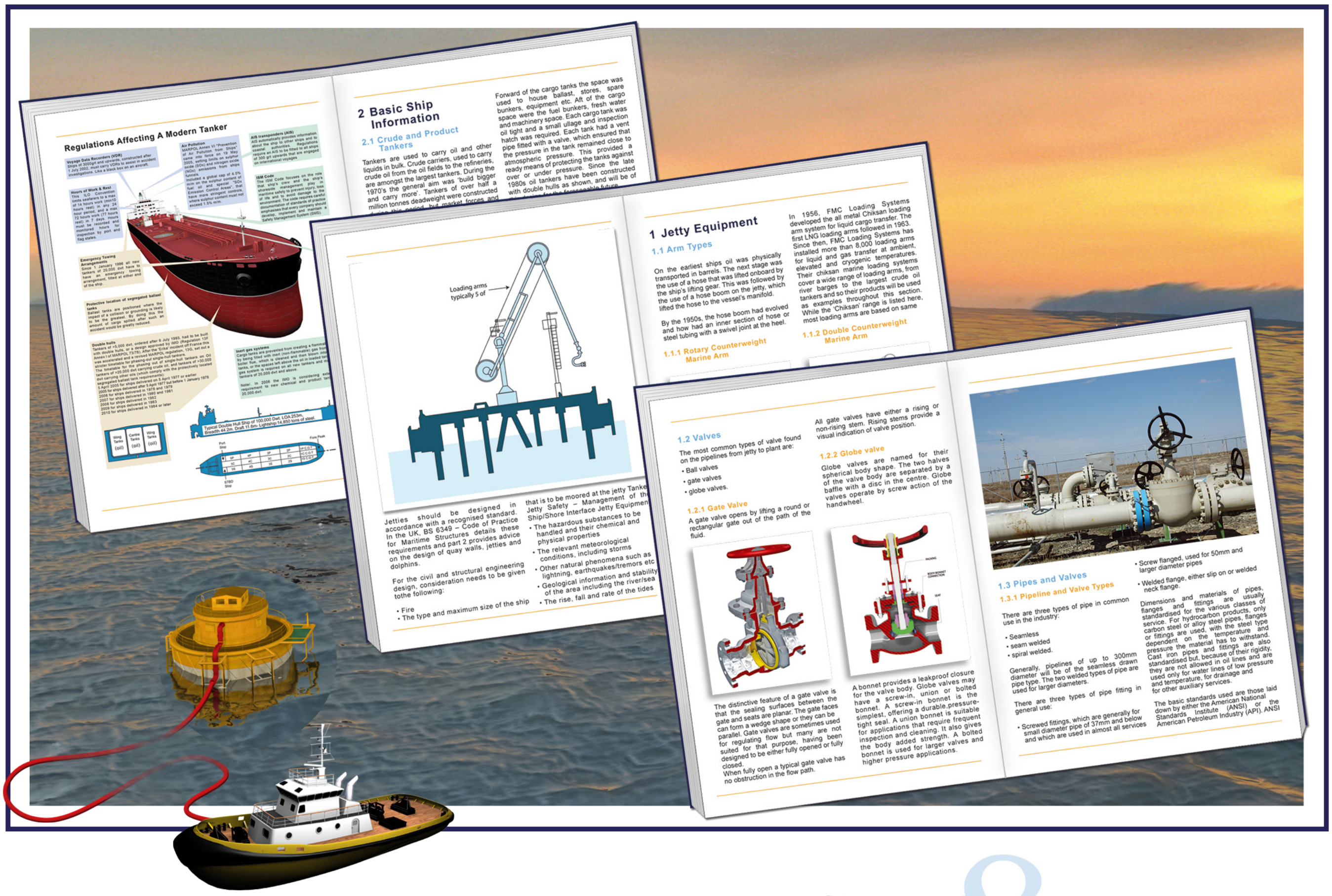
MOORING

a sample chapter taken from:

TANKER JETTY SAFETY

Management of the Ship/Shore Interface



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Mooring

Section 3

3 Mooring

The operations associated with berthing a ship alongside a berth or jetty are generally regarded as the ship's responsibility.

A properly moored ship is the most important requirement for safe terminal operations as securing the ship alongside for the duration is fundamental to prevent any strain on the cargo transfer equipment.

Securing alongside is affected by the external forces on the ship and this chapter of the book looks at them in more detail.

The mooring layout for all classes of ship, that the berth is designed to accommodate, is the responsibility of the terminal.

The terminal will understand the design characteristics of the mooring equipment installed, its location and the loads it can withstand and they will also be aware of the prevailing environmental conditions. Therefore, it is the terminal's responsibility to give the arriving ship all necessary information to optimise the distribution, heading and number of mooring lines used. This ensures a fully balanced mooring pattern, with loads evenly shared by all mooring lines.

The terminal will prepare an optimum mooring layout for each class of ship expected to visit. It describes the standard mooring requirements and possible alternatives for circumstances where the mooring equipment of the ship does not meet the standards.

Figure 3.1 – LNG Carrier Approaching the Berth at Cove Point

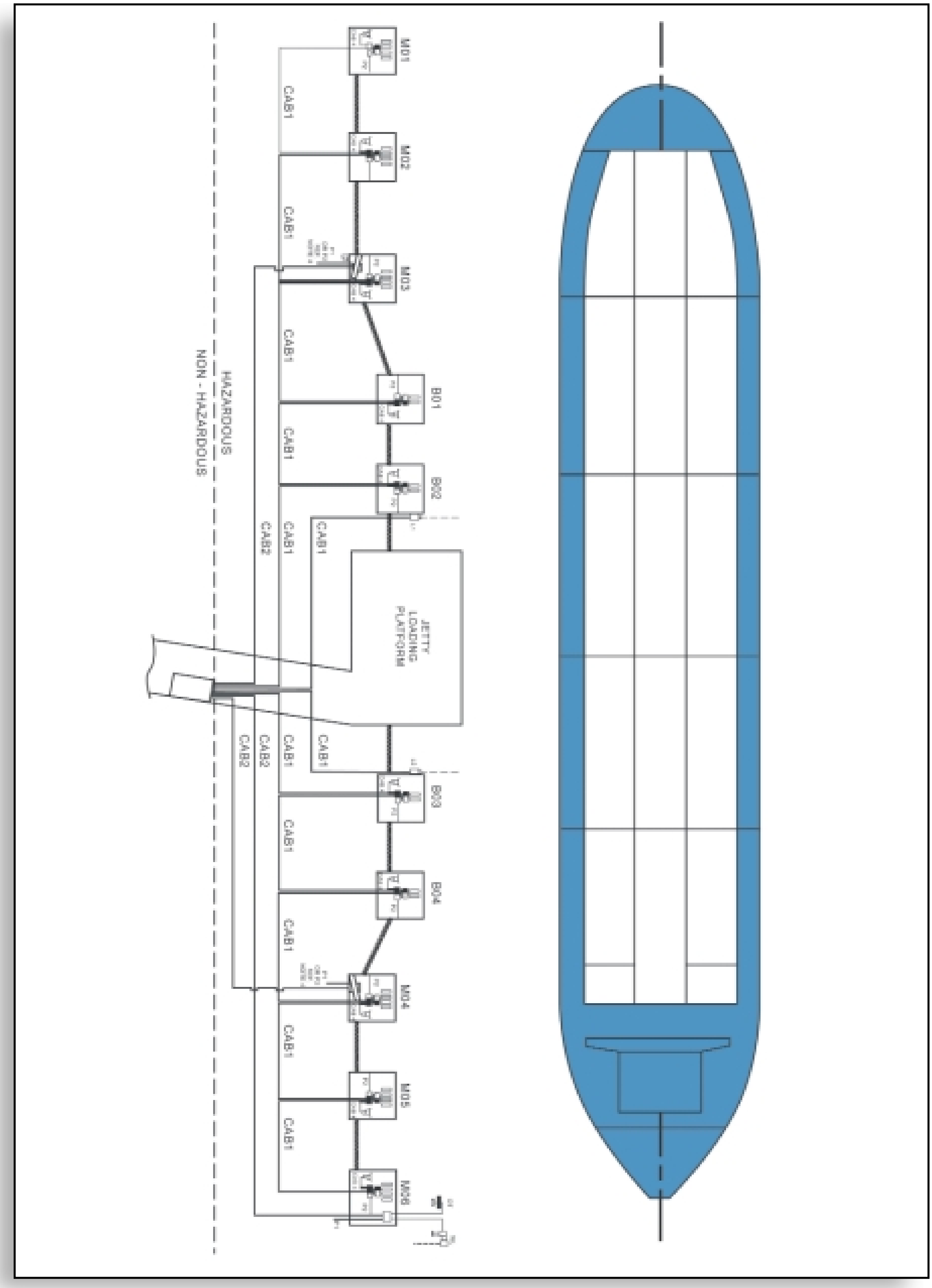


Figure 3.2 – Tanker Jetty Arrangement

> ***It is the Master's responsibility to ensure that the ship is moored to the suggested pattern. However, it is always a joint ship/shore effort to ensure that the ship remains secured alongside for the duration.***

There are a number of general principles that govern the restraint capability of a mooring pattern at a conventional pier. These, along with some guidelines for achieving an efficient mooring arrangement, are outlined in the following sections.

3.1 Mooring Forces

In the past, mooring arrangements were generally devised on the basis of operating experience. It was, and still is in many instances, common practice to run out the full complement of mooring lines carried onboard the ship.

Ships rarely broke out of these moorings, not because the mooring pattern was efficient, but because the ship was over-moored.

A ship's moorings must resist the large number of forces that are exerted on the ship, both environmental and operational. Failure of the moorings can result in damage to the ship and berth and injury to personnel.

The goal when berthing is the optimisation of the mooring arrangement to resist the applied forces. This problem is resolved by considering the following:

- What forces will the ship be subject to at this particular berth
- what will be the effect of these forces on the mooring lines
- what mooring arrangement is required to counteract these forces?

The forces acting on a moored vessel are both environmental and operational. Environmental forces are caused by natural phenomena such as wind, waves, currents and tides. Operational forces include those caused by passing ships, changes in the vessel trim, freeboard or draught and mooring line over-tension. The feature that distinguishes the operational forces from the environmental forces is that ship's personnel will generally have some level of control over the operational forces. However, a ship must be moored to resist whatever severity of environmental forces exist, and these are not controllable.

3.1.1 Wind and Current

In protected harbours the major sources of environmental force are the wind and

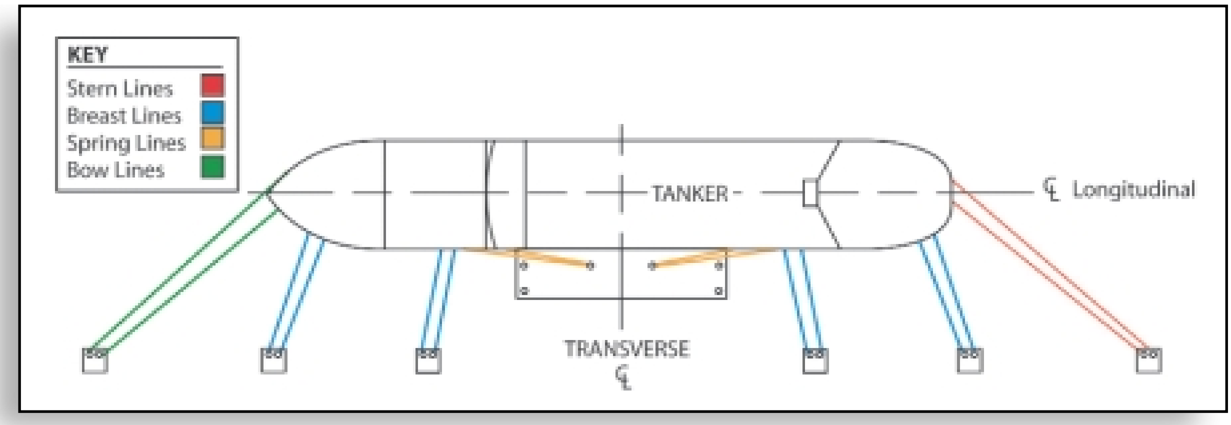
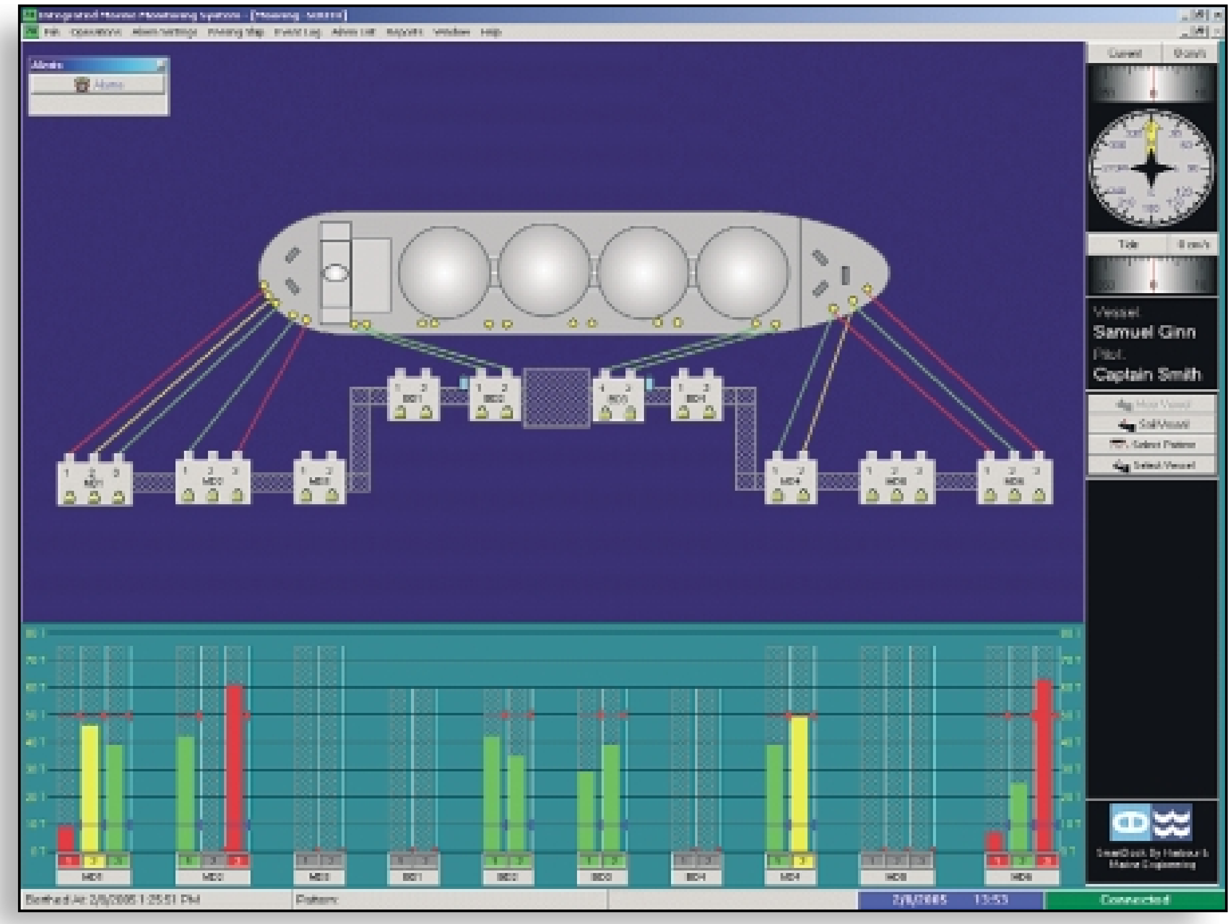


Figure 3.3 – Shows an Optimised Mooring Arrangement



Vessel
Samuel Ginn
Pilot
Captain Smith

Berthed At: 2/8/2005 1:25:51 PM

Pattern:

2/8/2005 13:53

Connected

Figure 3.4 – Mooring Load Monitoring
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current. Normally, in such areas ships are moored at conventional pier facilities.

