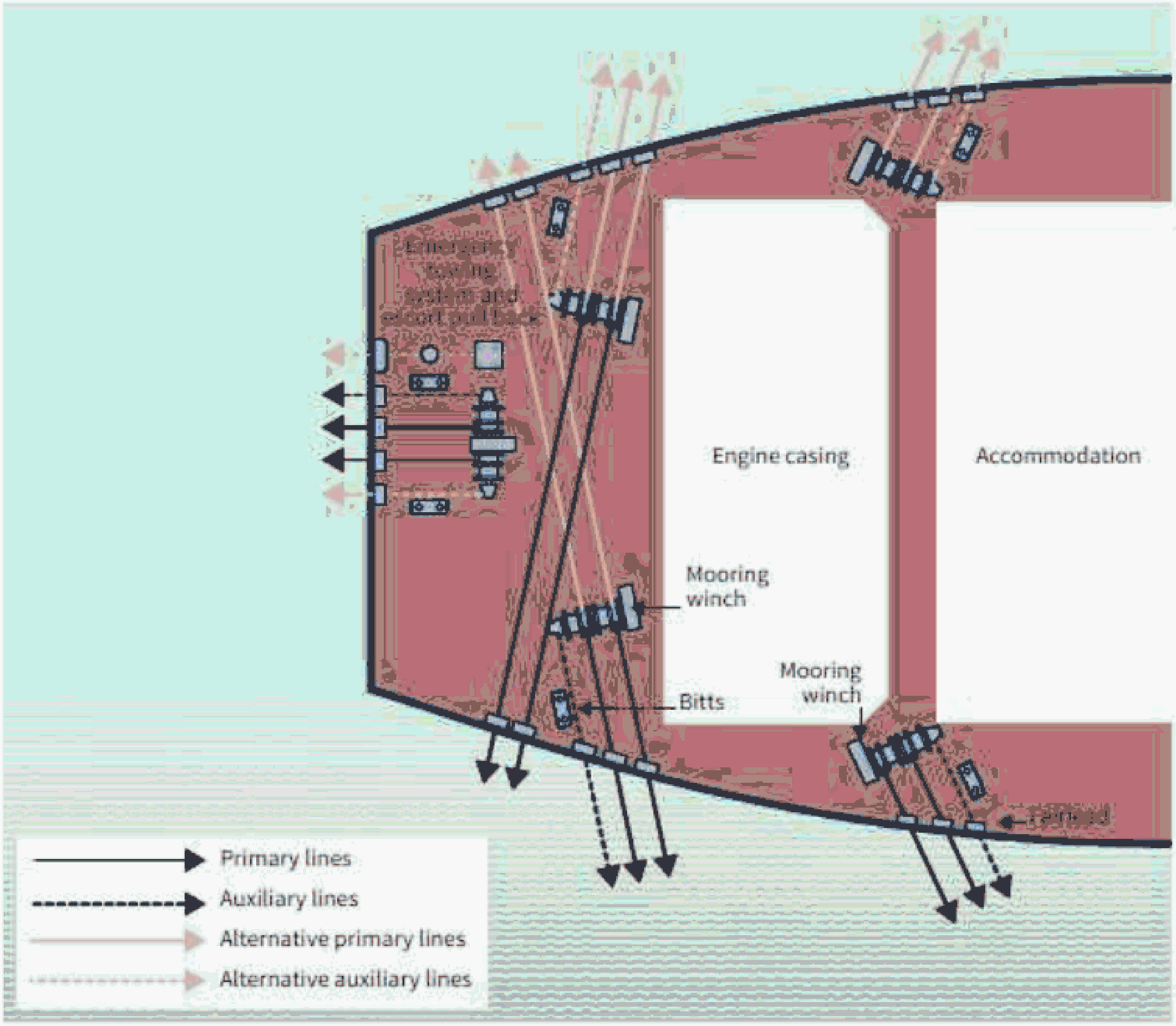

Figure 4.7: *Mooring arrangement on the aft deck of a large LNG carrier*

4.3 - Bow mooring at offshore terminals

This section describes the fittings required for bow mooring a conventional tanker to an offshore terminal (SPM or F(P)SO). This information is also published in OCIMF's *Guidelines for Offshore Tanker Operations*, which provides additional technical and operational guidance on bow mooring.

Ship operators should ensure their conventional tankers are provided with the equipment and capabilities recommended in this section. In particular, that bow chain stoppers are designed to accept a 76mm chafe chain as well as correctly designed bow fairleads and pedestal rollers, if required.

Some SPM operators may require a second bow chain stopper for all sizes of conventional tanker. Operators of conventional tankers that are expected to trade to F(P)SOs or SPM terminals are recommended to fit bow chain stopper arrangements in accordance with this section.

DP bow loading tankers specifically designed for offshore terminals are normally fitted with specialised bow chain stoppers, integrated with the cargo loading system emergency shutdown systems. These specialised systems are primarily single slack hawser systems with specific designs and dimensions and are out of scope of this publication. Details can be found in *Guidelines for Offshore Tanker Operations*.

Operators of DP bow loading tankers wishing to trade to offshore terminals set up for conventional tankers should consider provision/design of alternative bow mooring arrangements as closely aligned with this section as possible. However, if the recommendations in this section cannot be met, in particular the location of dual bow chain stoppers and their separation, and/or the fairleads/chain stoppers are at a height substantially above the forecastle deck, there is a high probability of rejection for service at terminals for conventional tankers, in particular those with dual hawser configurations.

4.3.1 Bow chain stoppers

Operators of conventional tankers that are expected to trade to F(P)SOs or SPM terminals are recommended to fit bow chain stoppers in accordance with table 4.1.

Ship Size	Number of Bow Chain Stoppers	Minimum SWL (Tonnes)
100,000 DWT or less (approx. 120,000 displacement) Note that ships in this size range may elect to fit two stoppers to ensure full range terminal acceptance.	1	200
Over 100,000 but not greater than 150,000 DWT (approx. 120,000–175,000 displacement) Note that ships in this size range may elect to fit two stoppers to ensure full range terminal acceptance.	1	250
Over 150,000 DWT (approx. 175,000 displacement)	2	350

Table 4.1: *Bow chain stopper recommendations (DWT refers to maximum design deadweight)*

The recommended minimum safety factor on the minimum yield load of bow chain stoppers on tankers is 2.0 SWL.

Conventional tankers that are expected to trade to F(P)SOs and SPM terminals should be equipped with bow chain stoppers designed to accept 76mm chafe chain. A typical design is shown in figure 4.8.

Bow chain stoppers, foundations and supporting structure should be adequate for the expected loads. The tanker should hold a copy of the manufacturer's type approval certificate for the bow chain stoppers. The certificate should confirm that the bow chain stoppers are constructed in strict compliance with a recognised standard that specifies SWL, yield strength and safety factors. The tanker should also hold a certificate confirming the strength of the bow chain stopper foundations and supporting structure, substantiated by detailed engineering analysis or calculations and an inspection of the structure. An independent authority, such as a Classification Society, should issue both certificates. Bow chain stoppers, foundations and supporting structures should be kept in good order and surveyed at least once every five years. Bow chain stoppers should be permanently marked with the SWL and appropriate serial numbers so that certificates can be easily cross-referenced.

Bow chain stopper manufacturers should provide basic operating, maintenance and inspection instructions which should be followed without modification, for example, wedges should not be used between the pin and tongue of bow chain stoppers. Where appropriate, manufacturers should also provide guidance on maximum component wear limits.

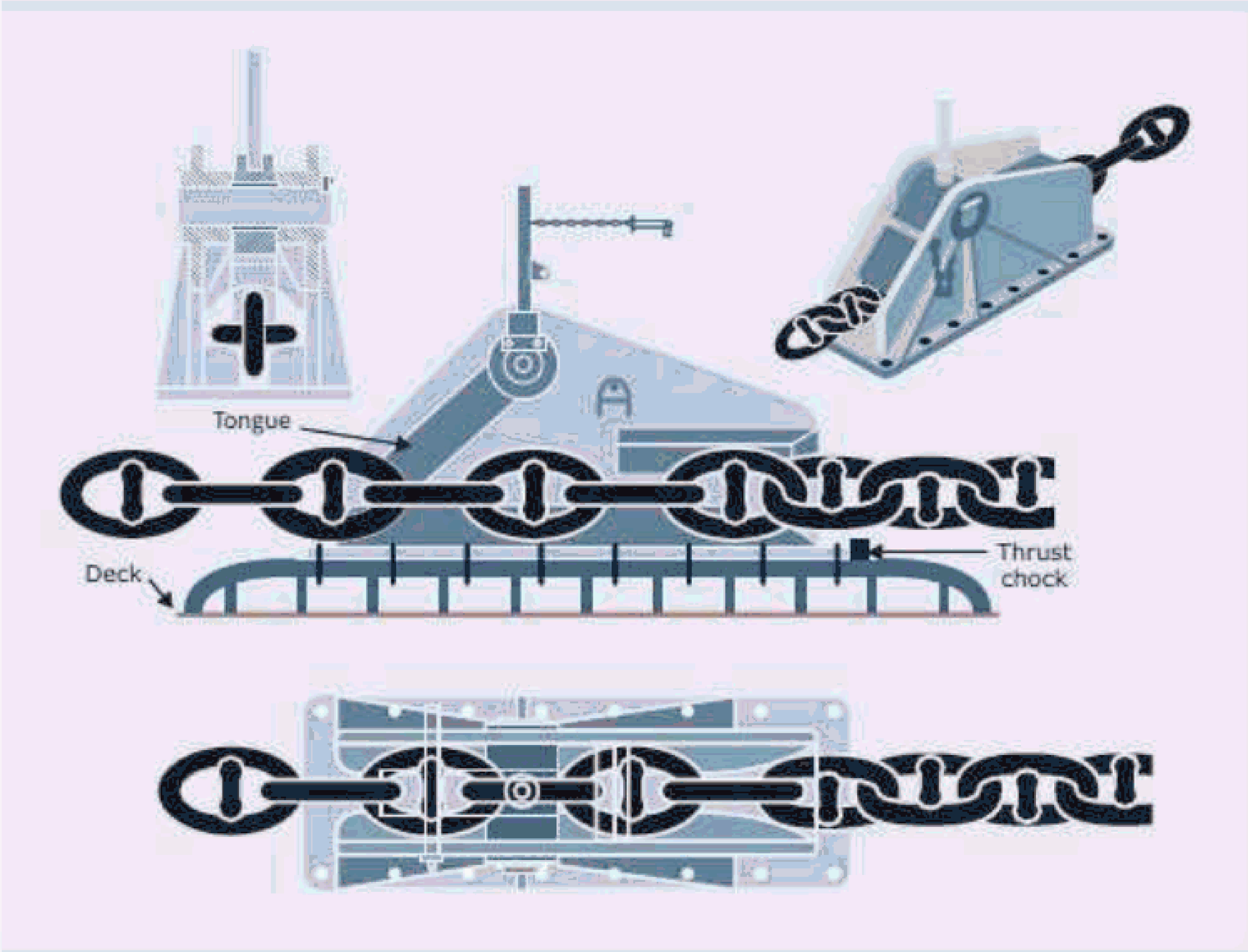

Figure 4.8: *Typical tongue type bow stopper*

These recommendations are based strictly on tanker size. Although terminal operators may change the type of chafe chain and equipment to take account of local environmental conditions, the dimensions of such equipment need to be as detailed in *Guidelines for Offshore Tanker Operations* to make sure it matches equipment specified here for offtake tankers.

Bow chain stoppers have been found to be safe and easy to use and maintain. The bow chain stopper should be designed to secure a standard 76mm diameter stud-link chain when the chain engaging pawl or bar is in the closed position. The bow chain stopper should be designed to freely pass a standard 76mm diameter stud-link chain and associated fittings when the chain engaging pawl or bar is in the open position.

Smit type towing bracket fittings should not be used as bow chain stoppers.