The magnitude of the wind force acting on a ship is influenced by the velocity of the wind and the area of the ship that is exposed it. The force effect of the wind will double as the exposed ship area doubles. The ship is least susceptible to wind forces when it heads into the wind and is low in the water, such as when fully laden.

A tanker is exposed to the highest wind forces when the wind strikes the ship abeam while it is in a ballast or light condition.

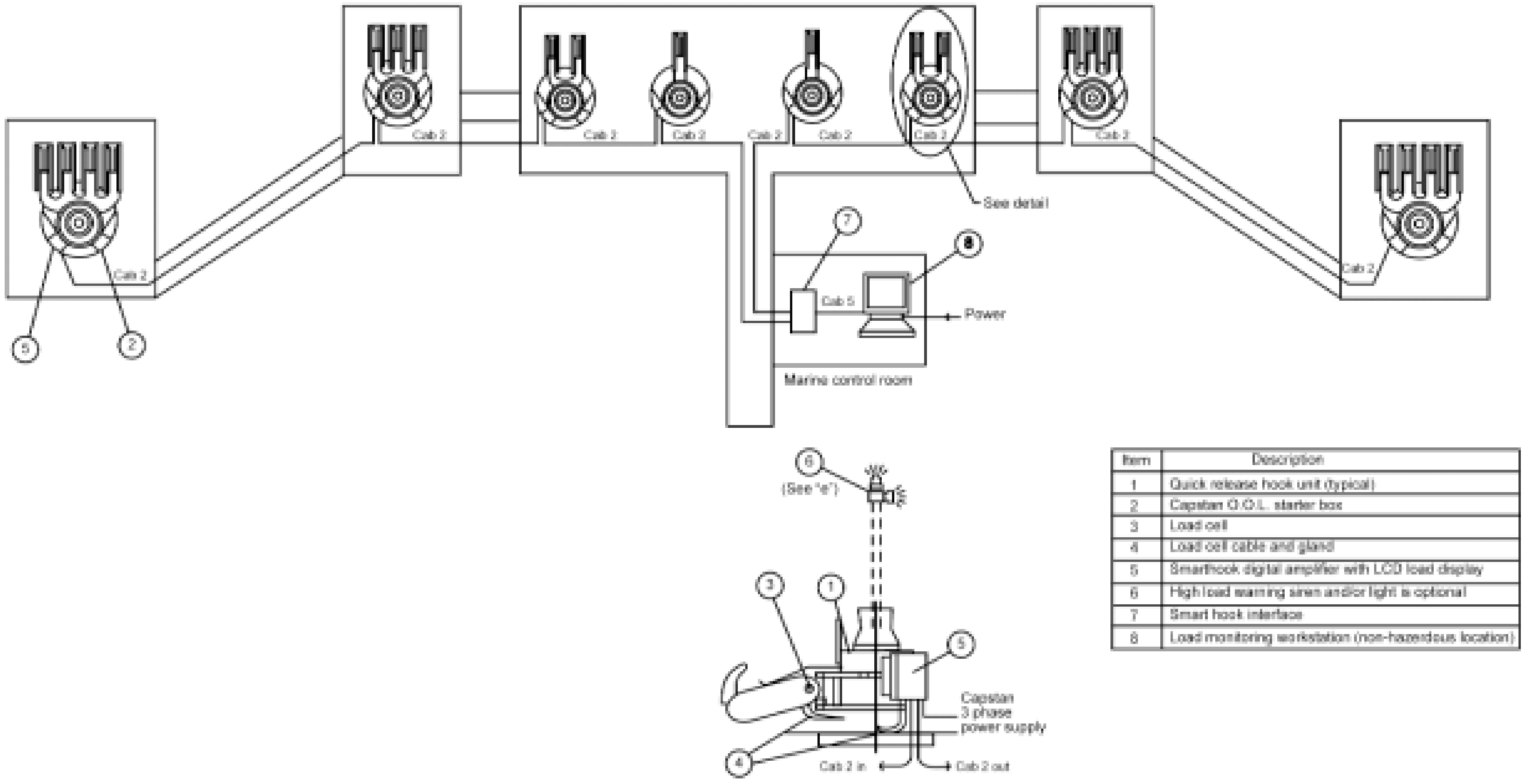
3.1.1.1 Wind

The force effect of wind is greater on a large ship than on a small ship in a similarly loaded condition as it has more exposed area.

Figure 3.6 demonstrates how the wind force of a tanker varies with wind velocity and direction. Wind forces on a tanker can be broken down into two components:

- Longitudinal force acting parallel to the longitudinal axis of the tanker
- transverse force acting perpendicular to the longitudinal axis.

The magnitude of wind force effect on the ship correlates to the square of the velocity. If the wind velocity doubles, the force due to



Item	Description
1	Quick release hook unit (typical)
2	Capstan O.O.L. starter box
3	Load cell
4	Load cell cable and gland
5	Smarthook digital amplifier with LCD load display
6	High load warning siren and/or light is optional
7	Smart hook interface
8	Load monitoring workstation (non-hazardous location)

Figure 3.5 – Quick Release Schematic

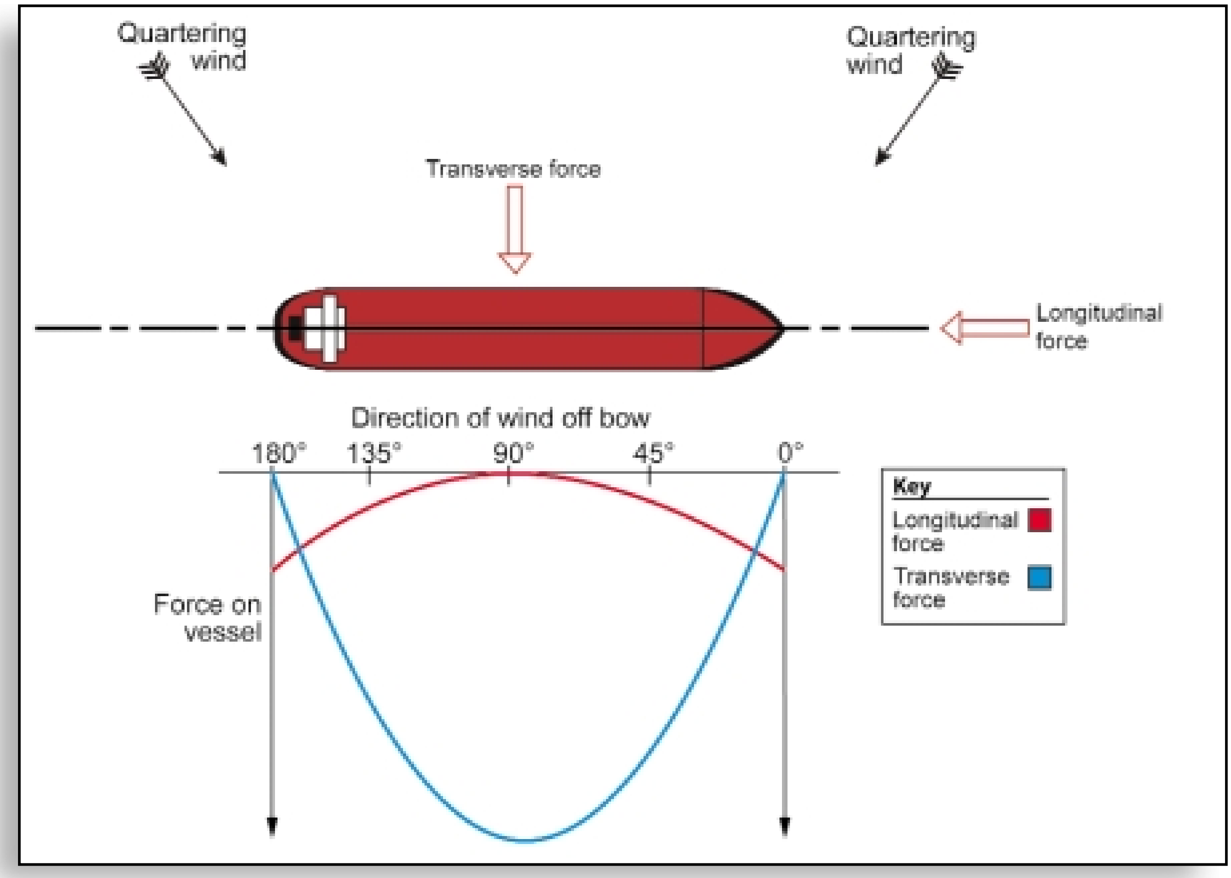


Figure 3.6 – Wind and Current Forces

wind will be four times greater. If the velocity triples, the wind force will be nine times greater.

Other factors that contribute to the magnitude of the wind force include the shape of the area on which the wind is acting and the angle at which the wind strikes the surface. However, such effects are complicated and, while important to the terminal designer, are of limited use onboard a ship when evaluating the effect of wind.

Though wind velocity can disturb a ship at a berth, it is the sudden squall increase of force associated with a dramatic change of direction that can be most dangerous.

3.1.1.2 Current

Water current force considerations are similar to those of wind force. The magnitude of current forces on a ship depends on the velocity of the current, the hull area exposed to the current and the underkeel clearance of the vessel.

As with wind, current forces are directly related to the area of the ship exposed to them. The maximum force of the current will be experienced when the vessel is in a loaded condition and the current is acting directly on the beam. The force is minimised if the ship is light in the water and its bow is headed into the current.

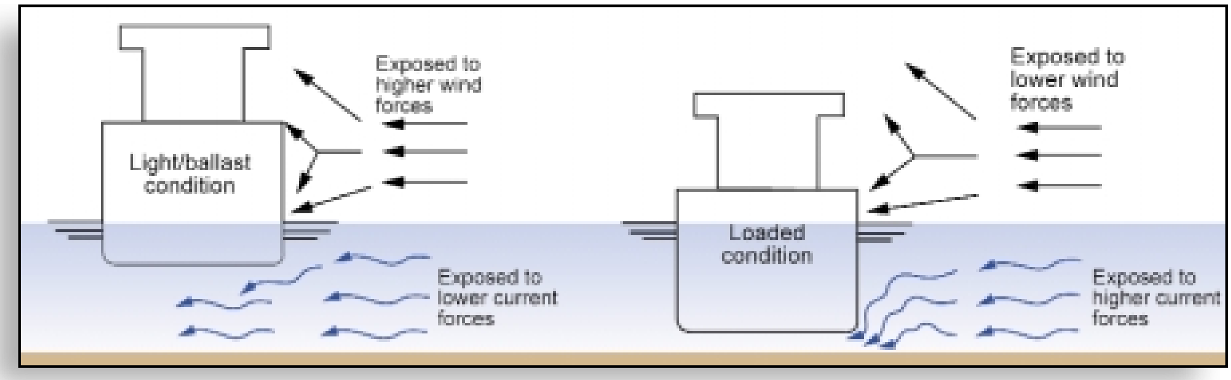


Figure 3.7 – Effect of Wind/current Forces on a Ship in Light/loaded Condition

The depth of the water under the keel greatly affects current forces. As the clearance under the keel decreases, the forces due to currents increase. The magnitude of current force can be three times as great on vessels with very small underkeel clearances than for vessels in deepwater.

Current force increases with the square of the current velocity. If the current velocity doubles, the current force is four times larger. If the velocity triples, the force is nine times larger.

Since current forces act on the submerged portion of the ship, they are likely to be most critical when the ship is loaded.

While it is usually evident when the wind is blowing at or near gale force, high current velocities are not as noticeable to the ship's personnel. Only a review of the current information for the terminal is reliable.

It should be noted that it is possible for the subsurface currents to have a different velocity and direction than surface currents, especially at offshore terminals.

3.1.2 Waves

Waves are a major force on vessels at exposed mooring locations. In such areas, ships are generally moored at sea-islands, single point moorings or multiple buoy moorings.

Wave direction and frequency (period) are two factors that influence the effect of waves on a moored ship. Whether the ship responds by surging, swaying or yawing will depend on whether the waves are striking the moored vessel head-on, beam-on or quartering, the frequency of the waves and the manner in which the tanker is moored.

Ships do not usually respond to a single wave but to a system of waves. It is the cumulative effect of each wave in the wave train that causes the tanker to move. It is possible to observe individual waves having little or no effect on the moored vessel, yet the vessel is moving slowly in response to the entire wave system. This behaviour is noticeable by observation of the rise and fall of the mooring line tension catenaries at a sea-island.

In harbours, there are sometimes very long period waves present, which are very difficult to detect visually. These waves are known as seiches and they are potentially dangerous because of their ability to disturb moored vessels. They are capable of forcing a moored vessel to move slowly in a

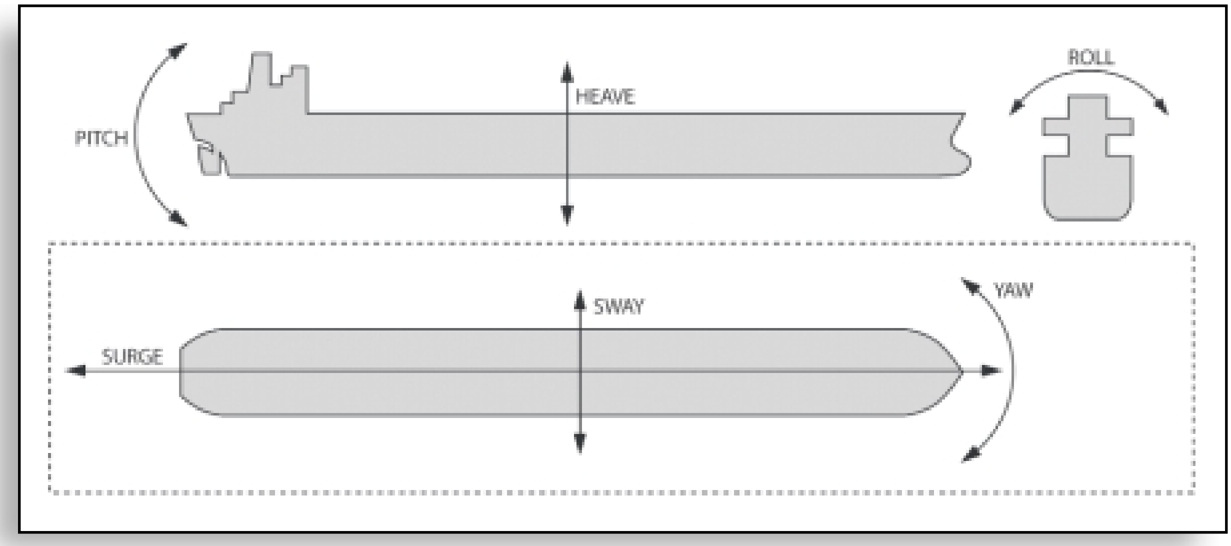


Figure 3.8 – Vessel Motion

cyclic manner, causing high mooring loads. Movements with periods of one to three minutes are typical and are best observed by noting the rise and fall of the mooring line catenaries. If a moored vessel is responding in this manner, the amount of ship motion can be modified by changing the tension of the mooring system (either by slacking-off or heaving-in mooring lines). Actual measurements of line loads for moored VLCCs show that harbour seiches can cause tanker mooring loads to increase by 15 to 20 tonnes.

3.1.3 Tidal Forces

Vertical forces due to the tidal rise and fall (not including the effects of tidal current) are predictable, as the variation in tidal patterns is well understood at most terminals. Changes in line loads are not in response to increasing or decreasing external forces but instead to changes in the elevation of a vessel relative to a jetty or pier. Forces caused by tidal rise and fall can therefore be controlled by slacking-off or heaving-in vessel mooring lines. However, without line tending, increased mooring forces due to tidal rise can be quite severe at some terminals.

3.1.4 Tanker Loading and Discharge

Mooring forces caused by tanker loading and discharge (ie sinkage while loading and rise during discharge) are similar to those caused by tidal elevation as they are created by a change in the height of the tanker deck relative to the pier. Line tending by ship personnel can minimise or eliminate these forces.

3.1.5 Forces Exerted by Passing Ships

A ship moving through the water exerts forces on moored ships and other objects in the vicinity. The magnitude of these forces depends on a number of conditions, the most important of which are:

- Clearance under the keel of the moored vessel
- separation distance between the passing ship and the moored vessel
- sizes of the passing and moored vessels
- the speed at which the ship passes the moored vessel.

A moored vessel is at its most vulnerable to the passing of another vessel when:

- It has little under keel clearance
- the separation distance between the ships is relatively small
- the passing vessel is travelling at a relatively high speed
- the passing vessel is of a comparatively larger size.

This can be particularly severe if mooring lines have already lost their pretension through reduced elevation as the ship falls with the tide. The most critical time for a loaded tanker (when moored) would occur at low tide, at which time the underkeel clearance would be at its minimum. However, a passing ship cannot be disregarded any time that a vessel is moored.

A report on an LNG carrier that was pulled off of the berth is detailed in the case studies section.

The water to landward of a ship at a jetty that has restricted underkeel clearance cannot flow easily under the ship to replenish the suction effect caused by a passing vessel.

3.2 Factors Affecting Load Distribution

The factors affecting load distribution can be divided into the following categories:

- Overall mooring pattern
- orientation of the hawsers
- elasticity of the hawsers.

3.2.1 Overall Mooring Pattern

The overall mooring pattern affects the load distribution to individual lines. Generally, the mooring pattern should be as symmetrical as possible, at about the ship's mid-point to ensure a uniform load distribution among the lines for varying wind and current conditions. Although an unsymmetrical pattern may be viable for some situations, such as where wind and current approach from one direction, there is always a risk of a limited number of lines resisting the entire load.

3.2.2 Orientation of the Mooring Lines

Figure 3.9 – Vertical Angle Mooring Line

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The effectiveness of a mooring line is affected by two angles, the vertical angle between the lines and the pier deck, and the horizontal angle between the mooring line and the parallel side of the ship.

The steeper the orientation of the mooring line, the less effective it is in resisting horizontal loads. As an example, a hawser oriented at a vertical angle of 45º is only 75% as effective in restraining the ship against wind forces as a line oriented at a 20º vertical angle. Similarly, the larger the horizontal angle between the parallel side of the ship and the mooring line, the less effective the line is in resisting a longitudinal force.

3.2.3 Elasticity of the Hawser

The elasticity of a mooring line is a measure of its ability to stretch under load. The effect of hawser elasticity is often overlooked, even though the differences between the mooring line elasticities can be very large, and where mooring lines of differing elasticity are connected at the same point, the stiffer mooring line will always take the greater load stress.

The hawser's material, diameter and length are the primary determinants of its elasticity.

Figure 3.10 demonstrates the significance of each factor on load distribution.

The effect of mooring line material on load distribution is generally recognised. Although "mixed moorings", consisting of various types (material) of mooring lines in the same service are generally condemned, within the industry they are still commonly used.

If a wire mooring rope is run out parallel to a fibre mooring rope, the wire will carry almost the entire load while the fibre rope will carry practically none.
Note: This also applies for different types of fibre ropes (Figure 3.10)

At times, the effect of line length on load distribution is overlooked in mooring arrangement evaluation. Line elasticity varies directly with line length and has a significant effect on line load. An 80 metre long wire line will take half of the load if it is used with a 40 metre line that is of the same size and material and is both parallel and adjacent to it. However, if fibre ropes are used, the longer line will carry less than half the load of the shorter line (possibly 25% for nylon) since the elongation curve for fibres is not linear.

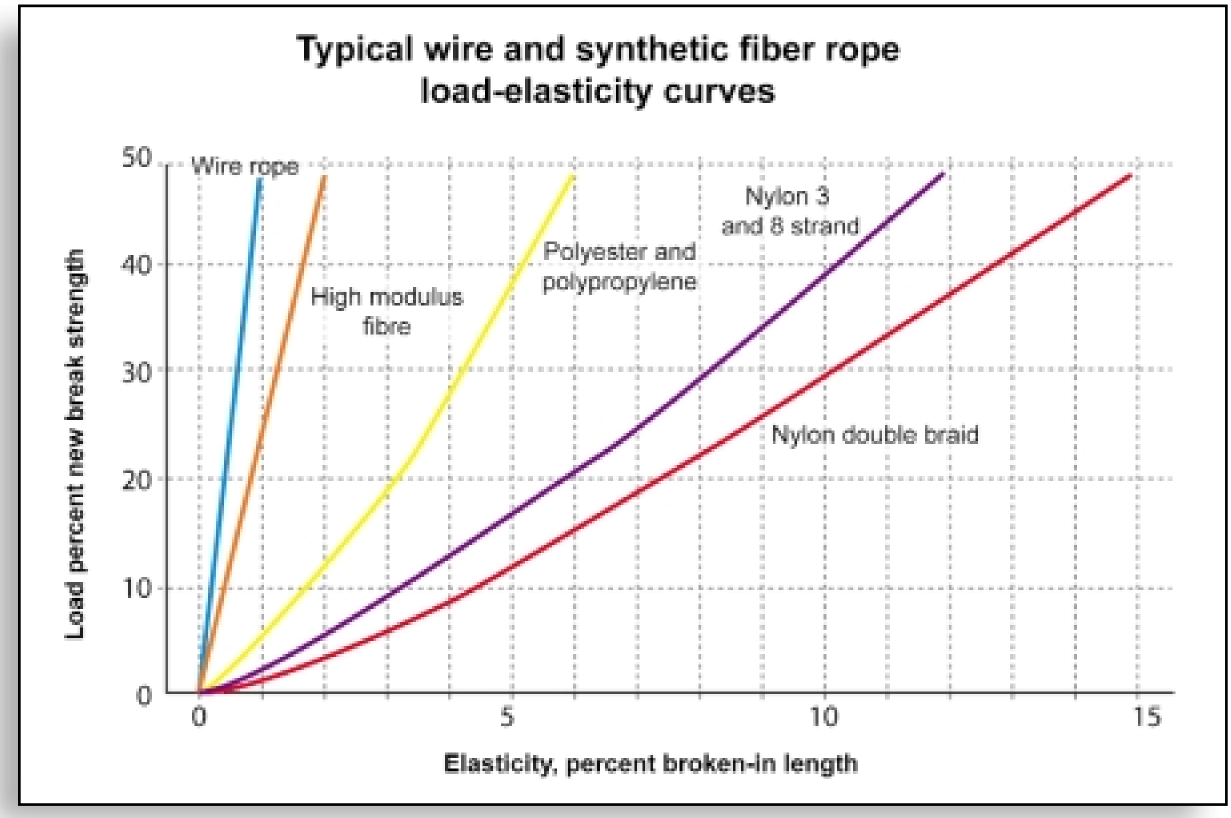

Figure 3.10 – Elasticity of Mooring Lines

The elasticity of each type of line also varies with its diameter. Usually, this factor is not an important consideration as ropes carried on board ships are of a uniform diameter

3.2.4 Mooring Distribution Summary

- Mooring lines should be symmetrically arranged on the transverse centre line of the ship to ensure a good load distribution
- where it is possible, breast lines must be perpendicular to the side of the ship
- spring lines should be arranged parallel to the ship's side
  - — a mooring system that adheres to the above three principles is shown Figure 3.10. By proper orientation of both breast and spring lines an efficient load distribution and tenability is assured. Normally, no more than two good spring lines are required to resist longitudinal wind, current and surge forces
- the vertical angle between the mooring line and the pier deck should be as small as possible.
- bow and stern lines, oriented at an angle of 30°-60° off the bow and stern, are not required for mooring when adequate berth facilities are available
  - — because of their long length and poor position, bow and stern lines are normally not very effective in restraining a ship in its berth, although they can be useful however for manoeuvring purposes
- mooring lines of the same size and type should always be used for all leads used in the same service, ie breast lines, spring lines, bow lines, etc
- mooring lines should be arranged so that all lines in the same service are approximately the same length between the ship and shore bollards (with breast lines for a VLCC normally at about 35-50 m).

3.3 Mooring Equipment

VLCC's have in the past been involved in a number of mooring incidents, some of which resulted in damage to terminal loading arms.

These incidents were attributed to winch slippage, broken mooring lines or tails and excessive ship movements permitted by the high elasticity of synthetic mooring lines.

The following section deals with some of the factors affecting the design and maintenance of mooring equipment.

3.3.1 All Wire Mooring and Synthetic Lines

The main reason for recommending wire mooring lines for VLCC's is because they prevent excessive ship movement, which is the usual cause of damage to shore based hardarms. A secondary reason is that when mixed moorings are used, the wire lines take most of the load and so early line failure can occur. Figure 3.10 illustrates the excessive elongation of synthetic (man made) fibre lines at relatively low load levels. New synthetic lines can have even greater extensions.

Some of the materials used for synthetic fibre lines are sensitive to weather exposures, particularly sunlight. Shock stresses applied to some types of synthetic fibre lines could significantly reduce their breaking load without any apparent visible damage to the line itself. Synthetic lines have a relatively short service life.

Many modern ropes are a blend or mixture of several fibres. Combinations of polyester and polypropylene fibres in ropes are common. Some, but not all, composite ropes made of polypropylene and polyester are as strong as ordinary polyester ropes.

Careful inspection should be carried out when an 'all synthetic lines' mooring is used. Attention should also be paid to ensure that all of the synthetic mooring lines used (or at least these positioned in the same direction) are made of the same material.

3.3.2 Selection of Wire Mooring Lines

To keep line handling and tending within manageable proportions for the larger sizes, ship mooring lines should be selected while considering the maximum breaking load compatible with ease of handling and reasonable flexibility. It is generally accepted by VLCC operators that wires of 42-44 mm diameter meet this criteria. The factors that contribute to the strength of wire mooring lines are construction and wire tensile strength. For mooring VLCCs it is recommended that, as a minimum, a 42 mm (1¾") diameter 6 x 37 class I.W.R.C. preformed, heavily galvanised wire line (minimum tensile strength of 180 kg/mm^2) with an MBL of 115 tonnes is used. The minimum lengths of wire should be 275 metres, to allow for berthing at multi-buoy moorings, piers and sea island berths.

Splices, other than eye splices, are not recommended and wires that are spliced between the mooring point ashore and the ship should not be accepted by the terminal.

3.3.3 Synthetic Tails

Wire mooring lines are generally fitted with a length of synthetic rope, normally nylon, on the shore end. The additional elongation of the mooring line system permitted by the tail reduces the risk associated with poor line tending, particularly in berths with large tidal variations and high loading/unloading rates. They are also valuable at berths that have short breast or spring leads.

Model tests and field measurements, as well as experience, confirm the effectiveness of the additional elasticity provided by the tails. This additional elasticity reduces the loads induced in wire mooring lines under dynamic loads, by permitting the ship to respond more favourably to various combinations of wind, waves and current, as well as to ships passing at slow speed in close proximity. Testing has shown a substantial reduction in breaking strength in new synthetic tails in a relatively short period of time.

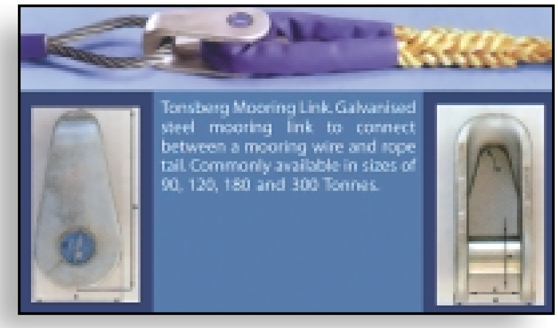
Tonsberg Mooring Link. Galvanised steel mooring link to connect between a mooring wire and rope tail. Commonly available in sizes of 90, 120, 180 and 300 Tonnes.

Figure 3.11 – Tonsberg Mooring Link

An incorrectly designed tail could introduce too much elasticity. The size of the rope chosen should be capable of easy handling and be of sufficient size to ensure that the synthetic rope has a breaking strength at least 25% greater than that of the wire line to which it is attached. It is most important that the tail is attached to the wire by use of a patent design such as a 'Mandal' or 'Tonsberg' mooring link.

3.3.4 Mooring Winches

Typical deck mounted reel stowing mooring winches are shown in Figures 3.12 and 3.13

Automatic tension winches have been designed so that a specific line tension can be preset, allowing the winch to pay out whenever the value is exceeded and then heave-in when the line tension falls below it. However, use of such winches should not be accepted at the tanker jetty as extreme wind/current forces can cause winch release at the weather end of the vessel, followed by heaving of the winches at the opposite end of the vessel. Such self-tensioning wind effects would allow the ship to 'slide' along the berth, disturbing the perpendicular angle desired for hose or hard arm connections to the ship's manifold. Mooring management is, therefore, a manual operation.

If automatic winches are installed, the winch should be placed on a manual brake while the vessel is moored alongside, as fore and aft spring lines and head and stern lines can work against one another when exposed to wind and current situations.