Recommendations for positioning bow chain stoppers are as follows:

- Bow chain stoppers should be located between 2.7m and 3.7m inboard from the bow fairlead.
- Bow chain stoppers should be aligned correctly in a direct lead with the bow fairlead and the winch storage drum. Ideally, the lead should be in a fore and aft direction.
- Bow chain stopper support structures should be trimmed to compensate for any camber and/or rake of the deck. The bow chain stopper base plate should be faired at the forward and aft faces to allow the chafe chain to run freely in either direction.
- Improperly sited bow chain stoppers and ancillary equipment will hamper mooring operations and may result in tankers being rejected by terminals until the arrangements have been modified to conform with these recommendations.

4.3.2 Bow fairleads

Bow fairleads should be of at least equivalent SWL to the bow chain stoppers. The recommended minimum safety factor on the minimum yield load of bow fairleads is 2.0 SWL. Operators of conventional tankers not meeting this value are recommended to upgrade the safety factor of their bow fairleads to 2.0 SWL. The load position should be based on hawser angles up to 90 degrees from the tanker centreline, both starboard and port in the horizontal plane and to 30 degrees above and below horizontal in the vertical plane.

Bow fairleads, foundations and supporting structure should be adequate for the expected loads. The tanker should hold a copy of the manufacturer's type approval certificate for the bow fairleads confirming that the bow fairleads are constructed in strict compliance with a recognised standard that specifies SWL and safety factor. The tanker should also hold a certificate confirming the strength of the bow fairlead foundations and associated supporting structure, substantiated by detailed engineering analysis or calculations and an inspection of the structure. An independent authority, such as a Classification Society, should issue both certificates. Bow fairleads, foundations and supporting structure should be kept in good order and surveyed at least once every five years in line with the special survey cycle.

The use of a single central bow fairlead has been found to create problems when heaving the second chafe chain inboard because the first chain tends to obstruct the direct line of pull. In this arrangement, there is a certain amount of interaction between the mooring hawsers, thimbles and floats and this frequently leads to chafing and damage to flotation material. Consequently, it is recommended that two separate bow fairleads are fitted to conventional tankers fitted with two bow chain stoppers.

The following recommendations refer to the size, location and type of bow fairleads (also see figures 4.9 and 4.10):

- All bow fairleads should measure at least 600 x 450mm.
- Bow fairleads should be spaced two metres apart, centre-to-centre, if practicable, and in no case be more than three metres apart. Tankers of 150,000 DWT or less fitted with a single bow chain stopper need only provide a single bow fairlead, which should be on the centreline.
- Bow fairleads should be oval or round in shape and adequately faired when fitted to prevent chafe chains from fouling on the lower lip when they are heaved inboard or let go. Square bow fairleads are not suitable for conventional tankers.

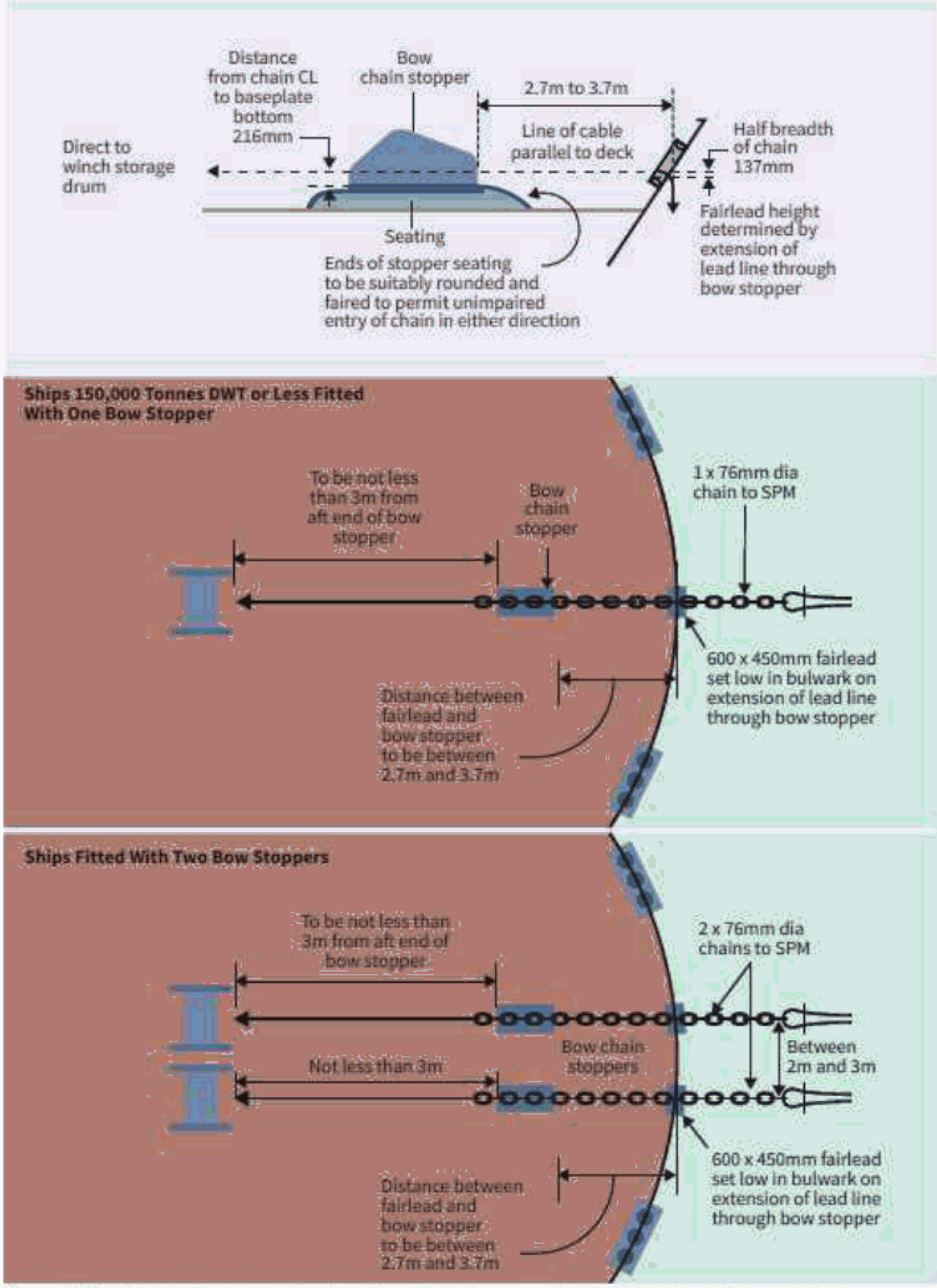

Figure 4.9: *Positioning of forward fairleads and bow chain stoppers with a direct lead to winch storage drum*

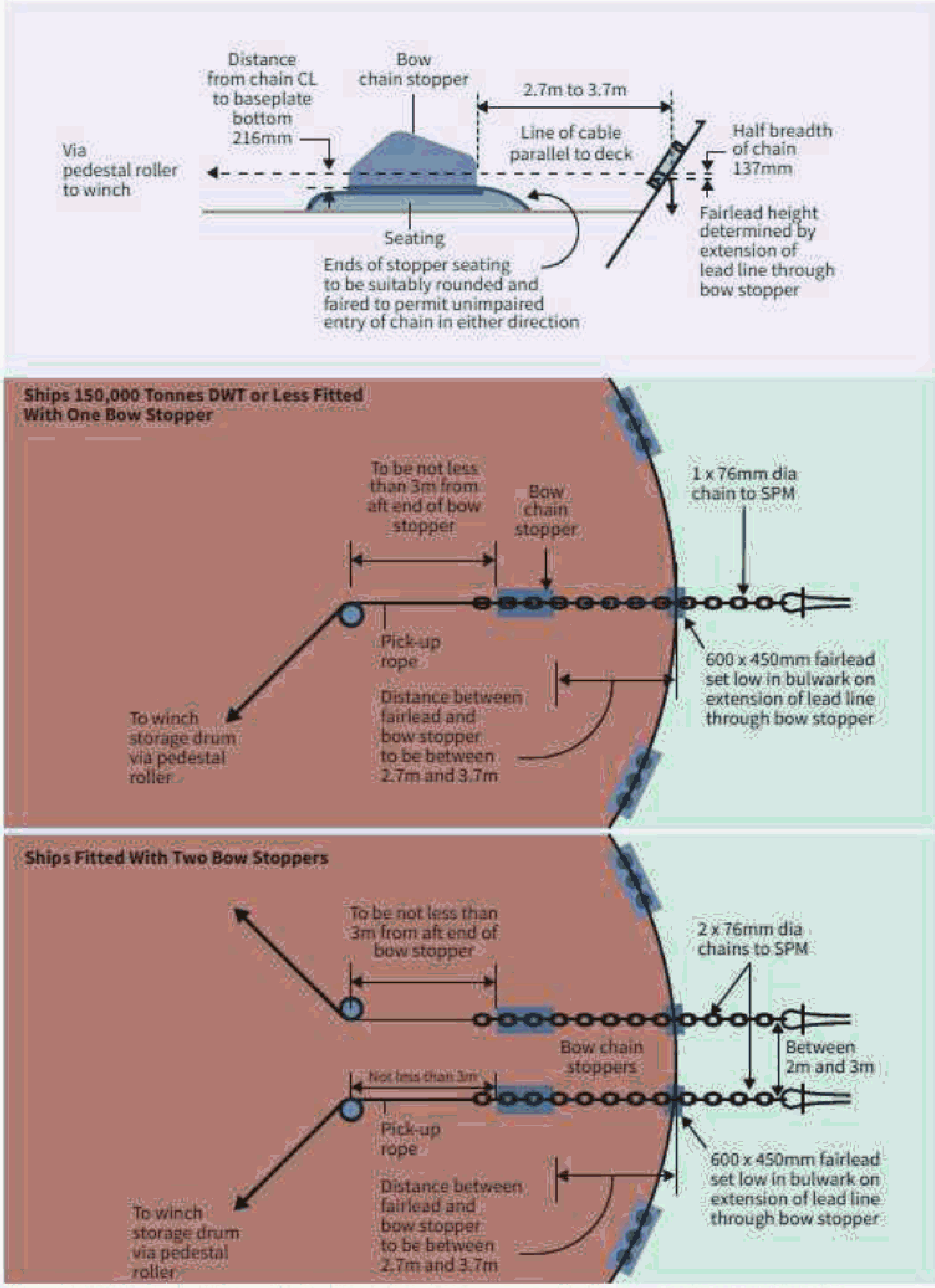

Figure 4.10: *Positioning of forward fairleads and bow chain stoppers with a lead to winch storage drum via roller fairlead*

4.3.3 Position of winch storage drums and possible pedestal rollers

Conventional tankers likely to visit F(P)SOs and SPM buoy terminals should be equipped so that winch storage drums used to recover the pick-up lines should be positioned in a direct straight lead with the bow fairlead and bow chain stopper without the use of pedestal rollers. This relative positioning of the tanker bow mooring equipment in a direct straight lead is a best practice and considered the safest and most efficient arrangement for handling the pick-up lines. There should be at least three metres distance between the bow chain stopper and the winch drum to allow for the pick-up line eye, joining shackle, shipboard-end oblong plate and a number of chafe chain links.

However, recognising that not all existing mooring arrangement designs will permit direct straight leads to a winch stowage drum, consideration of safety and protection of mooring personnel from risk of snap-back injury should take priority in determining the number and positioning of any pedestal rollers. However, only one pedestal roller should be used for each bow chain stopper and in no circumstances should the number exceed two. The angle of change of direction of the pick-up line lead should be minimal. Tankers may be rejected by some terminals if the angle of change of direction is large, such as an aggregate of all changes exceeding 90 degrees.

If used, it is essential that pedestal rollers are correctly aligned with the winch storage drum and the centre of the bow chain stopper. This enables a direct lead from the centre of the bow fairlead to the centre of the bow chain stopper while allowing the pick-up line to be stowed evenly on the stowage drum. There should be at least three metres distance between the bow chain stopper and the closest pedestal roller to allow for the pick-up line eye, joining shackle, shipboard-end oblong plate and a number of chafe chain links.

There should be no obstructions or fittings (e.g. a hatch with securing dogs) close to the route of the pick-up line or chain to ensure that if the line is allowed to run free during letting go it is unlikely to snag on any such structure.

On all conventional tankers, winch stowage drums used to stow the pick-up line should be capable of lifting at least 15 tonnes and be of sufficient size to accommodate 150m of 80mm diameter line. Using winch warping drums to handle pick-up lines is considered unsafe and should be avoided. This is because the combined weight of the pick-up line and buoys can lead to the line slipping and jerking on the drum end if not effectively handled. Remotely operated winch stowage drums may give some additional snap-back injury protection to the winch operator.

4.3.4 Additional guidance

At offshore bow moorings, bow mooring fairleads lined with stainless steel can have their surface damaged by the chafe chain. Removable fairlead inserts could be considered for bow fairleads if HMSF mooring lines are likely to also be run through them.

4.4 - Multi Buoy Moorings

An MBM consists of mooring a ship to several permanently anchored buoys in conjunction with the ship's own anchors. It is also called Conventional Buoy Mooring (CBM). A typical five-buoy configuration is shown in figure 4.11. In some cases, the ship is moored to buoys only, without using the ship's anchors. This type of berth is called an All Buoy Berth (ABB). ABBs are generally located where seabed conditions make the ship's anchors ineffective or where additional mooring restraint is needed for the anticipated environmental conditions. Further guidance can be found in OCIMF's *Guidelines for the Design, Operation and Maintenance of Multi Buoy Moorings*.

MBMs are usually located where environmental conditions are mild to moderate. This is because the mooring restraint is limited when the mooring lines are led out on both port and starboard sides, unlike at piers and sea islands where the mooring lines are led out on one side only.

When environmental conditions are approaching operational limits, the loads on an individual mooring line can become very high. Once one mooring line fails, other lines can fail from shock loads. Preventative or contingency measures may be required, e.g. use of tugs. In most cases, standard mooring equipment that complies with these guidelines will be adequate.

In addition to the standard mooring arrangement, the following factors should be considered:

- The terminal will normally require the ship to provide the mooring equipment. Some or all of the buoys may require two or three mooring lines each.
- Some terminals use the aft spring mooring lines for beam moorings. These are generally issued from fairleads forward of the deck house. This will enable all mooring lines on the aft deck to be used for the quarter and stern buoys.
- Adequate fairleads should be provided at the transom to facilitate mooring to the stern buoy.
- Steel wire mooring ropes with synthetic tails are sometimes used to reduce the ship's drift, although many MBMs require synthetic or HMSF lines for handling purposes and to better manage the dynamic forces in the mooring. Very stiff mooring lines should be avoided as these may create very high loads in the lines and increase the likelihood of line failure.
- Some berths provide mooring augmentation (secondary lines), which are permanently attached to the buoy and are towed to the ship with a launch. Handling and securing secondary lines to a ship's bitts can be difficult because the lines are relatively long and must be pre-tensioned to prevent drift. A ship's winch can be used to pre-tension secondary lines. This is done by removing the existing mooring line from the winch drum and reeving the secondary line in its place. If the secondary line is left in tension on the winch, the holding power will be governed by the winch brake and not the strength of the secondary line. To fully utilise the secondary line strength, after pre-tensioning on the winch the line should be transferred to a suitable set of bitts using a chain or carpenter's stopper. The ship will need to use a mooring line of similar material and stiffness to the secondary line to ensure forces are equally distributed between the lines. The MBL of secondary lines must not exceed the SWL of the ship fittings to which they are attached.

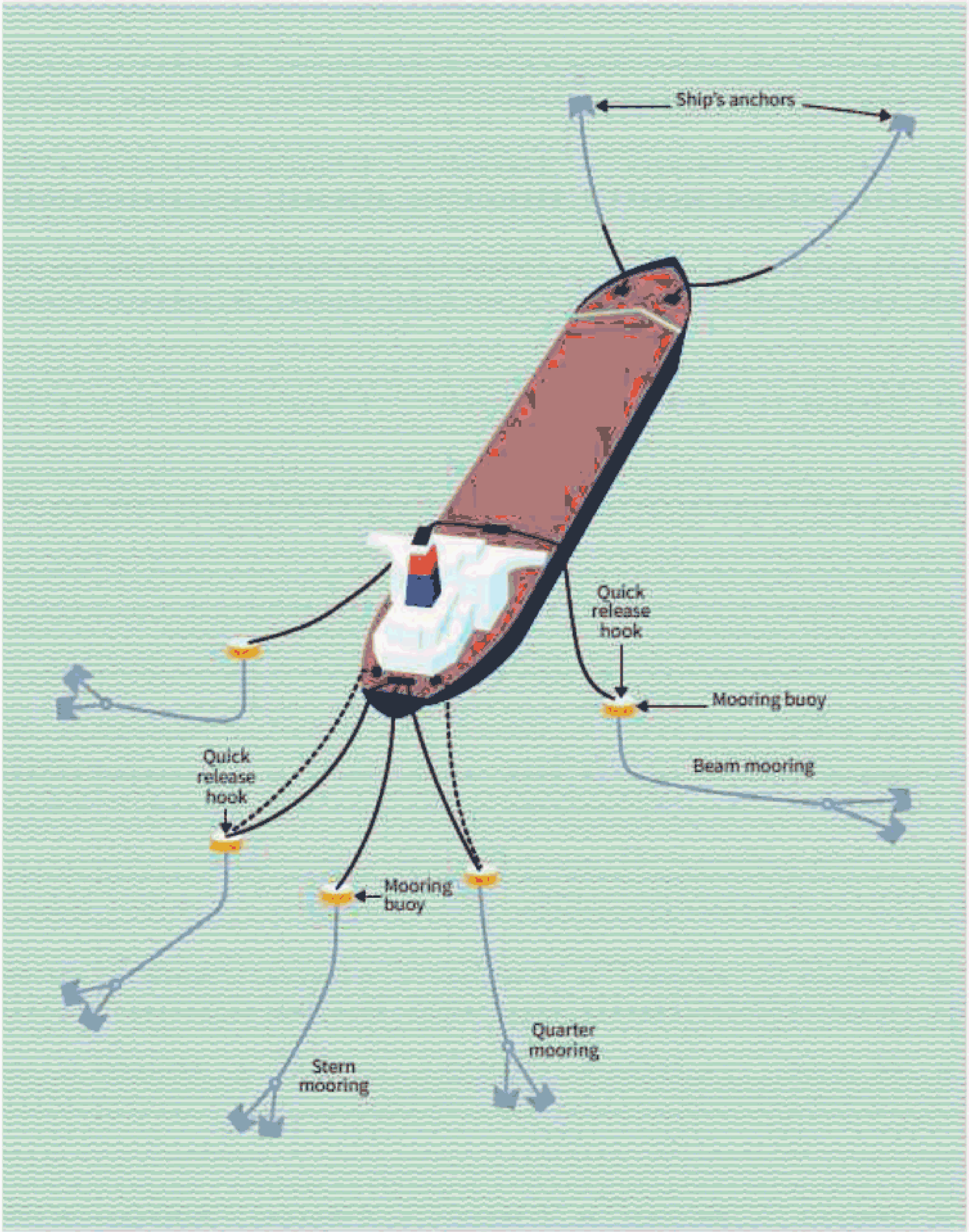

Figure 4.11: *Multi Buoy Mooring arrangements*

4.5 - Towing

4.5.1 Harbour (normal) towing

Harbour (normal) towing is used to manoeuvre a ship in sheltered waters to or from a berth.

Strength recommendations for harbour (normal) towing are described in section seven.

Provisions for tug handling consist of properly placed closed fairleads and associated bitts for guiding and attaching the tug's towing line. Some high freeboard ships, such as large gas carriers, may be provided with recessed bitts on the shipside shell instead of sets of bitts and fairleads on deck.

Means for hauling the tug's towing line aboard with a ship's heaving line/messenger should also be provided. These consist of suitable pedestal fairleads, guide posts or bitts to lead the heaving line onto the warping drum of a mooring winch. On some larger ships, dedicated capstans may be provided close to the bitts.

Figure 4.12: *Typical over-the-bow tug towing connection*

When determining fairlead locations, the following points should be considered:

- Fairleads should be adequately separated to allow tugs space to manoeuvre. For large tugs handling VLCCs or ULCCs, fairleads should be about 50–60m apart.
- At the shipside, fairleads should be located in the same transverse plane as tug push/pull locations because tugs may push or pull from the same location. The forward and aft fairleads should be placed to provide maximum leverage for turning the ship, but not be so far forward or aft that there is a danger of the tug getting trapped under the flare of the hull. The tug push location is normally near a transverse bulkhead or web frame.
- An alternate neutral pull or push location is required midships to allow the tug to check the lateral motion without applying a turning moment. The fairlead is generally located just aft of the cargo manifold hose support rail.
- Towing arrangements should accommodate a 180 degrees range of towline angles in the horizontal plane and a 0–90 degrees downward range in the vertical plane outboard of the fairlead.

Figure 4.13: *Typical over-the-stern tug towing connection*

For VLCCs and ULCCs these requirements generally result in five push/pull locations on each side of the ship. Smaller ships usually have three push/pull locations on each side.

A method of safely letting go the tug should be provided. When letting go, the towline should be slacked back to the fairlead in a controlled manner using a messenger line, if necessary, to avoid the line flailing.

4.5.2 Emergency towing, escorting and pullback

4.5.2.1 Emergency towing

Requirements for emergency towing are contained in IMO resolution MSC.35(63) *Guidelines for Emergency Towing Arrangements on Tankers*.

The forward arrangement of strong point, fairlead, chafe chain and roller pedestal fairlead may, on many oil tankers, be accommodated by the fittings recommended for bow mooring at offshore terminals (see section 4.3).

4.5.2.2 Mooring arrangement for tug escort and pullback, and aft mooring deck design

OCIMF recommends using the fairlead and strong point requirements in MSC.35(63) for emergency towing, escort towing and pullback.

The following arrangement design recommendations should be applied:

- Emergency towing, escort towing and pullback should take place through a fairlead on the centreline of the ship with a direct lead to the strong point.
- Escort towing and pullback arrangements should not impede the operation of the emergency towing arrangement.
- The winch used for handling the escort towing and pullback towline should be situated to allow a direct lead from winch drum to strong point/bitts and adequate visibility of the line by the winch operator.

4.5.2.3 Arrangement for escort and pullback if the emergency towing fairlead and strong point cannot be used

If the emergency towing fairlead and strong point cannot be used for escort and pullback then the escort/pullback arrangement is likely to be off-centre. This can present problems in terms of off-centre pull and should be avoided.

In this case the fittings and strong point should also meet the strength and geometry requirements of MSC.35(63).

4.5.2.4 Additional requirements for escort and pullback

MSC.35(63) does not provide detailed requirements for escort and pullback arrangements. The following arrangements are recommended for escort and pullback.

Layout

- The minimum distance from strong point to fairlead should be four metres. It is recognised that this may be difficult to achieve on ships of less than 50,000 DWT, but it is aimed at ensuring that the eye splice of the towing line sits inboard of the fairlead. If the distance from strong point to fairlead is less than four metres, the tug should be advised. (This recommendation does not apply if the emergency towing arrangement is used as the chafing gear will lie in the fairlead).
- The towing or connection point should be aligned longitudinally with the fairlead and clear of all obstructions.

Fittings

- The fairlead opening should be oval or have well-rounded corners.
- The recommended minimum dimensions for the fairlead are 600mm x 300mm. This takes into account the increased use of HMSF mooring lines as towing lines for escort duties. To minimise the performance reduction due to bending, a minimum D/d ratio of mooring line to fairlead curvature of 15 is recommended (see section five).
- HMSF mooring lines are susceptible to damage by cutting and abrasion. Fittings that have been used with steel wire ropes may have gouges and sharp edges that could damage HMSF mooring lines unless steps are taken to protect them. It is recommended that fairleads and strong points are kept smooth on the contact surfaces or inserts are used to avoid undue abrasion of towlines.
- Bitts used for escort and pullback should follow the recommendations in section seven.