Winch brakes should be set to hold a minimum load of 60% of the minimum breaking load of the wire. The winch brake holding capacity must be regularly tested. OCIMF recommends that this test is made, and the results recorded, at least once a year.

A torque incorrectly applied to the brake could result in a sharp reduction in brake holding capacity.

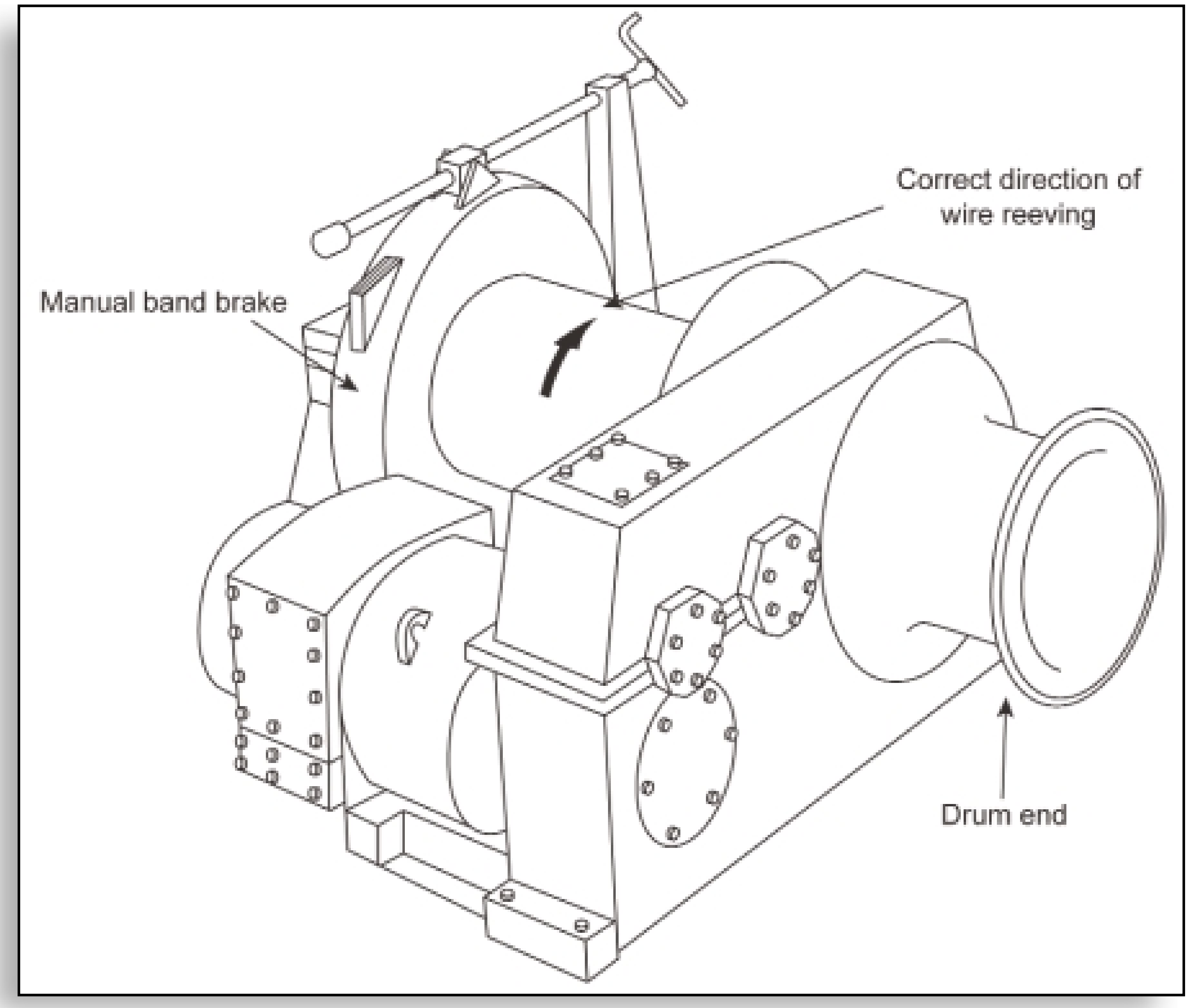

Figure 3.12 – Deck Mounted Mooring Winch

Care should be taken when reeling the wire onto the winch drum as cases of mis-reeling have been reported. Band brakes are designed for the wire to pull directly against the fixed end of the brake strap.

Figure 3.14 illustrates the correct method of reeling. Mis-reeling could reduce the holding load capacity to 30% of the capacity of a properly reeled wire.

3.4 Mooring System Management

The objective of good mooring system management is to provide for the safety of the ship and terminal, preventing damage to either.

Good mooring management requires the application of sound principles, well maintained equipment, trained personnel and proper co-ordination and interaction between the ship and shore.

The terminal can reduce the possibility of ship break-out in a number of ways. These include:

- Development of guidelines and a mooring layout for each class of ship that is acceptable at the berth
- ensuring that information about the ship's mooring equipment is obtained before its arrival
- after berthing, inspection of the ship’s mooring equipment to decide if any modifications must be made and subsequent periodic inspection of line tending
- by having good contingency plans for prompt cessation of cargo transfer, the release of cargo transfer equipment (hoses/hardarms) and the safe removal of the ship from the berth should there be a failure in mooring.

3.4.1 Operating Limits

Operating limits establish the environmental conditions within which the loading arms and other shore based equipment can operate.

Movement of the ship alongside may, in addition to suspending loading/unloading, require disconnection of cargo transfer equipment and the gangway.

Should the wind, wave or current forces (either individually or combined), be excessive, the moorings run the risk of being overloaded. Should the movement be excessive and not controllable, the ship may be required to vacate the berth to avoid damage to the ship or jetty.

3.4.2 Joint Terminal Meeting and Inspection

Once the ship has berthed the terminal representatives will meet the Master or other senior officer. At this meeting they will review and confirm the following:

- Freeboard limitations
- ballasting
- conditions for emergency disconnection
- actions where there are changes to the mooring loads
- weather forecasts
- complete the ship/shore safety checklist
- complete any oil pollution avoidance checklist
- obtain agreement on details of cargo, bunker and ballasting arrangements. This will include agreement about simultaneous cargo/ballast handling,

Figure 3.13 – Deck Mounted Reeled-Stowage Mooring Winches

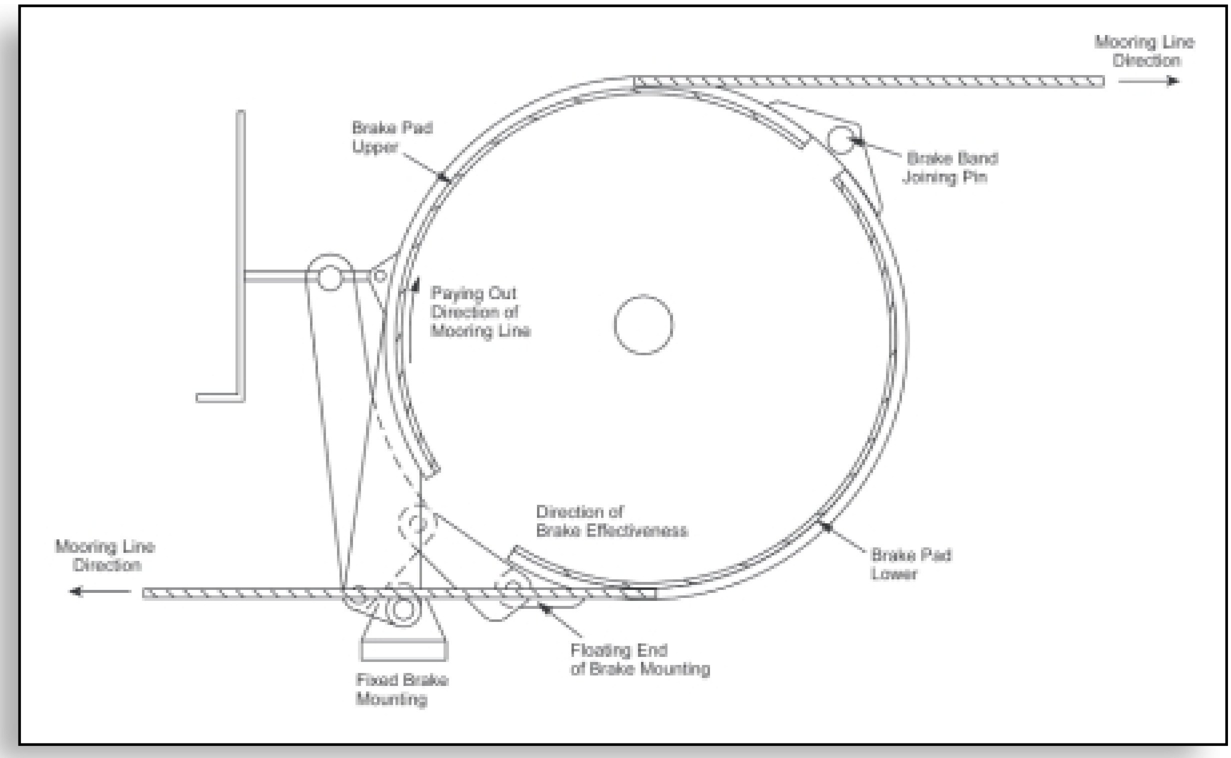

Figure 3.14 – Winch Brake and Reeling Arrangement

where and when it is required for operational/environmental limitations

- assess under keel clearance limitations
- agree on procedures for draining and disconnecting cargo transfer equipment.

3.4.3 Line Tending

Once all the mooring lines are made fast, they should be inspected regularly to ensure that all lines are taut and that the ship is hard against the fenders. This inspection will also allow all lines to assume their share of the loading on the ship. If lines are slack, or if the ship is lying off any fenders, the appropriate lines should be hove-in immediately to correct the situation.

Even though a ship may initially be properly moored and have lines that are adequately pre-tensioned, changes in weather, tide or freeboard will necessitate tending of the lines to prevent them from being overloaded or going slack.

The frequency of necessary line tending will be situation dependent.

A special emphasis should be placed on inspection of the tanker's mooring system whenever any of the following conditions are present:

- Periods of high loading and/or discharging rates, where the ship's freeboard changes rapidly
- a sudden increase in wind speed or a change in direction, whenever wind speed exceeds 15 m/sec, 30 knots, or where gusts are expected
- in swell conditions
- during periods of maximum tidal flow
- whenever underkeel clearance is low
- prior to, during and immediately after the close passing of other ships.

While it is the Master's responsibility to moor in a safe manner, according to the mooring layout supplied by the terminal, and to ensure that lines are properly tended during the entire stay alongside, the terminal representative must also satisfy himself that good mooring management is constantly followed.

3.4.4 Precautions Applicable in High Mooring Load Conditions

Overload of mooring lines is evidenced by either direct measurement, observation of the mooring by experienced personnel or by winch slippage. The following precautions and actions are likely to apply:

- Harden-up on the winch brakes. Do not release brakes (or slacken from the mooring bitts) and attempt to heave in
- discontinue cargo operations
- reduce freeboard by taking on ballast if loads are due to high winds.
- disconnect cargo transfer equipment
- call crew, linemen, mooring boats, tugs and put ship's engines on standby
- run extra moorings, as available, together with any shore moorings available.

3.4.5 Mooring at a Multiple Buoy Mooring

A Multiple Buoy Mooring (MBM) usually consists of between three and seven permanently anchored buoys and is a relatively simple and inexpensive type of mooring facility.

This type of berth is rarely used for large tankers but can be installed where weather and sea conditions are mild to moderate. A graphic of a typical 4-buoy MBM is shown in Figure 3.15.

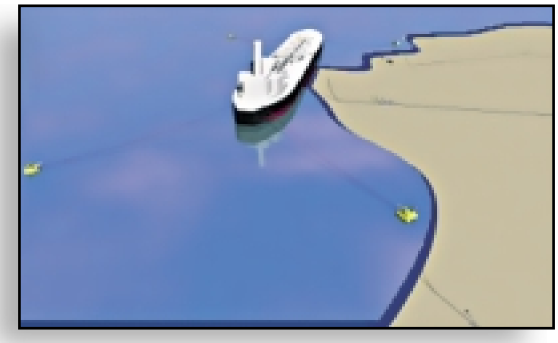

Figure 3.15 – Multiple Buoy Mooring
Reproduced with permission by APL Norway

*Note:*The mooring anchor lines allow the buoy sufficient elasticity so nylon tails are not used for the mooring lines.

In many MBMs the bow of the vessel is held in position by the ship's own anchors while the ship's mooring lines secure its stern to the mooring buoys. In general, the same good mooring practices that are recommended at conventional piers are also applicable to sea berths. However, shipboard and terminal personnel should be aware of several additional points that ensure the safe mooring of the vessel and the integrity of the cargo transfer system.

3.4.5.1 MBM Mooring Procedure

The same procedures are normally used to moor a tanker once it has entered the MBM berth. As soon as the tanker has manoeuvred into the berth a launch takes the tanker's lines, one at a time, and tows them to the various mooring buoys. The mooring line may be placed on the buoy hook from the launch or the buoy may be boarded to secure the line. Some berths use "preventer wires", which are permanently attached to the buoy and are towed to the tanker with the launch. At most berths, it takes about 2½ hours from the time the tanker is cleared for berthing to the point where all mooring lines are made fast.

The order in which lines are laid out to the buoys depends on the environmental conditions. The lines are set to counteract the effects of the prevailing winds and current. As an example, lines on the windward side are put out first.

When the tanker leaves the berth, the mooring procedure is reversed. The ship's lines are slackened and slipped off the buoy's quick release hooks by the launch. Once the lines are cleared, the anchors are retrieved. If forward breast lines are used, they are usually released before the stern lines. It normally takes between 60 and 90 minutes for the unberthing operation, once the hoses are on the seabed, depending on the capabilities of the tanker's mooring equipment.

It must be remembered that while stern lines are in the water, the ship's engines should not be operated

3.4.5.2 Berth Layout and Proper Anchor Deployment

The primary restraint for a ship's bow on an MBM is generally provided by the vessel's own anchors. This is because the ship requires unrestricted manoeuvring room in the vicinity of the bow to be able to enter and exit from the berth, so buoys cannot usually be placed near the bow.

To provide adequate restraint for the ship when it is finally moored, the angle between the anchor lines should be between 60-90º. If the angle between the anchor cables (or chains) is too small, insufficient resistance to lateral sway may result. However, if the angle between the anchor cables is too large there may not be enough resistance to a sternward surge.

Sufficient anchor cable must be paid out from the ship for the pull of the anchor cable to be in a horizontal direction. If the pull of the anchor cable is not in a horizontal direction on the sea-bed, the anchor will tend to be pulled out under severe wind and wave conditions.

The pilot or berthing master, through his experience at a particular facility, will know at which point each anchor must be let go to ensure an adequate length of cable and the required angle between the cables. The importance of anchor release of anchors and cable payout /retrieval being done properly is emphasised by the fact that the weak link at an MBM, even for a properly moored ship, is the vessel's own anchors.