- The equipment to be used for the guidance and connection of the tug's towing line should be clearly marked as such and preferably painted a distinctive colour.
- The fittings for escort and pullback should be tested, marked and included on the ship's towing and mooring arrangements plan as recommended in section seven.

4.5.3 Stern mooring winch arrangements

The winch used for handling the escort towing and pullback towline should be situated to allow a direct lead from winch drum to strong point/bitts and adequate visibility of the line by the winch operator.

4.5.4 Disconnection of towline

Means should be provided for safely disconnecting the tug towline in a controlled manner in all expected environmental conditions. When disconnecting, the towline should be slacked back, allowing the tanker crew to safely clear the eye from the securing point using a winch and the messenger line. The towline should then be payed out through the fairlead in a controlled manner to the tug to avoid flailing the towline end.

Unplanned or emergency release of the towline by the tug could endanger the tanker's manoeuvrability if the towline drops around the tanker's propeller or drags along the seabed.

It may therefore be necessary to disconnect the towline while it is under load. This is most likely to happen in pull-back operations at terminals with limited facilities and with rapidly changing environmental conditions. A risk assessment should be conducted by the terminal to understand the likelihood of this happening.

Emergency disconnection of the towline may be appropriate in the following circumstances:

- The tug is unable to maintain station due to the rate of change of the tanker's heading.
- The tug's emergency release gear fails, or is accidentally activated.
- The tug is manoeuvring incorrectly, e.g. towing incorrectly due to human error.
- There is an emergency situation on the tug, e.g. girting or man overboard.

The use of any emergency disconnection equipment should be thoroughly risk assessed and address safety aspects and risks to all personnel and assets (tanker, tug and terminal) involved in the operation. Terminal senior management should take part in in the risk assessment, which should clarify whose responsibility it is to use such equipment, and be used to develop appropriate written procedures.

Additional guidance on this equipment can be found in *Guidelines for Offshore Tanker Operations*.

4.6 - Transits of canals and waterways

The authorities overseeing major canals and waterways often have specific requirements for the placing, size and strength of mooring equipment to meet their operational requirements for safe and efficient transit. These requirements may include very specialised equipment in some places, e.g. in locks. Meeting these requirements will be part of the appropriate ship certification process. If not addressed at build these requirements may lead to substantial retrofitting of appropriate equipment.

Shipyards, designers and ship operators are recommended to integrate such requirements into the ship design, unless the operator is sure that such canals and waterways will not be part of the ship's trading pattern. However, some of the simpler requirements may include additional mooring lines that can be purchased at an appropriate future date (to avoid unnecessary degradation while in long term storage). However, the selection of additional mooring lines should still be included within the mooring assessment and follow the same criteria as for the other mooring lines on board.

The appropriate authorities, e.g. Panama Canal, Suez Canal, St Lawrence Seaway, etc., will be able to supply the latest requirements.

It is recommended that where there is potential conflict between various local rules, or between local rules and the guidance in this publication, ships should be fitted with equipment to meet the most onerous of all recommendations and requirements.

4.7 - Emergency tow-off pennants

OCIMF does not support the use of emergency tow-off pennants although some terminals may still require such lines, often known as fire wires, to be provided when tankers are moored alongside.

Any requirements for emergency tow-off pennants should be subject to review and risk analysis by terminals to determine whether or not there should be a requirement for ships to deploy them. Questions that should be asked include:

- Are emergency tow-off pennants really necessary and what is the possibility of them being used?
- Do the terminal emergency procedures require a ship to be removed from the berth if it is immobilised by fire?
- Is it possible to release the ship moorings to permit the ship to be removed from the berth?
- How long will it take for tugs to be mobilised?
- Could the deployment of emergency tow-off pennants compromise security arrangements for the ship and terminal?
- What personnel resources are available on the ship and at the terminal to allow it to be safely removed from the berth in an emergency?

Some terminals require different methods and operators should be aware of local requirements.

4.8 - Barge and small ship mooring

In many cases, barges and small ships can be moored with fittings provided for other mooring requirements. However, some VLCCs and ULCCs lack suitable fittings for mooring barges and small ships alongside the amidships manifold, or the aft bunker manifold if fitted. In these cases, it is recommended that a set of closed fairleads and bitts be provided, port and starboard, about 35m forward and aft of the amidships manifold and, where appropriate, the aft bunker manifold.

Figure 4.14: *Example of small ship (bunker barge) moored alongside a larger tanker*

4.9 - Ship to ship transfers

4.9.1 General

When organisers are planning an STS transfer operation they should ensure that the ships to be used are compatible in design and equipment. Ship designers should take into consideration that every tanker may be nominated at some point for an STS.

All mooring lines should be deployed from winch drums and lines should not be turned up on bitts.

4.9.2 Mooring arrangement versatility

Regardless of the size of the ship, the most versatile and effective STS mooring arrangement is to put bitts on either end of each deck space and align each winch so that the mooring lines on drums are deployed away from incoming mooring lines to the bitts. This should enable the best combination of mooring lines and minimise the need to cross mooring lines (see figure 4.15).

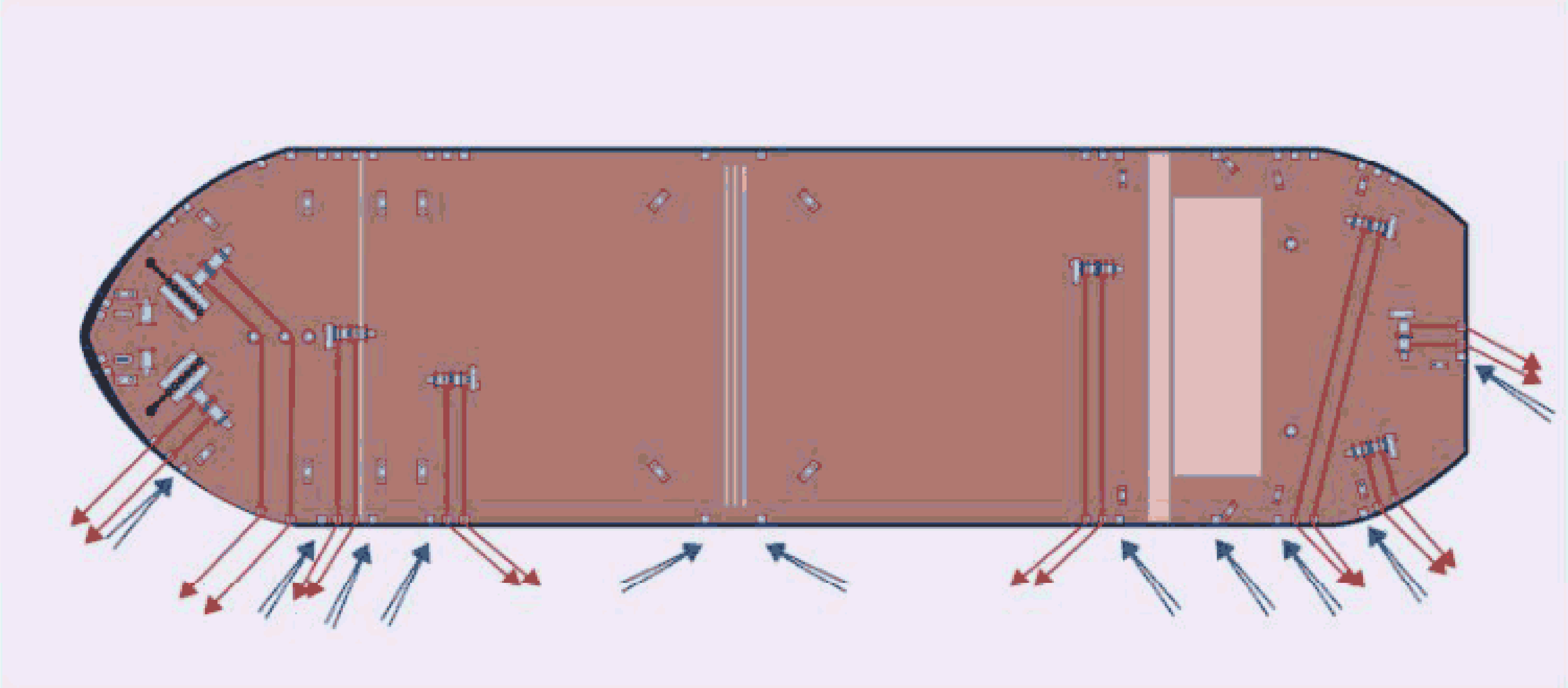

Figure 4.15: *Positioning of bitts and winches. The red lines are winch mounted to the other ship and the blue lines are on bitts and from the other ship*

It is also recommended that the bitts serving the forward spring winch are placed forward of the winch so that they can be used for mooring lines from the other ship. Bitts serving the aft spring winch should be placed aft of the winch to accommodate an additional set of mooring lines. Positioning of warping drums should be aligned with the bitts.

4.9.3 Forecastle arrangements

An effective forecastle mooring arrangement is important, especially when the ships remain anchored during STS cargo transfers. A large number of fairleads and bitts with good leads available on the forecastle will improve the possibilities of an effective mooring.

For smaller ships, there should be at least two sets of closed fairleads and bitts on each side of the forecastle and at least one set of bitts serving the bow mooring fairlead at the bow centre (see figure 4.16).

Larger ships with an additional breast winch should have at least three sets of bitts and closed fairleads on each side and at least two sets of bitts and bow mooring fairleads at the bow centre (see figure 4.17).

For bow loading tankers, a set of bitts should be considered forward of the windlasses on the port and starboard side instead of centreline bitts (see figure 4.18).

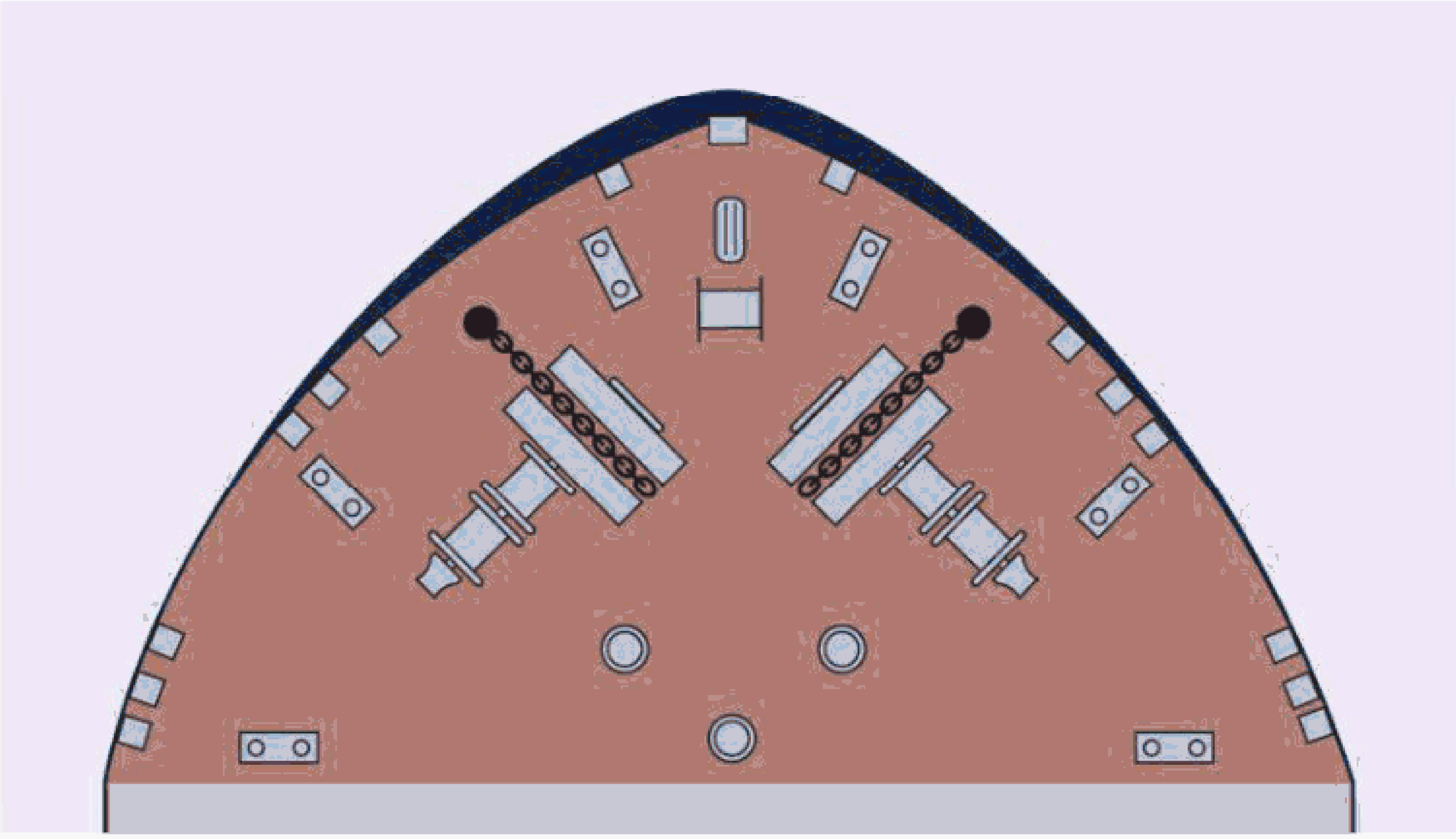

Figure 4.16: *A forecastle mooring arrangement for smaller ships*

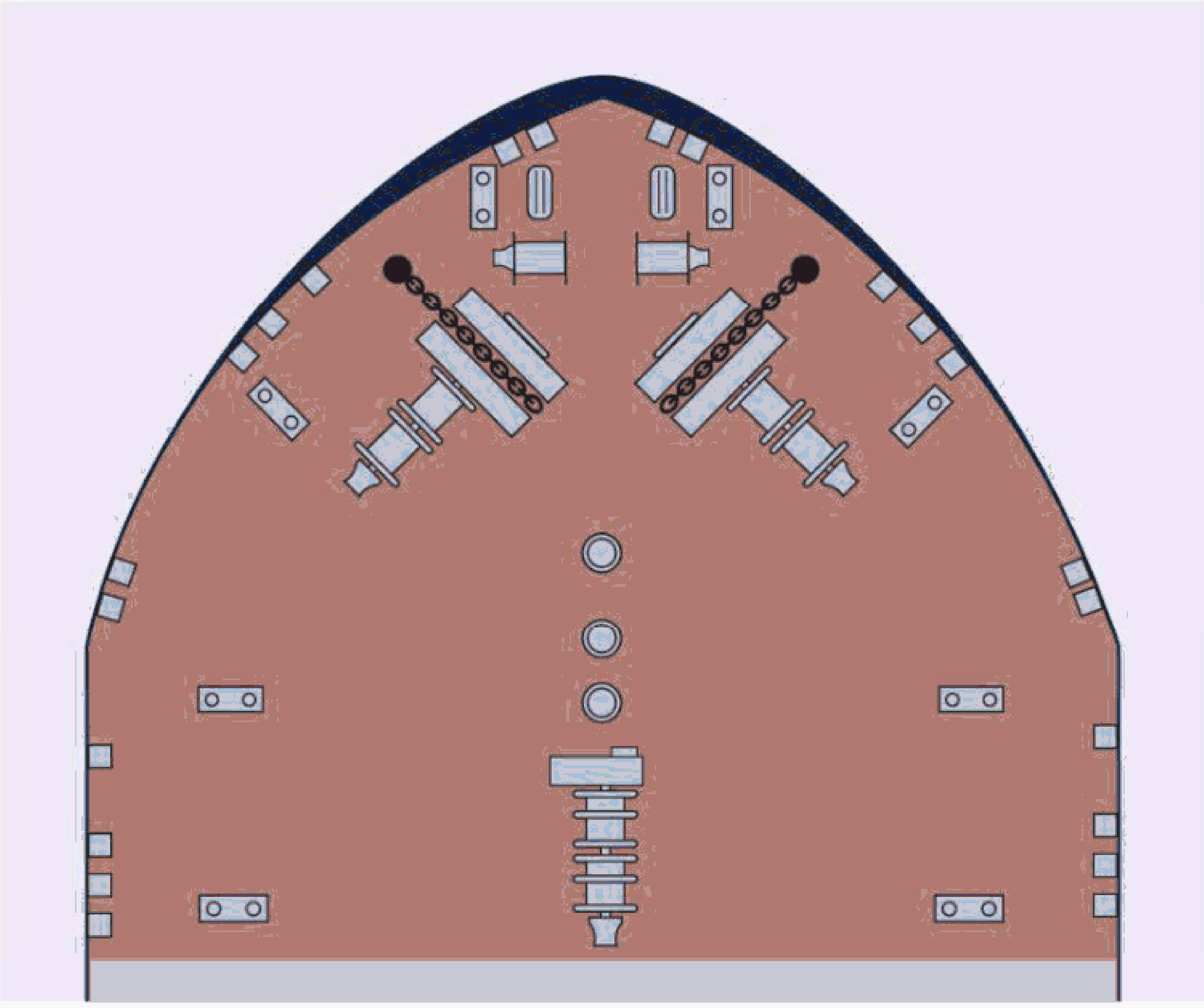

Figure 4.17: *A forecastle mooring arrangement for larger ships*

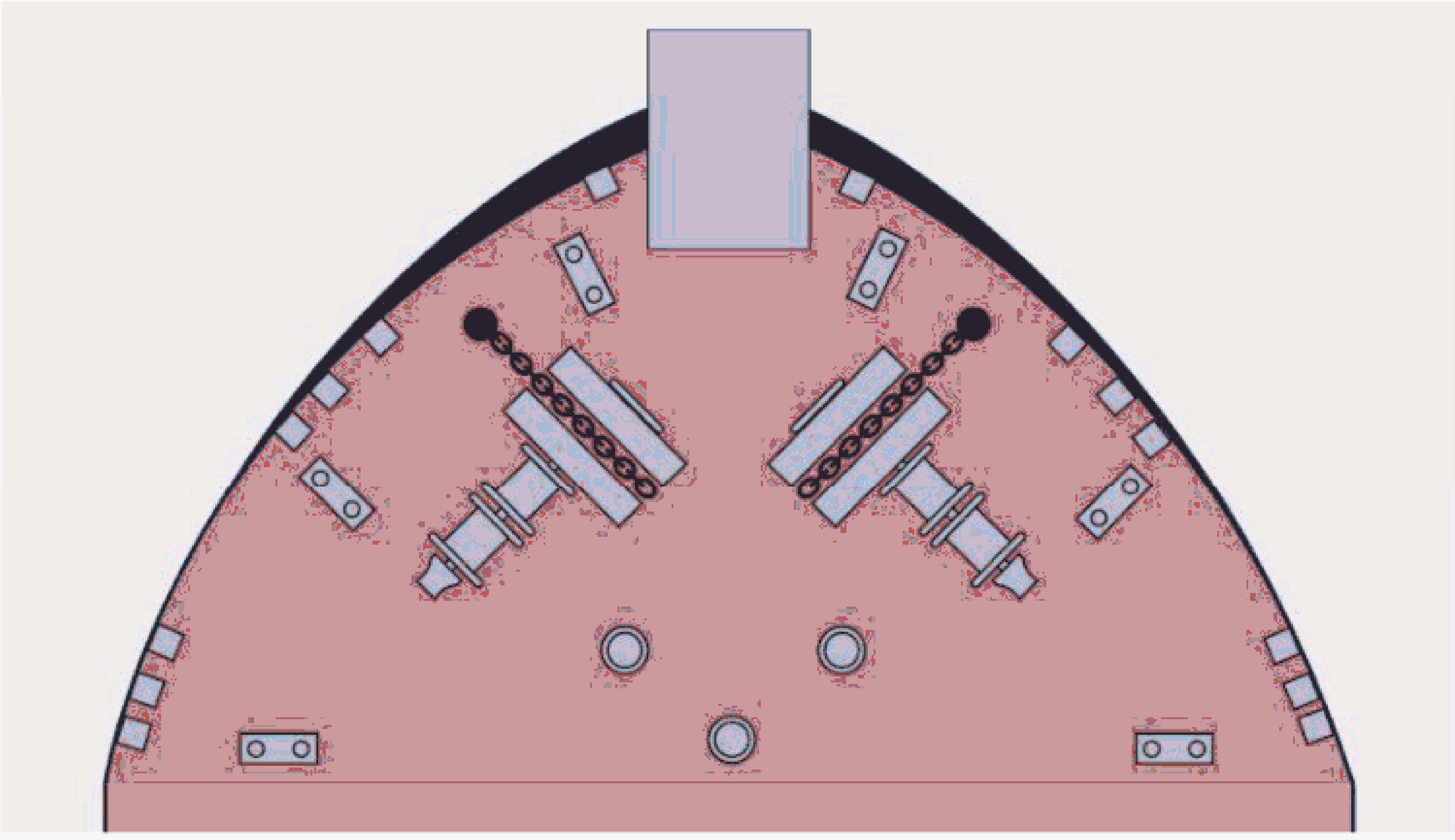

Figure 4.18: *Effective forecastle mooring arrangement for bow loading tankers*

4.9.4 Symmetrical design

In most STS transfers the larger ship is the stand-on ship. The stand-on ship maintains a constant heading and speed or remains at anchor while the smaller manoeuvring ship approaches with its port side to the starboard side of the stand-on ship. It is common for ships to be fitted with STS fairleads and bitts on one side only, but this does not take into consideration those operations where approach is made on the opposite side. For example, a VLCC is normally expected to be the stand-on ship so it is common for these ships to have fairleads and bitts just forward and aft of the manifold to accommodate spring mooring lines on the starboard side only. But in double-banking operations where the VLCC is moored to dolphins on the starboard side, the manoeuvring ship must moor to the VLCC's port side where there are no fairleads and bitts to accommodate the spring mooring lines. It is recommended that fairleads and bitts are arranged symmetrically so that ships are not restricted to mooring operations on one side only (see figure 4.19).

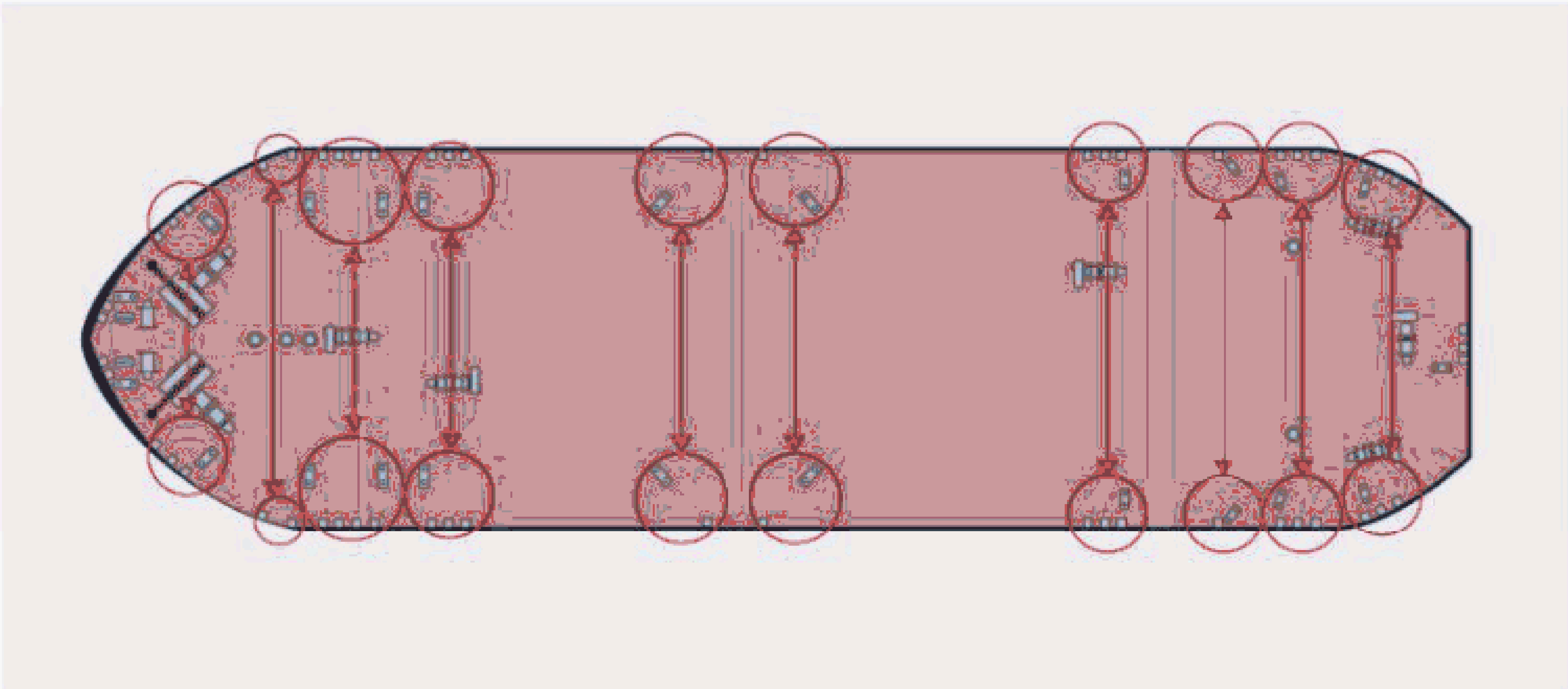

Figure 4.19: *In this arrangement, the fairleads and bitts are arranged symmetrically. The ship is suitable as either the stand-on or the manoeuvring ship on both sides*

4.9.5 Fairleads for secondary fenders

Secondary fenders are used to protect the bow and stern plating from contact if the ships get out of alignment during approach and separation. Any contact is likely to occur on the manoeuvring ship's side where the parallel body ends and the curve toward the bow and stern begins.