Since the MBM system needs submerged hoses to be lifted and connected to transfer cargo, ship movements while in the berth must be confined to prevent damage to either the hoses or the pipeline and manifold. If the hose string is made too long, it will chafe either on the ship or on the sea-bottom. The tolerances are relatively small and proper use of mooring lines is required to maintain the vessel within the designed berth arrangement. Use of all-synthetic lines could result in excessive movements, with subsequent damage to the hoses.

3.4.5.3 Pre-Tension Lines to the Full Capacity of the Winches

The buoy legs of an MBM allow considerable drift when under little or no load. To prevent excessive drift of a ship and damage to hoses and/or pipeline and manifold, mooring lines should be pre-tensioned to the full heaving capacities of the winches.

3.4.5.4 Use of Preventer Lines

Preventer lines are steel wire lines permanently attached to the mooring buoys. The preventer lines are hauled to the tanker and tied off to bitts on the vessel's deck. They are intended to act as backup lines in case the ship's line should fail and they will prevent the excessive movements that occur when synthetic lines are used to moor the tanker. Occasionally, they are used as the principal mooring lines if the ship's lines are either too short to reach the mooring buoys or are in poor condition. Preventer lines would also be used to ensure the vessel's safety if the tanker has mixed moorings.

The use of preventer wires as principal mooring lines is not normally recommended. Since 38 mm-50 mm diameter wires are difficult to handle, it will be hard to adequately secure the wires around the bitts and they can never be manually pre-tensioned to the same level as shipboard winch-operated lines. The ship should ensure suitable wire stoppers are available to restrain the wires when securing them around the bitts.

Use of preventer lines does not double the mooring restraint capacity offered to the ship since preventer lines, due to the lack of pretension, will rarely share loads equally with winch-operated lines. Wire rope handling at an MBM berth incurs strenuous work for the ship's crew and great care and attention is necessary to manage this safely.

3.4.5.5 Operating Limitations

The operating limitations of the berth and the advice of the berthing master should be followed when disconnecting the hoses and departing the berth. As weather and sea conditions deteriorate, the MBM is more difficult to depart from than other offshore berths as a launch is generally required to release the ship's wires from the buoys and the ship's anchors must be weighed. Simultaneously, care must be exercised to prevent mooring wires from fouling the propeller during the operation.

Consideration should be given to suspension of loading/unloading operations and getting underway when waves from ahead are approaching 3 m maximum or when waves off the bow are 1.5 m maximum.

MBMs require more moderate wind conditions than other offshore berths as they can become untenable in beam or quartering winds greater than 25-35 knots. Limiting current conditions are normally 1 knot from abeam and 2 knots for head currents.

Very little can be done by the ship to extend its berthing capacity in hostile situations at an MBM so care must be exercised when taking the decision to disconnect hoses and mooring lines and depart the berth.

3.4.6 Single Point Mooring Systems

Figure 3.16 – Single Point Mooring System
Reproduced with permission from Harbour & Marine Engineering www.harbourmarine.com

At a Single Point Mooring (SPM), which is also called a Single Buoy Mooring (SBM), a mono-mooring or a bow mooring, the tanker is moored by the bow, using one or two hawsers, to a buoy or tower. The tanker is free to rotate about this point under the influence of wind, waves and current. Because the tanker is free to align itself with these forces, the total force is less than if the tanker were held at a fixed heading.

There are two basic types of SPMs at which a tanker may berth, the Catenary Anchor Leg Mooring (CALM) and the Single Anchor Leg Mooring (SALM).

CALM

The Catenary Anchor L eg Mooring (CALM) (sometimes called a Single Buoy Mooring or SBM), illustrated in Figure 3.17, is the most common. The CALM consists of a large buoy held in place by four or more anchor cables that extend in catenaries to anchor points some distance from the buoy.

The ship to buoy mooring hawser(s) is/are fastened to a turntable or platform on the deck of the buoy. The loading hose, floating in the water, connects to a pipe or pipes on the buoy turntable. This pipe is connected through a fluid swivel unit in the centre of the buoy to an underbuoy hose that extends downward, and sometimes to the side, to a submarine pipeline.

SALM

The SALM, shown in Figure 3.19, consists of a deep-draught buoy, anchored by a single anchor leg, which is tensioned to pull the buoy against its buoyancy. The anchor leg is provided with an anchor swivel, which allows the buoy to rotate. The anchor leg is attached to a large base that is held to the ocean floor by internal fill and/or piling. A fluid swivel, connected to the submarine pipeline, surrounds a shaft in the anchor leg and is located either at the base or at a point above the base. An underwater hose rises from the fluid swivel to the sea surface at a point some distance from the buoy and a floating hose extends from that point to the midpart or bow loading connection of the moored tanker.

Mooring Tower

The third form of SPM that may be encountered is the mooring tower. Mooring towers have a floating hose connected to the turntable at a point near the water surface.

The tower has a rigid loading arm that connects to the edge of the turntable, drops down and extends again alongside the tanker. The bow mooring tower consists of a rigid or semi-rigid structure, held to the sea floor by piles and rising above the sea surface. A mooring turntable, with a fluid swivel at the centre, is mounted on the top of this structure.