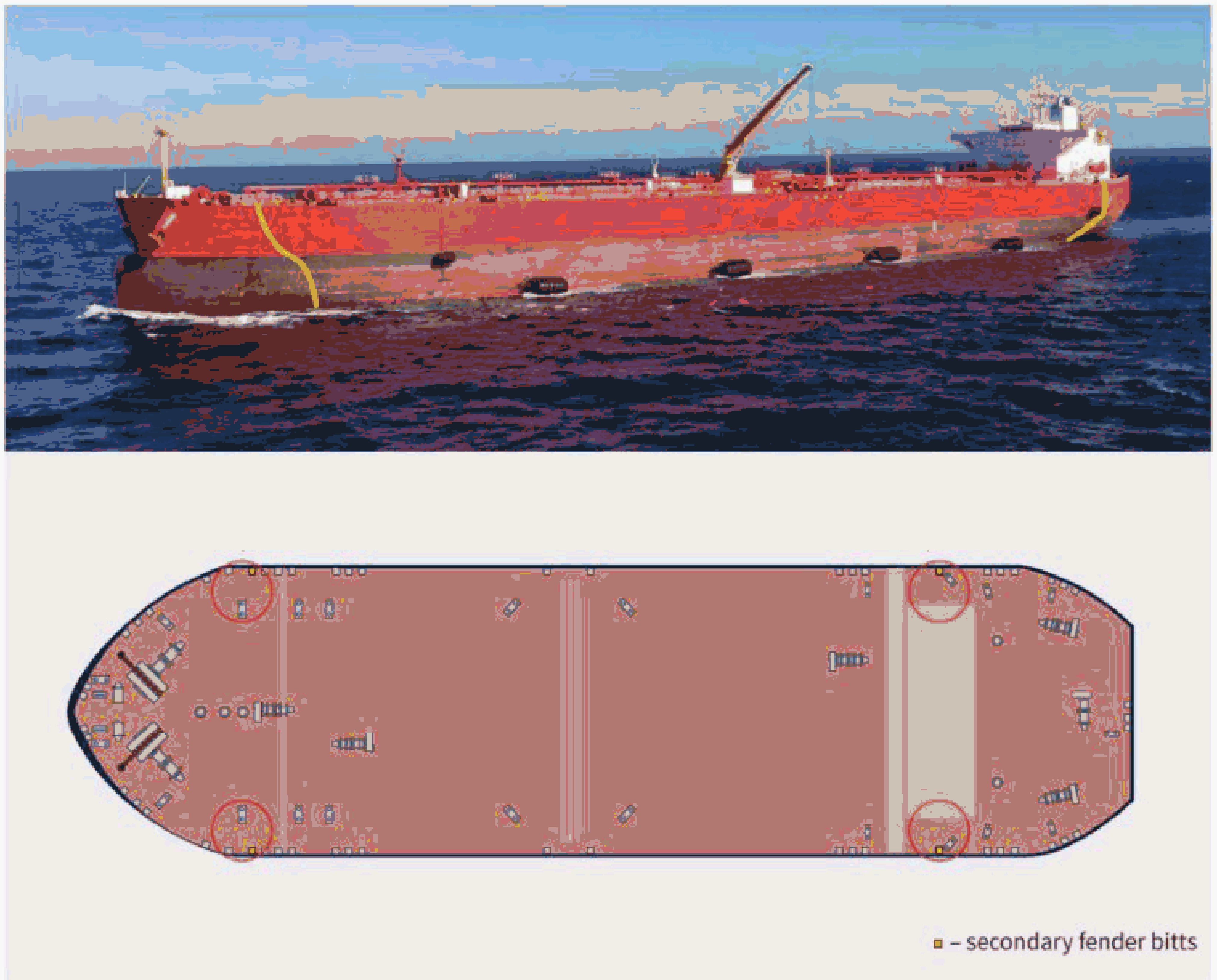

Figure 4.20: *Use of bitts to secure secondary fenders*

It is recommended that ships are fitted with a fairlead and bollard located at the beginning and end of the parallel mid-body along the deck edge. Symmetrical design is important as a ship could be employed as a manoeuvring ship or as the stand-on ship. There are cases where the design of the ship requires additional fendering, e.g. extreme flares. Figure 4.20 shows the relative positions of bitts and secondary fenders in plan view (red circles) and in elevation (at top and bottom of yellow lines).

4.9.6 Spring mooring lines

In general, long mooring lines are preferred for STS. It is recommended that all tankers are fitted with full-sized bitts and closed fairleads as close as practical to the forward and aft ends of the manifold, without interfering with safe hose handling operations. Ideally this distance would be within two to five metres of the manifold rail.

Spring winches should be located as far forward on the main deck for increased length of spring mooring lines. These recommendations are particularly important when the two ships engaged in STS operations are of similar length.

4.9.7 Closed fairleads

Closed (Panama style) fairleads are the most suitable for STS mooring because they ensure effective control of mooring lines as the freeboards of the two ships change, and have the greatest D/d ratio of standard fittings.

Open type roller fairleads are not recommended for STS mooring because the changes in the relative freeboard of the two tankers may allow an upward line lead, with risk of the line jumping out of the fairlead.

Universal roller fairleads can often present a number of challenges for STS operations. On the forecastle, universal fairleads are often built into the bulwark and are designed to lead mooring lines downward. In STS transfers where the freeboards of the two ships change, mooring lines will likely lead upward during some of the transfer. Because these fairleads are not designed for lines to lead upward, mooring lines can make contact with the upper support structure and are susceptible to chafing (see figure 4.21).

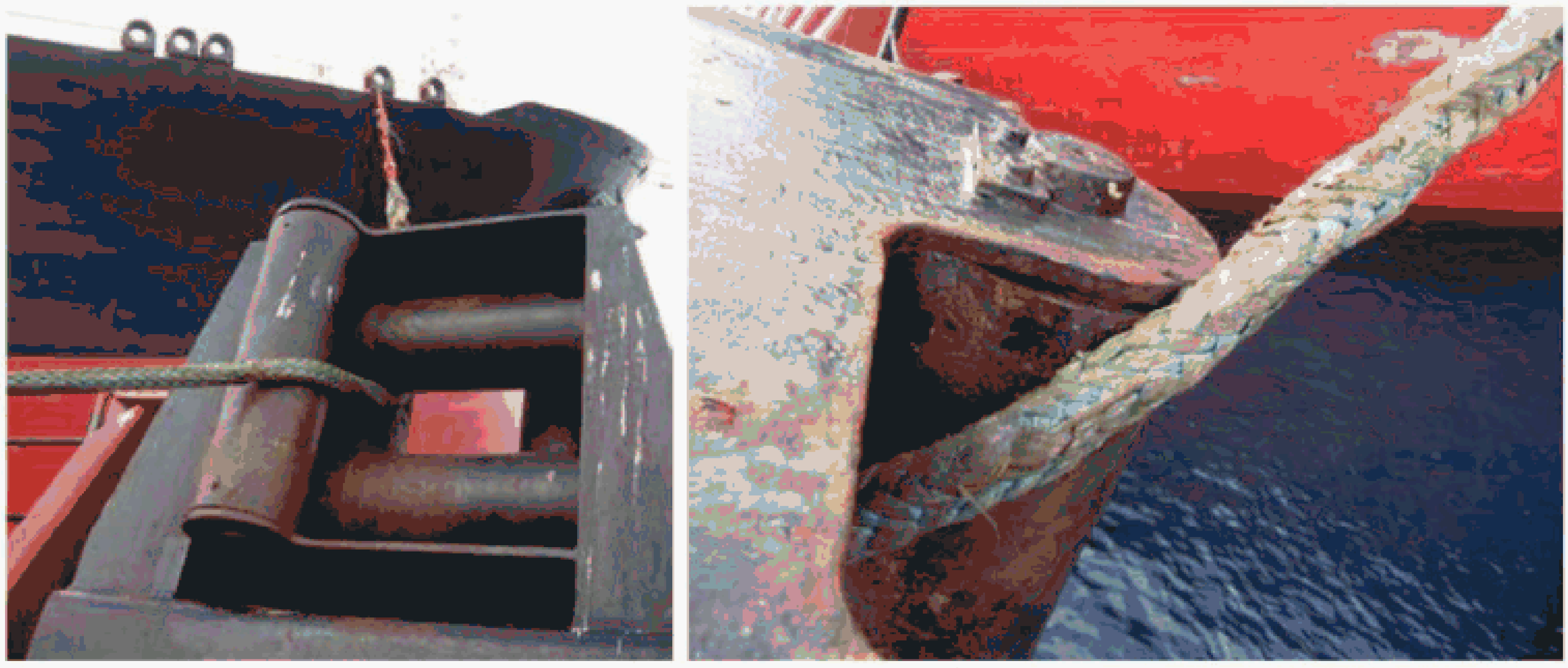

Figure 4.21: *A universal closed fairlead leading a mooring line upward. The mooring line contacts the fairlead structure in two places*

Some ships have the gutterplate (or fishplate) situated outboard of the fairleads. This should be avoided as mooring lines that lead in a downward direction will cross over the sharp edge of the fishplate, which will lead to chafing, strength reduction due to bending and potential line failure.

4.9.8 Cross-deck mooring lines on the forecastle

In STS operations both ships are expected to deploy mooring lines. In order to achieve the greatest flexibility and compatibility, ship mooring arrangements should be designed to make use of all available lines. It is not recommended for mooring lines to curve around the bow, so it is important that winches on the offshore side of the ships are capable of having their mooring lines led across the deck. This is accomplished with roller pedestals positioned to lead mooring lines through dedicated fairleads on either side of the ship (see figure 4.22).