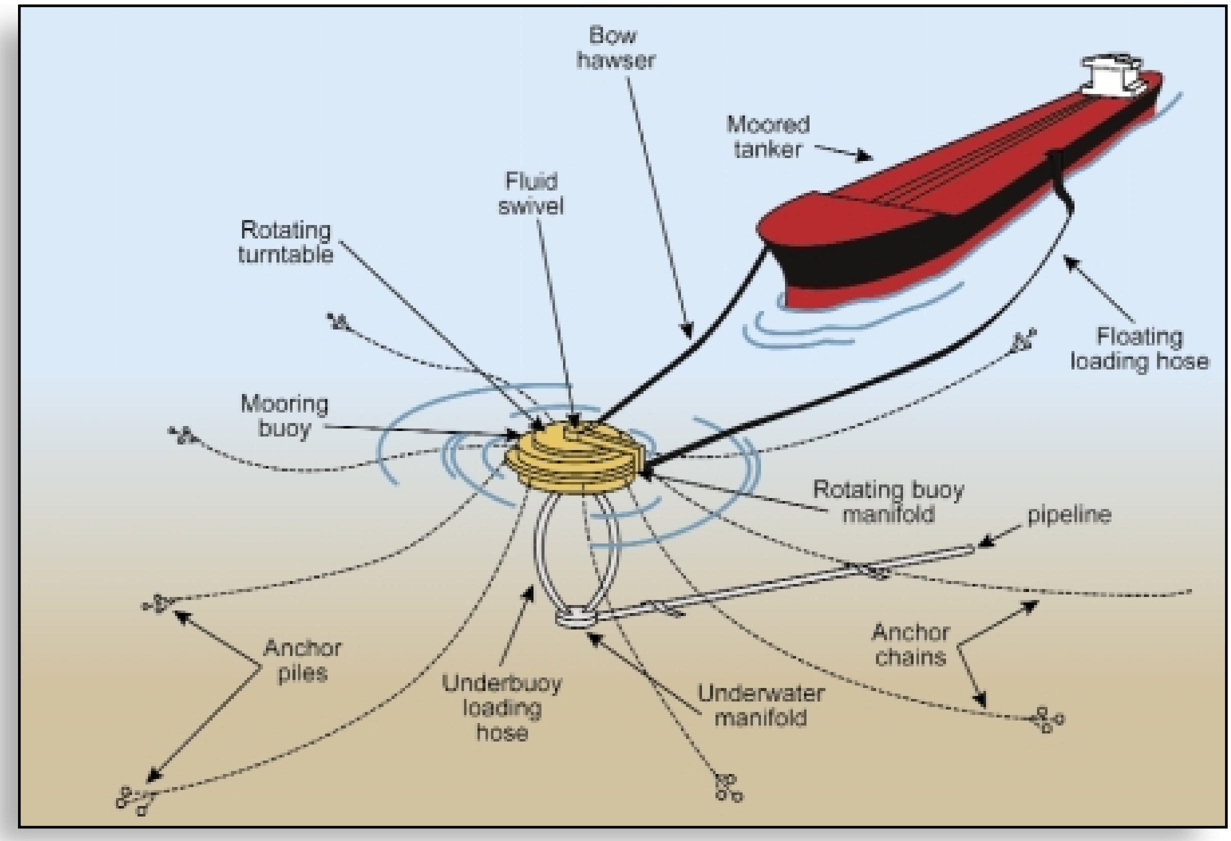

Figure 3.17 – Catenary Anchor Leg Mooring

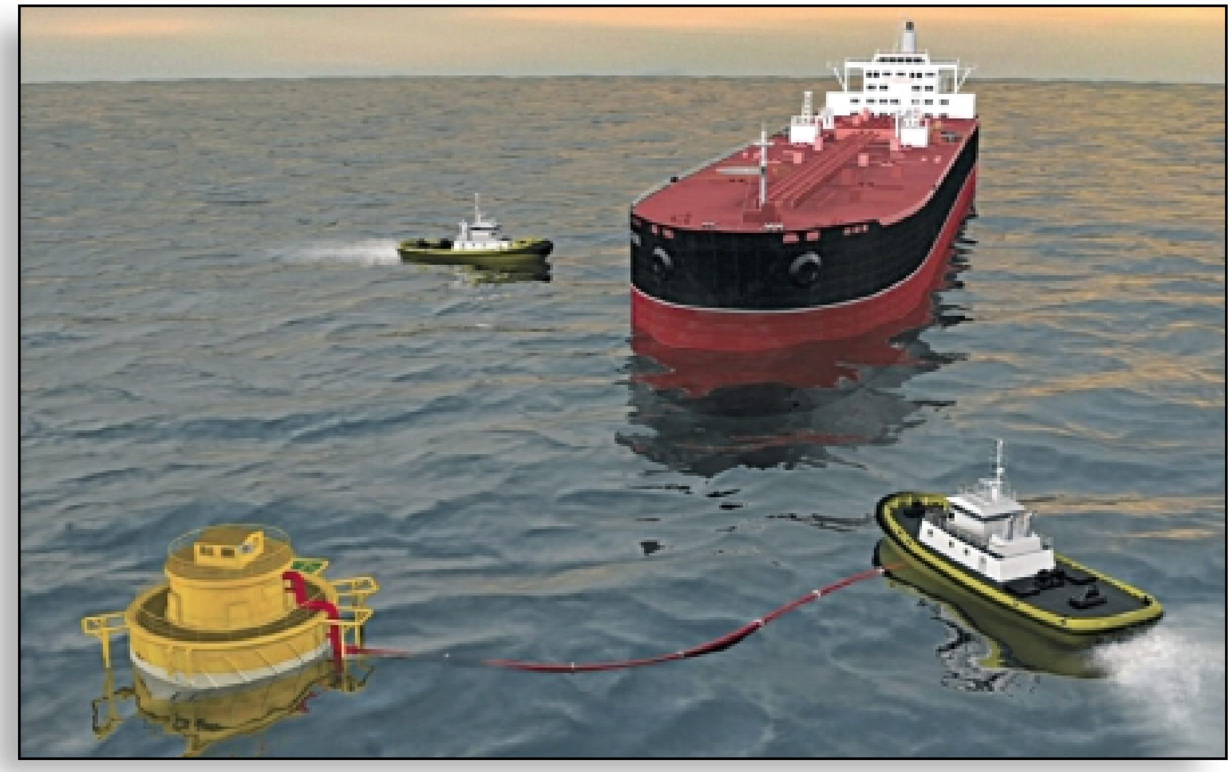

Figure 3.18 – VLCC Approaching an SPM

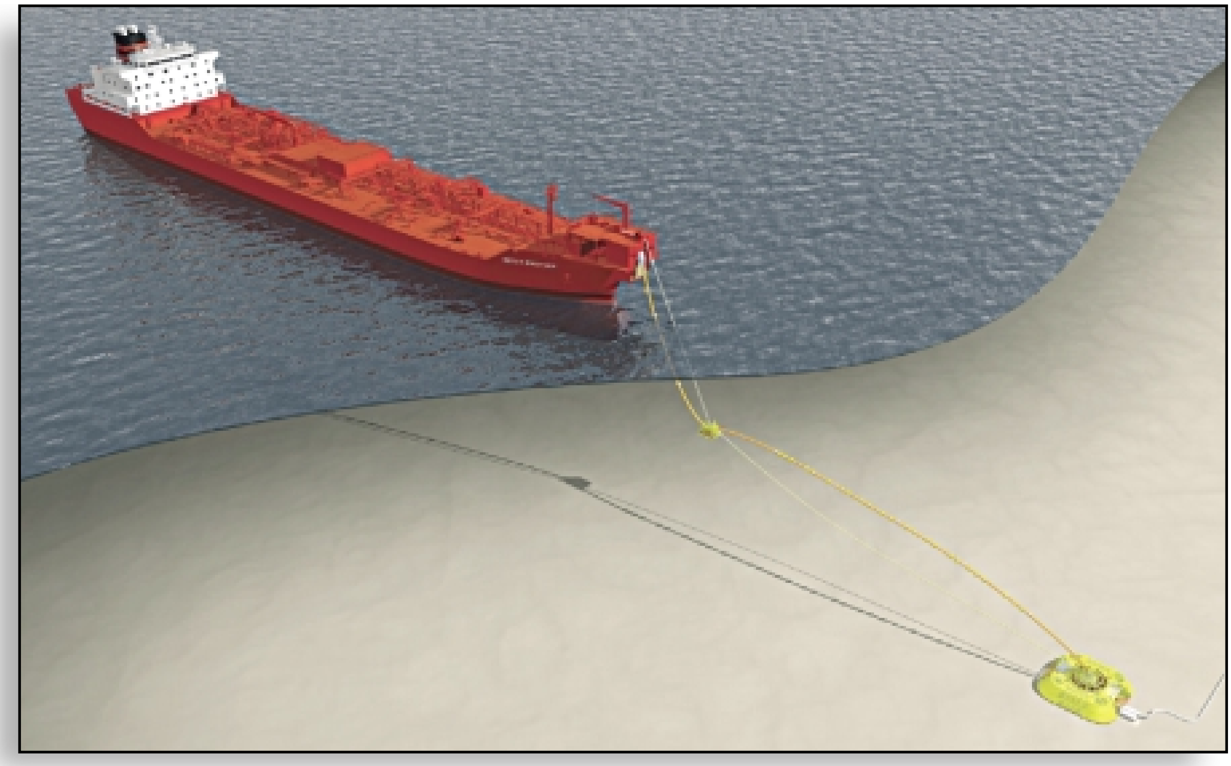

Figure 3.19 – Single Anchor Leg Mooring
Reproduced with permission by APL Norway

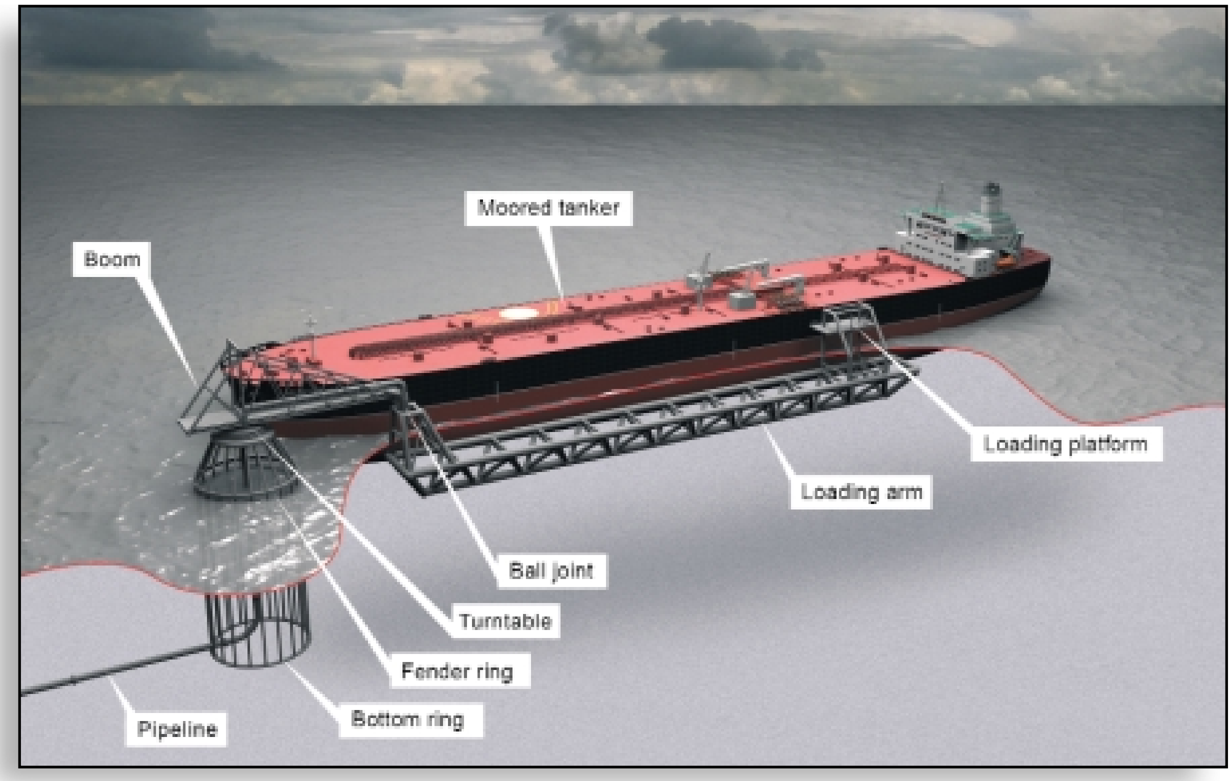

Figure 3.20 – Mooring Tower

3.4.6.1 SPM Mooring Equipment and Fittings

At all single point moorings, the mooring ropes are provided by the terminal. Usually, at older SPMs, they consist of two large-diameter nylon hawsers.

These hawsers are permanently attached to the mooring buoy, or tower, or are stored elsewhere and attached to the buoy by the launch crew prior to the tanker's arrival. Generally, flotation collars are placed on the hawsers to keep them afloat when not in use.

Many tankers larger than 150,000 dwt are equipped with towing brackets and large Panama fairleads or chocks for mooring at an SPM (note: that the terms, "fairleads" and "chocks", are used interchangeably) and some are now being equipped with bow stoppers, also known as 'Smit Brackets' or 'AKD Stoppers'. However, most smaller ships have only bow fairleads and bitts for accommodating mooring equipment.

In general, ships of approximately 200,000 dwt and larger will have 2 bow mooring stoppers. As a result, and because of the variety in shipboard equipment, many types of mooring arrangements are provided by the terminals. At the older SPM terminals that cater for smaller tankers, a typical arrangement is as shown on Figure 3.24. In this arrangement, a single chafing chain is brought through the tanker's bow fairlead. Note that both hawsers are passed through the same fairlead whenever possible. Passing the individual mooring lines through widely separated fairleads could lead to an extremely unequal distribution of the loads taken by the two lines.

For terminals handling tankers of up to the 250,000 dwt class, the "Buoy Mooring Forum" recommends an arrangement as shown in figure 3.24. In this arrangement, the twin mooring lines from the buoy are attached to a triangular plate, which in turn is connected to a three-inch chafing chain. The figure shows the connection for ships having a towing bracket and a sufficiently large panama chock (or fairlead).

Figure 3.21 – Bow-mounted Twin Hawser Hooks on Texaco's FSO 'Lombo Este', Angola
Reproduced with permission from Harbour & Marine Engineering www.harbourmarine.com

Note: Figure 3.21 and 3.22 show a 'quick release' bow stopper arrangement. They are useful for illustration purposes but differ from the tanker mooring arrangement in that the chain is not pulled through the stopper, as can be seen in figures 3.23 and 3.24

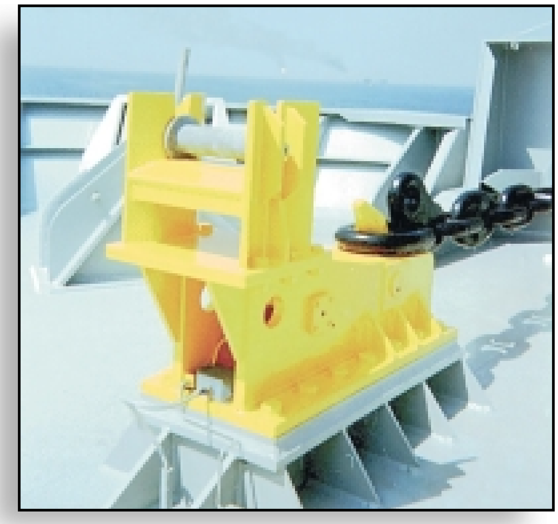

Figure 3.22 – Quick-release Chain Hawser Hook Fitted with Hydraulic Remote-Release, Load Pin and Hawser Fast Lead
Reproduced with permission from Harbour & Marine Engineering www.harbourmarine.com

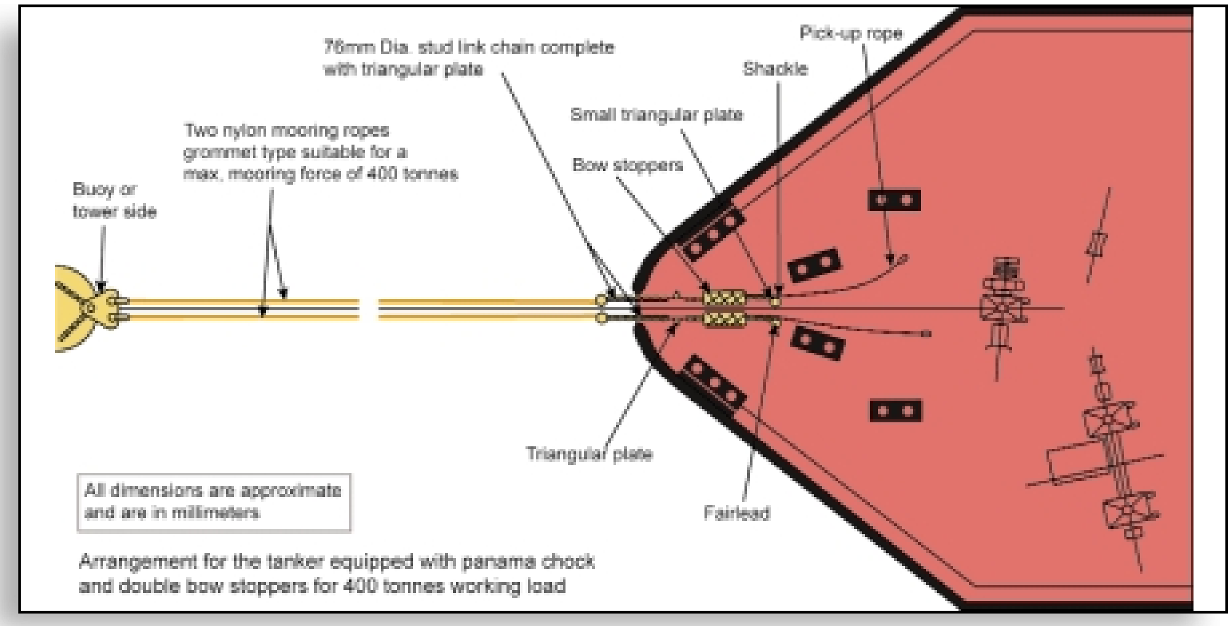

Figure 3.23 – Mooring Arrangement up to 500,000 dwt

Should the ship lack the proper sized Panama fairlead or towing bracket, it will be necessary to shackle a smaller size chafing chain to the triangular plate. This chain can terminate with suitable sized wire or nylon snotters in a figure of eight around the bitts. Care must be exercised by the ship and terminal since the ship's bitts may fail at lower loads than the terminal's hawsers.

The following are considered safe working loads for various diameter mooring bitts:

Bitt Diameter	* Safe Working Load (metric tonnes)
500	155
550	190
600	250

* These loads are based on well designed, fabricated and installed bitts.

For tanker terminals designed for tankers larger than 200,000 dwt, dual mooring arrangements (each with a safe working load of 200 tonnes) are recommended. Some of these tankers will have a bow stopper, others will have towing brackets, see figures 3.21 and 3.22.

3.4.6.2 Preparations for Mooring at an SPM

Since special mooring gear such as shackles, strop ropes and messenger ropes are provided at some terminals, they are usually delivered to the tanker at the same time as the Pilot. A boom should be rigged to lift this equipment onboard from the launch. Hose connection gear may also be delivered at this time. The Pilot and gear should be taken aboard on the side to which the hoses will be connected to avoid carrying the hose connection equipment across the tanker. The hose is connected to the port side at almost all SPMs.

Any SPM mooring gear should be taken promptly to the forecastle and preparations should be made for receiving and securing the mooring lines. The arrangement of fairleads, fittings, winches and obstructions should be selected to provide the best means of securing the tanker to the mooring.

3.4.6.3 Mooring Operations at an SPM

While the mooring procedures employed by a Pilot (or berthing master) and launch crew

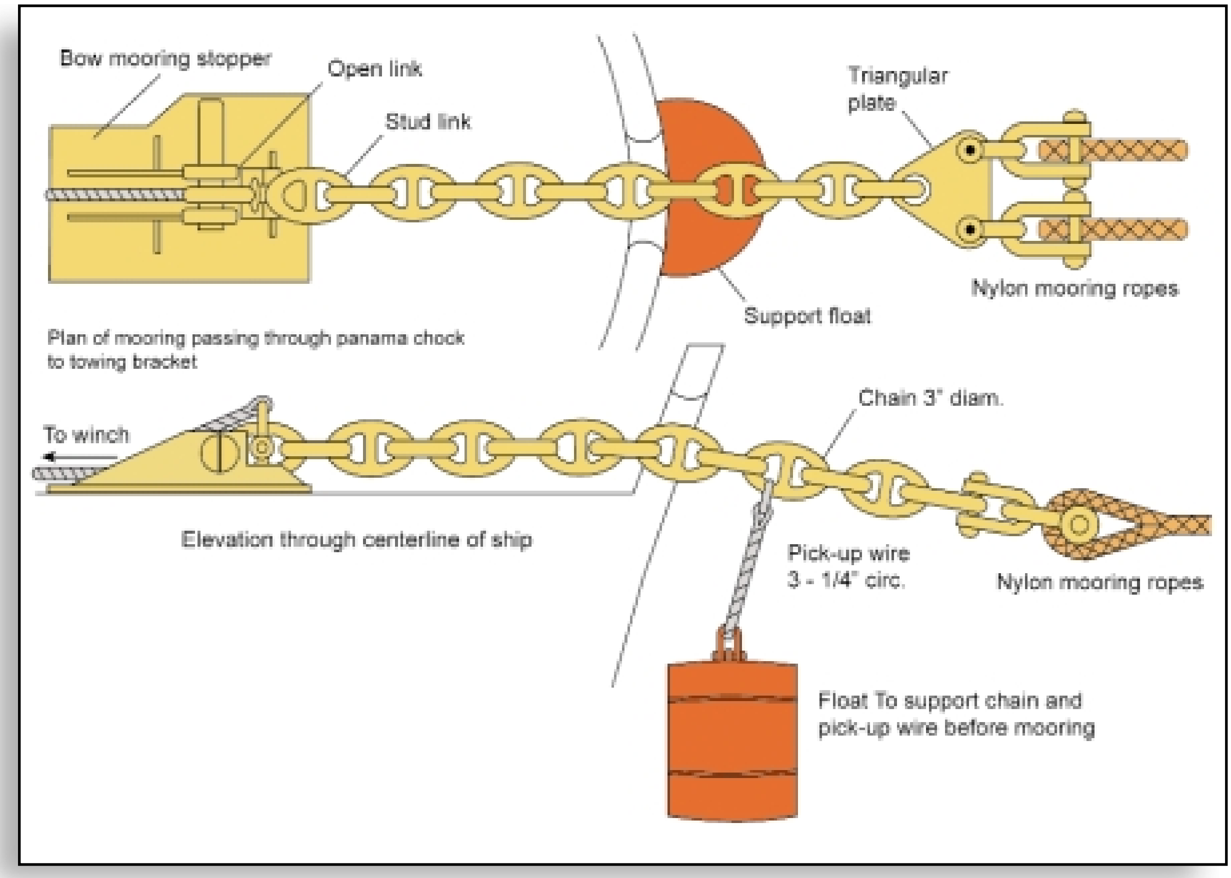

Figure 3.24 – SPM Mooring Arrangement to 250,000 dwt

may vary, the following is a general description of a typical SPM mooring procedure that illustrates good practice.