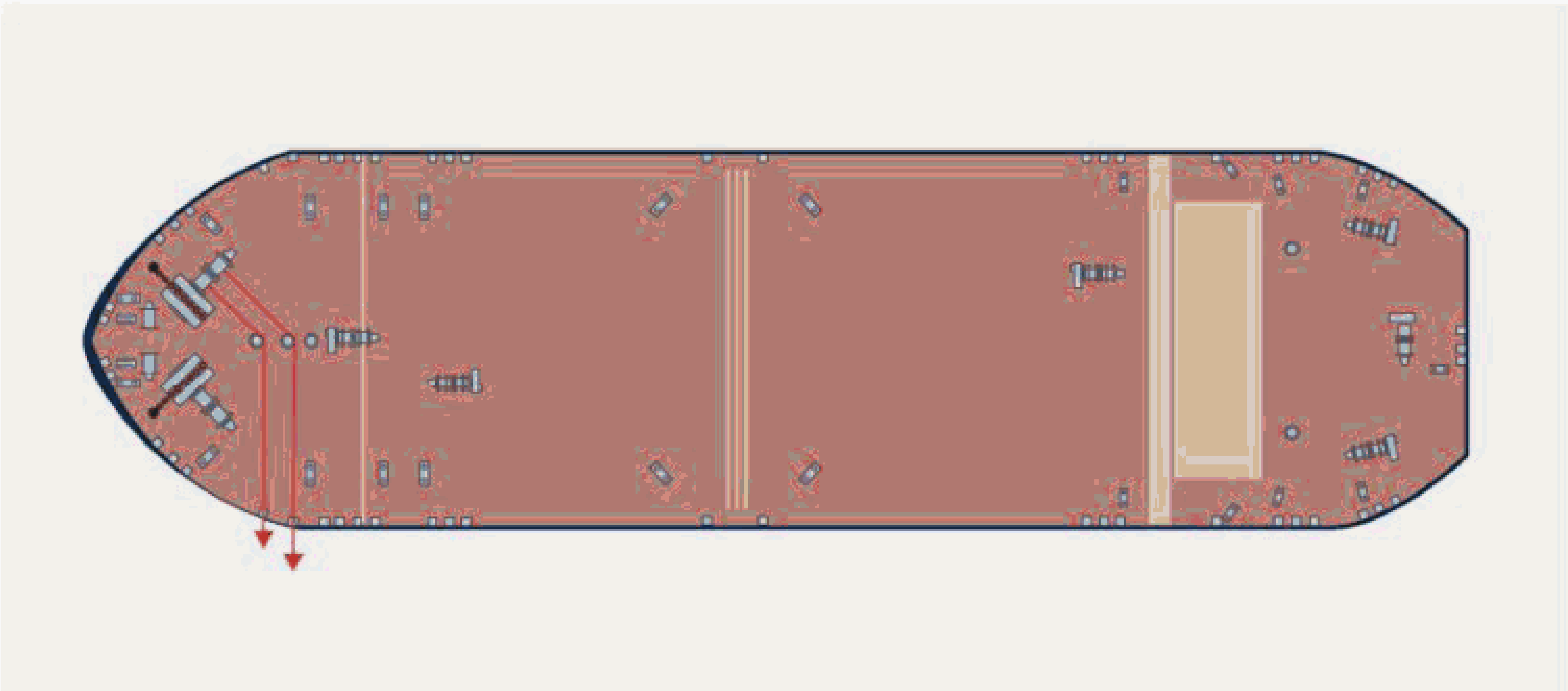

Figure 4.22: *Cross-deck mooring lines needing pedestal rollers*

4.9.9 Crossing stern winches

It is also useful to have stern winches with mooring lines that cross the stern. This enables the port winch mooring lines to be led through fairleads on the starboard side and starboard winch mooring lines to be led through fairleads on the port side (see figure 4.23). This is particularly useful when sending mooring lines to a similar sized ship or to a smaller ship. Lines leading directly aft through fairleads on the transom should not be used as mooring lines to similar sized ships or to smaller ships (see figure 4.24).

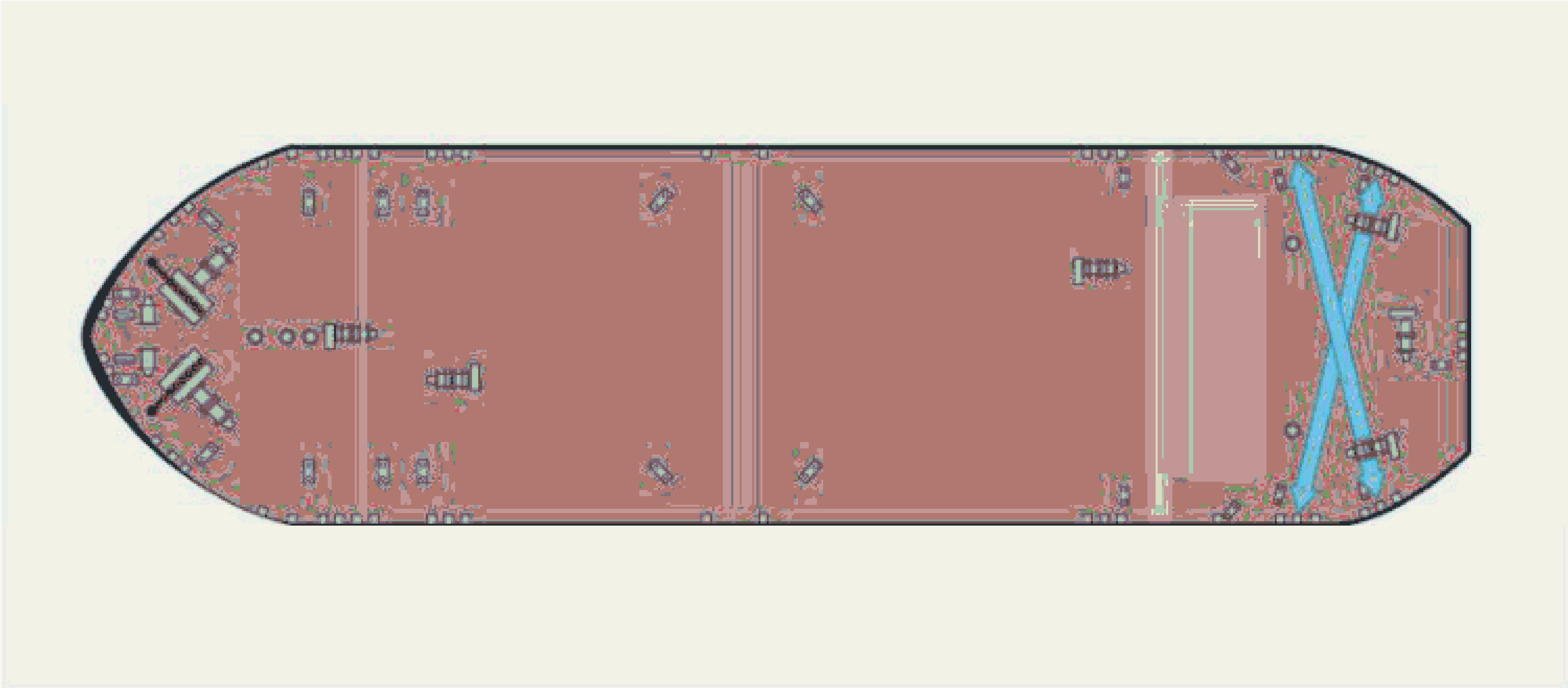

Figure 4.23: *Crossing of stern mooring lines direct to fairleads*

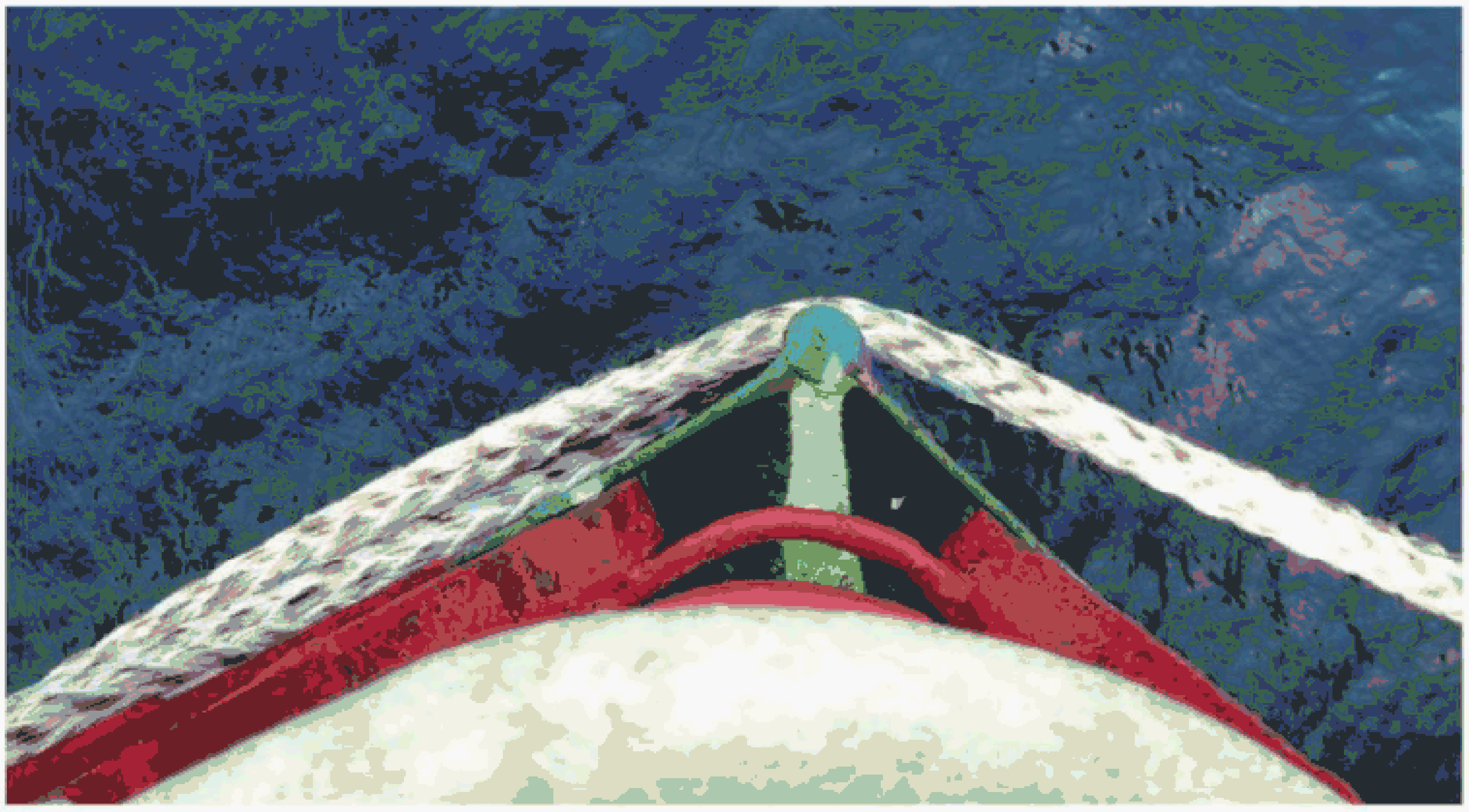

Figure 4.24: *Mooring lines sent forward from an aft facing fairlead to a smaller ship. These lines will be damaged as they turn around the quarter*

4.9.10 Warping drums, split drums, double-drums and capstans

Ships engaged in STS operations are expected to send and receive mooring lines. In order to receive mooring lines safely and efficiently, each winch should have a warping drum or have an empty drum to pull in the line from the other ship.

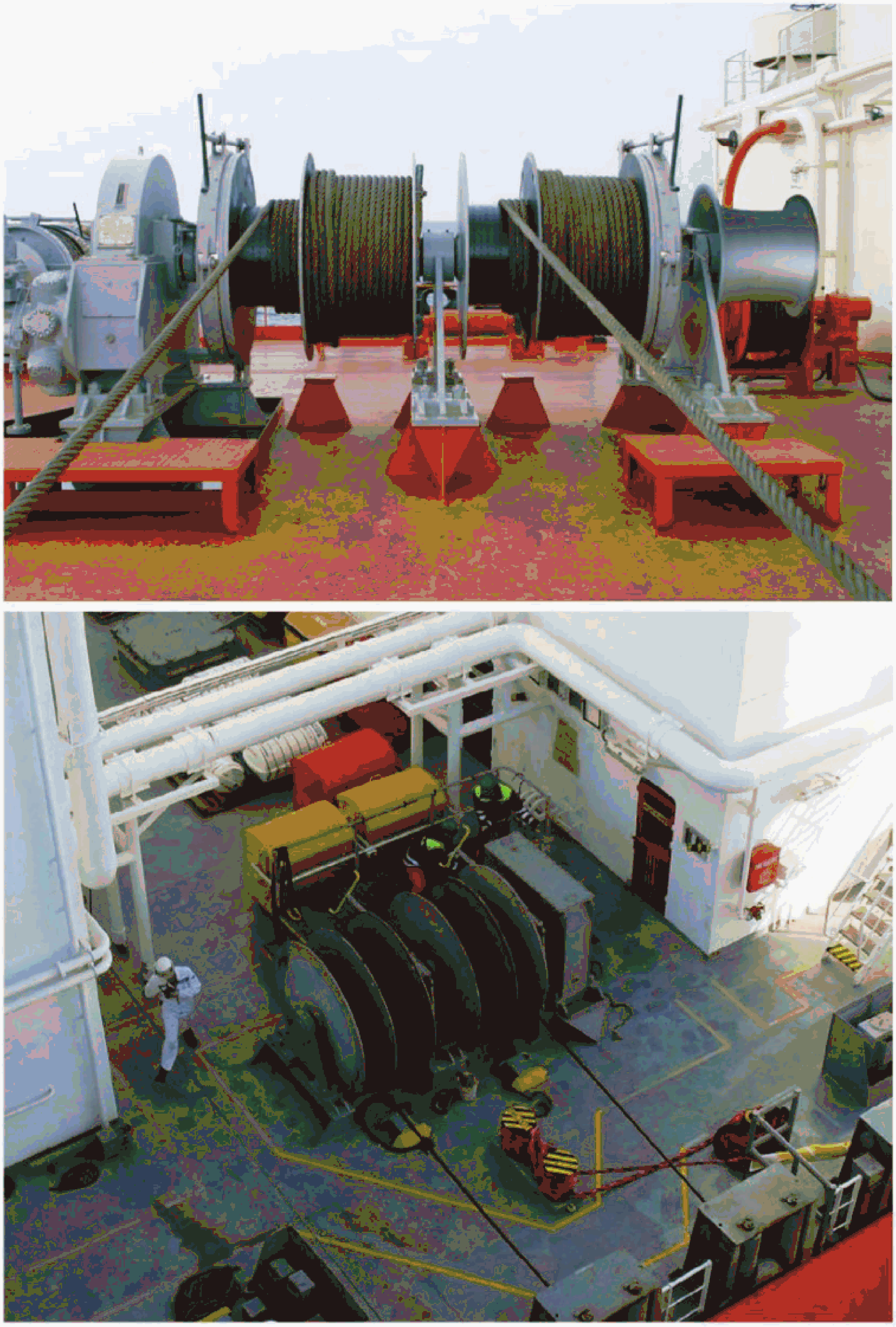

Figure 4.25: *A winch fitted with a warping drum and split drums (above) and a winch fitted without a warping drum (below)*

It is recommended that all winches, especially spring winches, should be in pairs or at least be fitted with double-drums so that two spring mooring lines can be deployed effectively. Some smaller ships have only a single winch in each location, which may not enable the desired redundancy.

Deck mounted small capstans are typically inadequate for full size line handling, particularly if they are spring mooring lines. Ship designers should consider the limitations of these capstans and make provision to lead a messenger to a winch fitted with a warping drum. Leads should have a direct line from fairlead via the bitt to be used to a winch drum without using a roller pedestal. If a roller pedestal is necessary, any change in line direction should be minimised.

4.10 - Arrangements at cargo manifolds

Deck fittings in the manifold area of oil tankers should be provided in accordance with OCIMF/CDI's *Recommendations for Oil and Chemical Tanker Manifolds and Associated Equipment* or SIGTTO/OCIMF's *Recommendations for Liquefied Gas Carrier Manifolds* . These fittings will include cruciform bollards, closed fairleads and mooring bitts that are intended to facilitate the hoisting and hanging of cargo hoses at sea berths.

The fittings provided at the manifold in accordance with the above publications are not intended for mooring operations. These fittings should not be used for mooring.

4.11 - Mooring augmentation in exceptional conditions

It is not practical to design all ships for the worst possible operating environment, as explained in section 3.2.3. Where the standard environmental criteria are exceeded, the ship should either leave the berth, get continuous tug assistance or arrange for additional mooring restraint.

4.11.1 Provision of shore moorings

Ships and berths are not normally designed for conditions above the standard environmental criteria (see section 3.2). When conditions exceed the standard environmental criteria, additional shore moorings may be provided to augment the ship mooring system. To receive these moorings on board, it is recommended that ships are provided with enough closed fairleads, bitts and warping drums to serve 1.5 times the standard number of mooring lines. The additional closed fairleads will usually be located next to the fairleads for the standard mooring lines. This allows shore lines to be brought aboard using the same winches as the standard mooring lines. The strength of the additional fairleads and bitts should be based on the ship design MBL of the ship's standard mooring lines.

Some ships (such as those that are externally framed) may have the mooring winch and drums mounted at a higher level than the deck on which the fairleads and bitts are sited. This multi-level arrangement is not recommended because, should secondary mooring lines from shore be required, the line may pass over the top of the bitt with a geometry that will not allow an effective stopper to be used in the securing process.

However, if the winch must be mounted at such a height, additional higher-level bitts and fairleads should be fitted, to allow the mooring line to be held correctly at an appropriate position to stopper off, make fast and lead to shore effectively and safely.

Horizontal side bars attached to the normal deck mounted bitts, or cruciform bitts should not be fitted or used. These attachments to the bitts are not covered by construction standards and the SWL cannot be known. There is a risk that mooring lines can slip off these fittings as the tension in the line changes.

4.12 - Combination of various requirements

The requirements set out in sections 4.2 to 4.9 may be combined during the design stage to reduce the complexity of the mooring arrangement. For example, the location of shipside fairleads may be slightly adjusted so that one fairlead or set of bitts can serve several requirements.

At the same time, all possible line leads for the various requirements should be considered without introducing potential problems from:

- Large changes of line angle.
- Inappropriate D/d ratios (see section five).

These factors may mean that additional separate fittings need to be provided, such as the installation of separate fittings for each mooring line type (steel wire rope or synthetic fibre). The strength of the fittings should be designed for the highest possible load that the fitting may experience.

4.13 - Equipment and fitting line-up with operational considerations

Mooring lines should lead from winch drums directly to the shipside fairlead. If the use of pedestal fairleads cannot be avoided, the change of angle for the line should be minimal and the winch controls should be located to minimise snap-back risk to the operator.

Equally, mooring fittings need adequate clearance for safe operations. Winches have to be arranged to provide an adequate fleet angle for the drum. This is the maximum angle the mooring line deviates from a direction perpendicular to the drum axis and is necessary to allow each turn to sit flush next to the previous turn and for each layer to lie cleanly on top of the previous layer. The following are basic guidelines.

The minimum distance between a fairlead and bitts should be 1.8m to provide adequate space for the application of mooring line stoppers.

The minimum distance between a winch drum and the nearest fairlead (deck edge or pedestal) should be such that the fleet angle does not exceed 1.5 degrees. This equates to approximately 19 times the drum width, if the mooring line rests in one position in the fairlead, e.g. in a pedestal fairlead. If the mooring line position in a fairlead is variable, e.g. in a deck edge closed fairlead, the distance should be increased to meet the 1.5 degrees requirement in any position. If the design results in fleet angles in excess of 1.5 degrees, powered spooling assistance should be considered.

In the case of split drum winches, only the tension part of the drum should be considered in establishing maximum fleet angles. Figure 4.26 shows the recommended line-up for split drum winches. The shaded area in figure 4.26 should be kept clear of any obstructions. This is because an unloaded mooring line may be paid out or heaved in directly from any part of either the tension or storage drum during the beginning and end of mooring operations.

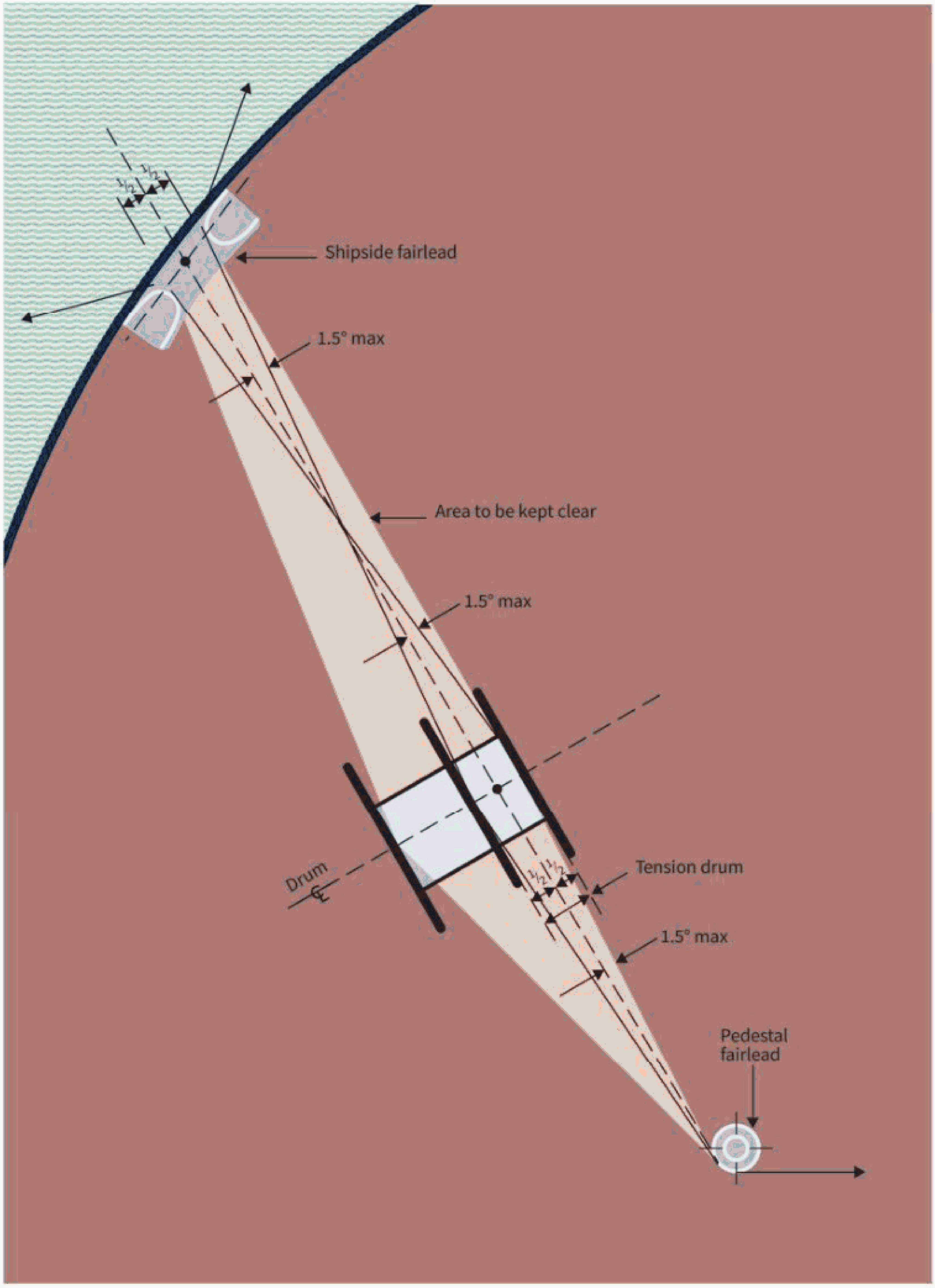

Figure 4.26: *Alignment and maximum fleet angle for mooring winches*

In the interest of safe and efficient mooring/unmooring operations, it is recommended that all mooring lines should be deployed from drums and consideration given to the provision of winches that have an individual drive for each drum without the need for clutching and declutching. This will eliminate the sometimes difficult task of clutching and declutching drums from a common drive shaft in combination with setting and releasing drum brakes. While it may be commonplace to have a winch motor drive more than one winch drum, more than two should be avoided because of the impact on redundancy and the complexity of the mooring arrangement in both normal and emergency operating modes.