1. A messenger rope should be rigged through the fairlead selected for the first mooring rope and brought back over the rail in preparation for lowering to the launch. The first mooring rope to be brought aboard will usually be the port line. However, to avoid crossing the mooring ropes, the instructions of the berthing master or pilot as to which rope should be rigged first should be followed.
2. The messenger rope should not be lowered over the centre of the bow, but should instead be lowered over the side of the forecastle. This ensures that the launch does not have to position itself directly ahead of the tanker to receive the messenger. This is especially important for tankers fitted with large bulbous bows.
3. The other end of the messenger rope should be wrapped around the forward windlass (gypsy) on the winch in readiness to heave up. As soon as the launch has made the messenger fast to the pick-up rope and is clear of the ropes, the messenger should be winched aboard the tanker as rapidly as possible.
4. As the mooring pick-up rope is winched in, it should be flaked on deck. When the chafing chain passes through the fairlead it should be stopped.
5. Once the first mooring line is secured, the messenger rope should be rigged through the fairlead selected for the second mooring rope and then dropped to the launch as before. The second

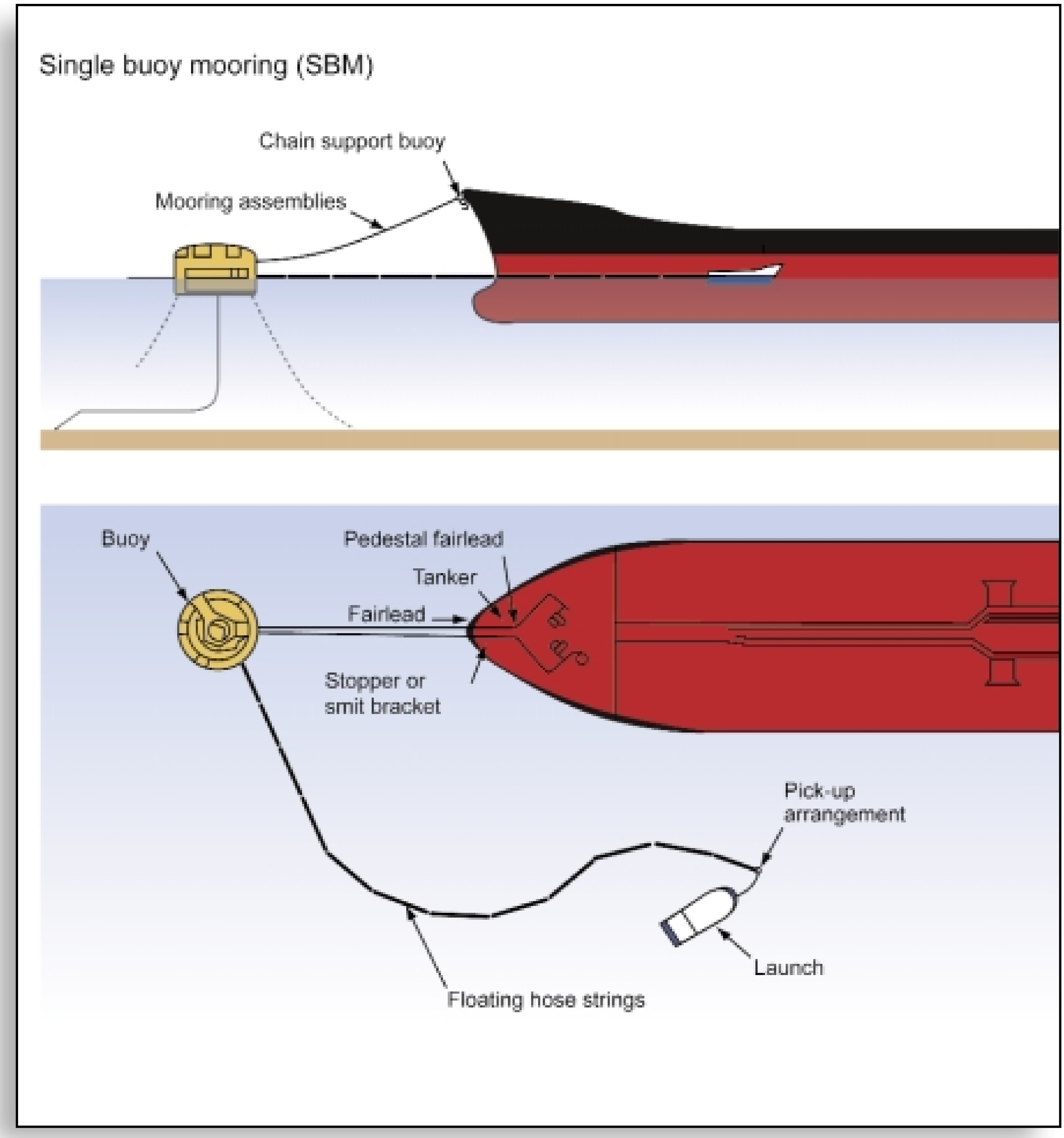

Figure 3.25 – Single Buoy Mooring

mooring rope is then brought aboard and secured.

3.4.6.4 Practices at SPMs to Reduce High Mooring Line Loads or Buoy Ride-Up

Once moored, the terminal may request the ship to go astern slowly to prevent the ship riding up on the buoy, or to keep tension on the mooring rope, so that the ship may weathervane with a change in tide. Care must be exercised in agreeing to these requests. On many ships, when less than 10 rpm is requested over protracted periods, damage to stern tube bearings from lack of positive lubrication could occur.

Similarly, a number of terminals request 25 rpm astern for protracted periods of time to reduce the vessel's yawing, thereby reducing mooring loads. Before agreeing to this type of request, the ship's personnel should confirm that the ship actually has this capability.

In many ports where this is required, a tug is fixed to the stern of the vessel to keep it away from the buoy.

3.4.6.5 SPM Load Monitoring

Load Monitoring will be achieved through systems that incorporate load pins into the connector plate/joints or by audible and visual alarms located on the buoy. Alarm status will be displayed remotely via telemetry.

Power on a buoy for telemetry, navigation light etc, is often generated by marinised solar panels or by using 12V DC batteries with back up capacity.

Continuous telemetry monitoring, which is typically via a UHF radio link, is also possible and the range can be up to 20 kilometres over water.

Remote Displays will display and record signals for:

- Hawser load dynamics
- wind speed/direction
- current
- line pressure
- temperature
- alarm status
- battery voltage
- navigational aids operation
- lighting status
- manned/unmanned indicator.

'Intelligent' load pins such as the SmartCell® shown in Figure 3.28, which are instrumented to allow mooring line tensions to be measured can replace the standard connector swivel pin.

SPM monitoring instrumentation, such as shown in Figure 3.26, will provide load data to the operator. Alarm warnings should require operator acknowledgement.

3.4.7 Shore Based Mooring Equipment

This equipment must be compatible with tanker moorings, be properly located and be of sufficient capacity to ensure safe moorings and straightforward line handling.

3.4.7.1 Capstans

Line handling units for pulling tanker mooring lines ashore have vertical spindles and should be located at each mooring point. They will be either integrally built into the quick release mooring device or be located immediately adjacent to it, in a position that enables the eye of the mooring line to be slipped over the mooring hook. The unit should have a minimum loaded pulling capacity of approximately 2000 kg at a speed of about 24 m per minute. Conditions requiring long pulls over soft sea beds may require higher pulling capacity for gear operated capstans. The motors should be the reversing type to allow unwrapping of a seized tag line or messenger. Capstans should be able to hold the load with the motor stopped.

The use of capstans often results in surplus bights of messenger line and slippage, requiring greater operator care compared to winch operations.

3.4.7.2 Winches

Winches (ie with horizontal drums), are preferred by some operators. They have the same pulling and load characteristics as capstans and are generally preferred for use with a gallows, which permits the line to be placed over the quick release hook more readily.

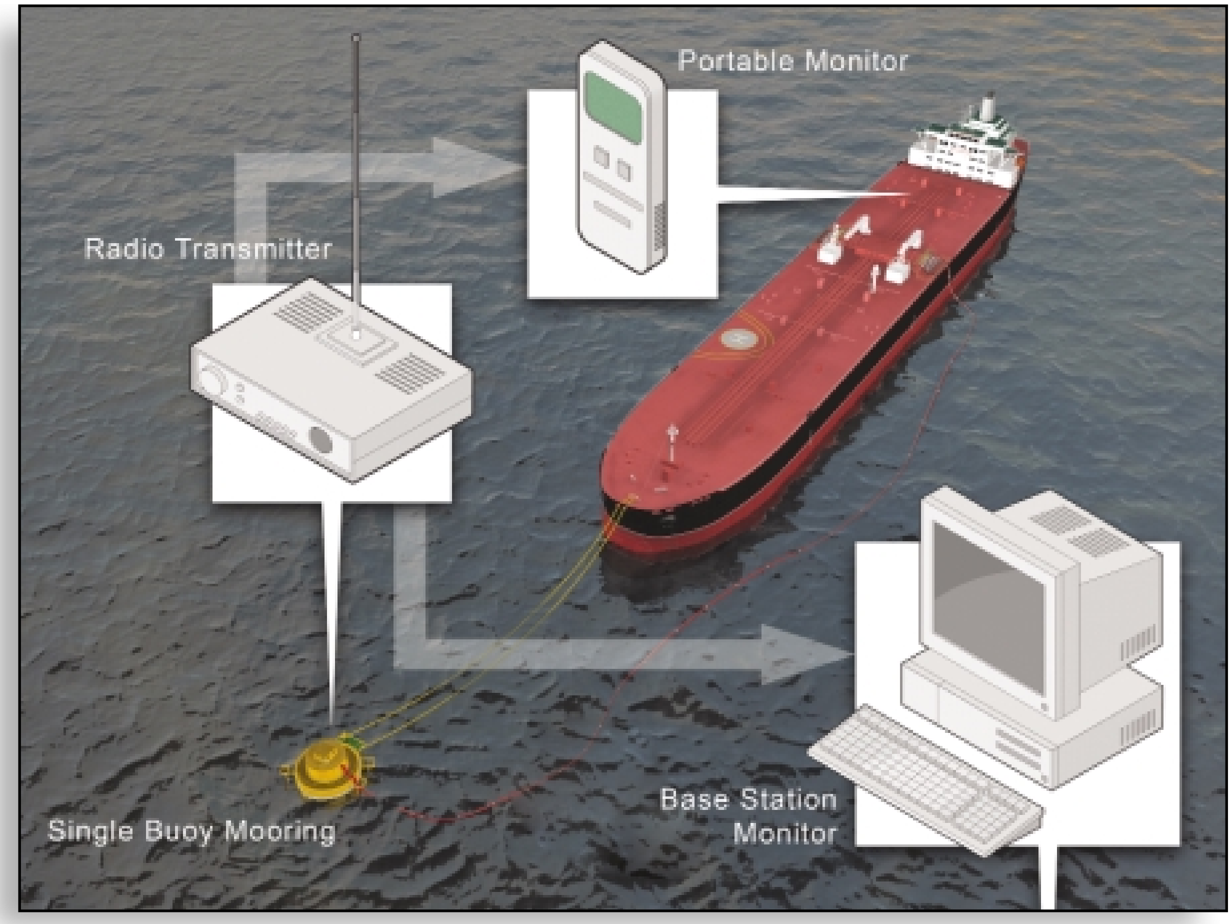

Figure 3.26 – SPM Monitoring Schematic
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Figure 3.27 – SPM Handheld Remote Monitor
Reproduced with permission from Harbour & Marine Engineering

Intrinsically safe handheld monitor. This receives data from the SPM every 5 seconds, displays up to 4 pages of LCD data and features both audible and vibrating alarms.

Figure 3.28 – SPM Load Pin
Reproduced with permission from Harbour & Marine Engineering

Figure 3.29 – Capstan
Reproduced with permission from Harbour & Marine Engineering

3.4.7.3 Fairleads for Messengers

Suitably located fairleads should be provided adjacent to the capstan or winch to facilitate the placing of mooring lines on quick release hooks.

3.4.7.4 Quick Release Hooks

This type of mooring unit is recommended for the safe mooring of large ships (figure 3.30). Each hook, whether single or part of a multiple hook unit, should have a safe working load of not less than the MBL of the largest line anticipated.

One mooring line should be placed on each quick release hook so sufficient hooks must be provided to allow this. All hooks should be capable of separate release, safely from the mooring point area, under full to no load conditions. Remote hook release facilitates emergency sailing with minimum manpower availability.

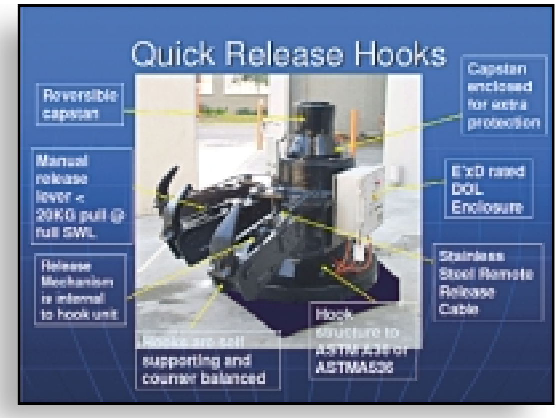

Figure 3.30 – Quick Release Hooks
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3.4.7.5 Bollards

Fixed shore bollards require a line to be lifted from the mooring point when getting underway under slack conditions and so are not recommended for large tanker berths.

3.4.7.6 Strength of Equipment

All of the equipment should be designed using appropriate safety factors, and fabricated and installed to withstand the expected maximum loads.

3.4.7.7 Increasing Restraint Provided by Ship's Mooring

An alternative to the use of shore moorings is the provision of a shore mooring point attachment for the bight of the vessel's mooring wire. The end of the ship's wire can then be hauled back onboard and secured to the ship's mooring bitts, after which the standing part is hove taut by the mooring winch and the brake is secured in the normal manner. In this way one mooring wire can be used to provide a restraint of approximately twice its normal capability.

3.4.8 Laser and GPS Docking Systems

Laser and GPS docking and piloting systems provide real-time feedback of a vessel's position during approach and

Figure 3.31 – Horn Bollard
Reproduced with permission from Harbour & Marine Engineering

Figure 3.32 – Pillar, Kidney, Horn and Tee Design Bollards
Reproduced with permission from Harbour & Marine Engineering

berthing at the jetty. Key information such as speed, distance and angle relative to the jetty are displayed to the pilot, ship's Captain and jetty operators. Data is logged and reports are available for later review or audit.

3.4.8.1 Laser Docking Aid System

A Docking Aid System is a tool used by jetty operators and marine pilots during vessel docking. The primary benefit is the provision of real time data on the vessel's position and progress, relative to the jetty, by measuring distance from the jetty and speed of approach in the critical 0 to 300 metres zone. With this data the vessel's Master and Pilot can better direct tug and shipboard personnel.

A display board that is mounted in a position clearly visible from a vessel's bridge will provide vessel speed and distance in numbers, speed trend indication and speed warning by using a red, amber and green light system. Speed and distance units are normally (see Figure 3.33):

Speed:	0.0 to 99 centimetres per second
Distance:	0.0 to 199 metres

Laser Docking Aid Systems are a reliable and precise method of measuring vessel approach over the final 200 metres to the jetty, with accuracy to 1 cm.

As an example, a system such as 'SmartDock®' uses two laser sensors located on the jetty that measure distance to the bow and stern sections of the ship. This, together with average speed, is captured at a jetty control unit and displayed to the ship and mooring crew on a wireless monitor, computer screen or jetty mounted display board. Laser sensors are the most reliable technology employed for vessel docking and operate very effectively in poor visibility and heavy rain.

The basic components of such systems are:

- Laser sensors, which may be fixed on the jetty head or provided on elevators
- jetty controller/interface which can be located indoors or on the jetty
- computer workstation to monitor, display and record information in the jetty control room
- handheld monitors, certified intrinsically safe to provide constant update of docking information to the pilot
- jetty mounted display boards, visible from the vessel's bridge to display speed of approach, distance from jetty and optional angle

Figure 3.33 – Docking System Display
Reproduced with permission from Harbour & Marine Engineering

- speed warning indication lights, which can be totally independent or integral with the large display board.

3.4.8.2 GPS Docking System

An example of a new development utilising the latest in GPS technology is the SmartDock® PILOT. This system calculates the vessel's position and displays it on an electronic chart on the pilot's laptop,

Figure 3.34 – Bulk Carrier Docking Using Laser Docking System
Reproduced with permission from Harbour & Marine Engineering

Figure 3.35 – SmartDock® DAS Screen for an LNG Vessel
Reproduced with permission from Harbour & Marine Engineering

offering piloting assistance that is berth independent.

To meet the demands of navigating and docking large vessels, the measurement of low speeds, precise heading and Rate of Turn is of utmost importance to the pilot. SmartDock® PILOT derives these measurements using GPS and Rate Of Turn (ROT) Sensors integrated via an advanced Kalman filter to create an independent system that is more accurate than ship-installed gyros, ROT sensors, and speed logs.

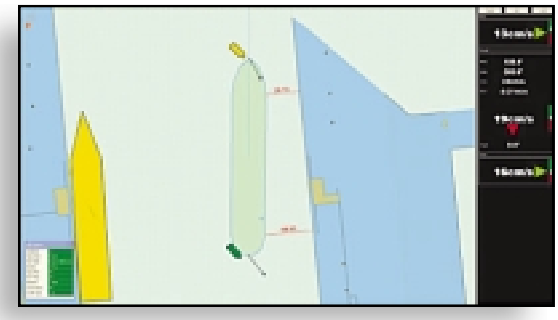

Figure 3.36 – SmartDock® Pilot Screen
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Data provided by systems such as SmartDock® PILOT system are completely independent of the ship instruments. This makes Pilots more familiar with the system and less reliant on the ships equipment, which may not be accurately calibrated.

As the laptops are self-contained and portable, the pilot will have access to navigation data from all over the bridge.

3.4.8.3 Optimoor

There are also mooring analysis software packages such as "OPTIMOOR" by Tension Technology International Ltd. These packages are designed for use by ship and terminal personnel to assess whether the ship can safely moor at that berth before it arrives. The packages follow the mooring guidance issued by OCIMF and include the OCIMF wind and current coefficients for tanker moorings. At tanker jetties, OPTIMOOR can be used to assess the adequacy of the ship's mooring equipment for the berth's mooring arrangement. Wind or current limitations and details of tides can be used to predict mooring line tending requirements.

3.4.8.4 Vessel Drift-Warning Monitoring

Following the mooring of the vessel, the docking system can be switched to drift-warning mode. Should the vessel drift a pre-determined distance away from the fenders, alarms will be raised to notify both jetty and ship's staff.

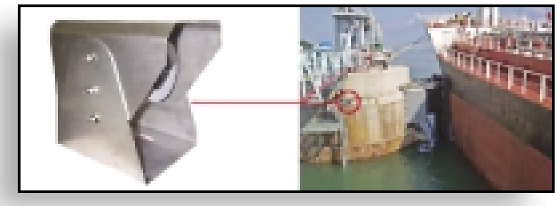

Figure 3.37 – Laser Sensor Installed on Elevator System to Accommodate High/Low Tidal Range.
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3.5 Tugs and the Safety of Tankers

There are four areas where tugs are used to maintain the safety of tankers:

Escorting tankers
This is carried out from the tanker's arrival position off the port, at speeds of 7 to about 12 knots.

Ship-handling and berthing assistance
Manoeuvring and berthing assistance within the port or harbour.

Offshore berthing
Assistance in mooring and hose handling operations at offshore terminals with Single-Point Mooring (SPM) or Single-Buoy Mooring (SBM).

Fire-fighting and stand by duties
Provision of a rapid response to cover fire-fighting and emergency towing within the port area.

3.5.1 Escorting Tankers

Tankers are escorted by tugs in high traffic tanker routes and in narrow or dangerous waters. The basics of ship-handling continue to apply but the key areas for the tug are available speed, towline force and available time.

Tanker escorting is comparatively new and its need was proposed after a number of severe tanker accidents occurred. The case for escorting is based on a risk analysis of possible and likely accidents and their severity. The primary benefit provided by an escort or safety vessel is immediate assistance to the vessel, achieved by

Figure 3.38 – A Tanker in a Confined Environmentally Sensitive Waterway

connecting the tug to the tanker. The best connection position is at the stern of the tanker. Rudder or engine problems are a frequent cause of incident, as braking and steering forces are exerted most efficiently from here. In certain cases, such as fire or explosion, connection to the stern of the vessel may be hampered and the alternative is to make fast at the bow of the tanker.

While under escort a tanker must reduce to a speed that allows the tug to provide efficient assistance in the event of loss of control, taking into consideration the inertia forces of the tanker. The tanker's speed must be sufficient to allow control of the vessel in the prevailing conditions.

An escort vessel should:

- Be able to quickly and safely make fast at the stern of a tanker at escorting speed
- under normal circumstances, follow the tanker with as little interference to the behaviour of the tanker as possible
- be able to immediately exert an effective braking force
- be able to immediately apply active steering forces that exceed the tanker's own capabilities under the prevailing conditions
- be able to make fast at the bow of a tanker safely and at high speed, taking into consideration the existing pressure conditions in this area
- be able to immediately fight any fire on board the tanker while moving
- be able to take immediate appropriate action in order to prevent any oil spill spreading.

3.5.2 Ship-handling and Berthing Assistance

The modern tug can deal with:

- The forces interacting between the tug and the vessel to be assisted at slow and high speeds

Figure 3.39 – Tug Escorting a Tanker

Figure 3.40 – Tug Assisting a Chemical Tanker to Berth

- the two principle forces acting on the tug whilst berthing, ie the propeller thrust and towline force. The aim is to minimise the danger of capsizing under all operating conditions.

3.5.3 Offshore Berthing

At offshore terminals with Single-Point Mooring (SPM or SBM), oil is handled by floating hoses.

Tugs are used to connect the hose lines to the tanker. As the hose lines are easily kinked or squeezed, control must be extremely sensitive and precise. Heavy seas and swells in these locations frequently makes the task more difficult.

3.5.4 Fire-fighting and Stand-by Duties

The modern tug is an ideal fire-fighting vessel as a vast amount of power can be diverted from the main engines to power the fire-fighting pumps without rendering the engines either ineffective or incapable of keeping the vessel under control. In the case of escort vessels, effective fire-fighting could even begin while the tanker is still on passage or while reducing her speed.

At many loading and discharge berths it is common to have the tug acting on stand-by duties. This allows it to be quickly deployed if it is required for fire-fighting or emergency duties. In the event of oil pollution, the tug can be used to position skimmer arms, operate skimmer vessels without self-propulsion or to arrange oil spill booms.

Figure 3.41 – Modern Tug with Fire -fighting Capabilities

3.5.5 Types of Tugs

3.5.5.1 Conventional Tugs

Still operated in many parts of the world, the conventional tug is recognisable by the following features:

- Its propulsion unit, which is generally a single screw propeller and a standard rudder. This is similar to the configuration on many merchant ships today, though more recently they may have been replaced by a controllable pitch propeller.
- the location of the towing hook, which is generally fixed amidships, tends to limit the tugs manoeuvrability and leaves it at risk of capsizing (or girting) if it gets in to an awkward position, particularly if the vessel she is connected to is turning. The risk of capsize to the tug is the same, regardless of whether she is connected to the bow or the stern.

3.5.5.2 Tractor Tugs

A tractor tug uses multi-directional propulsion units that consist of controllable pitch rotating blades located below the conning position in the wheelhouse. A leading manufacturer of this type of propulsion unit is Voith Schneider and, in the hands of a skilled tug Master, they create a highly manoeuvrable vessel. In addition to the high degree of manoeuvrability that the propulsion unit offers, the towing line is operated from a winch drum, which the tug master can operate remotely from the wheelhouse, to increase or decrease the length of towline as required.

3.5.5.3 Azimuth Stern Drive Tug

This type of tug combines the benefits of both conventional tugs and tractor tugs. The main propulsion units are located aft, like a conventional tug, but these units are two

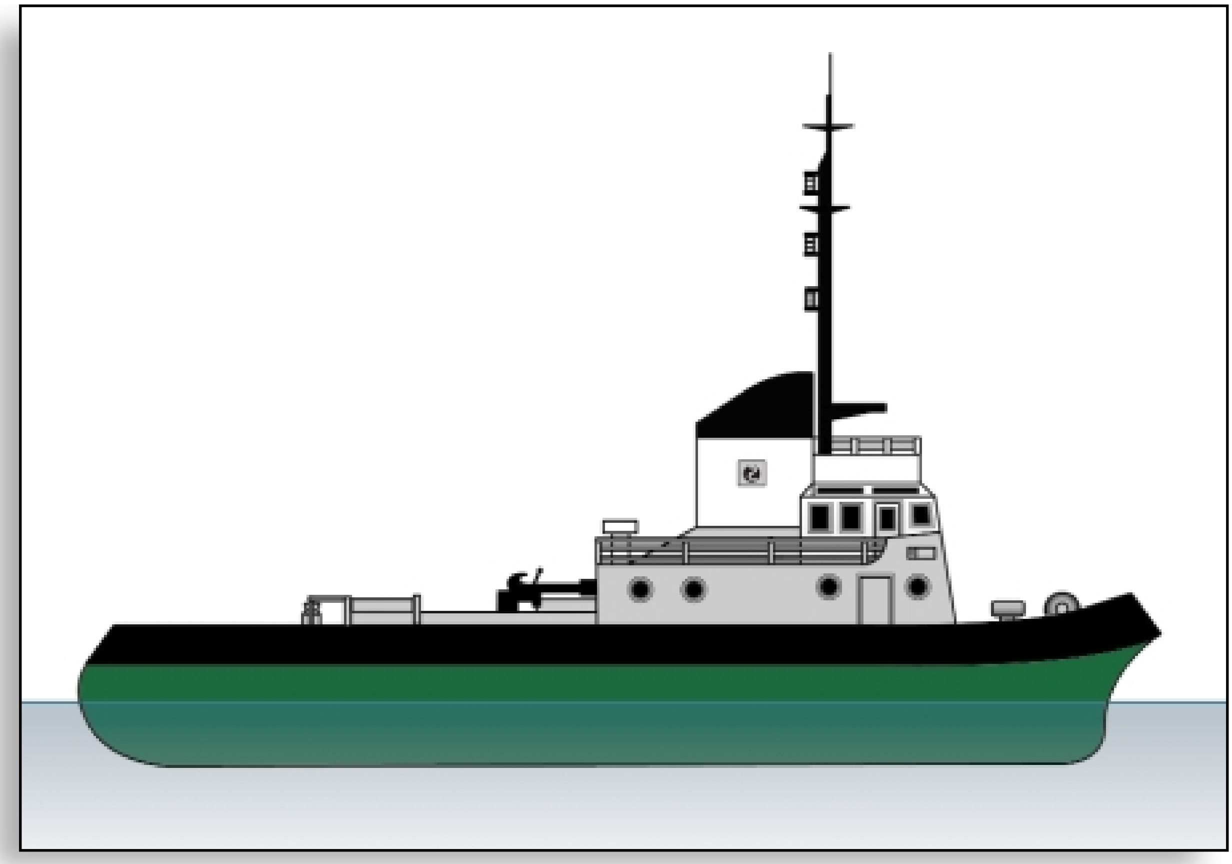

Figure 3.42 – Conventional Tug

rotating azimuth systems, similar to those in use on a tractor tug. The towing position can be either located amidships like a conventional tug or located forward. When secured to the forward winch, this tug can push or pull (tow) and, when pulling, gains a huge lever effect from the distance that the propulsion units are from the forward winch position.

Tugs are generally rated by "Bollard Pull", This is the force produced by a tug, in tonnes, when pulling against a static bollard.

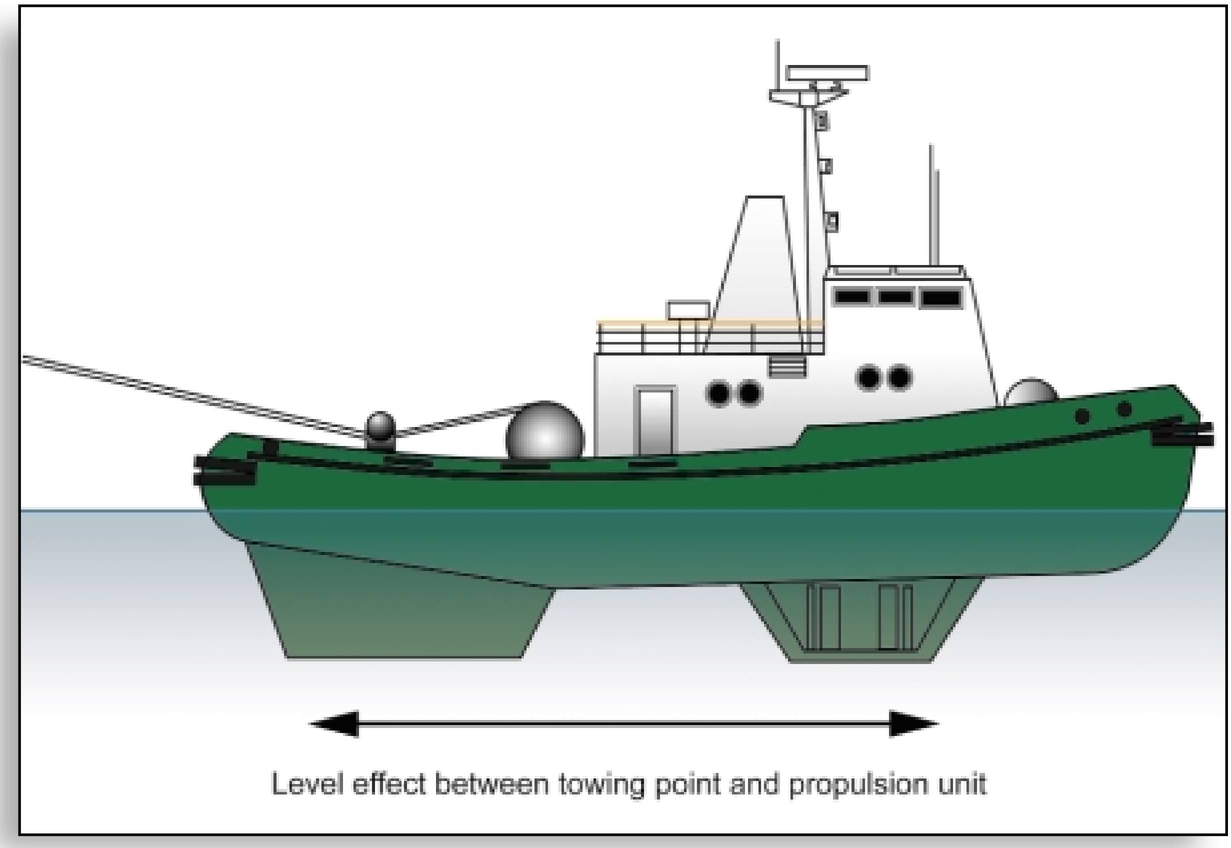

Figure 3.43 – Tractor Tug

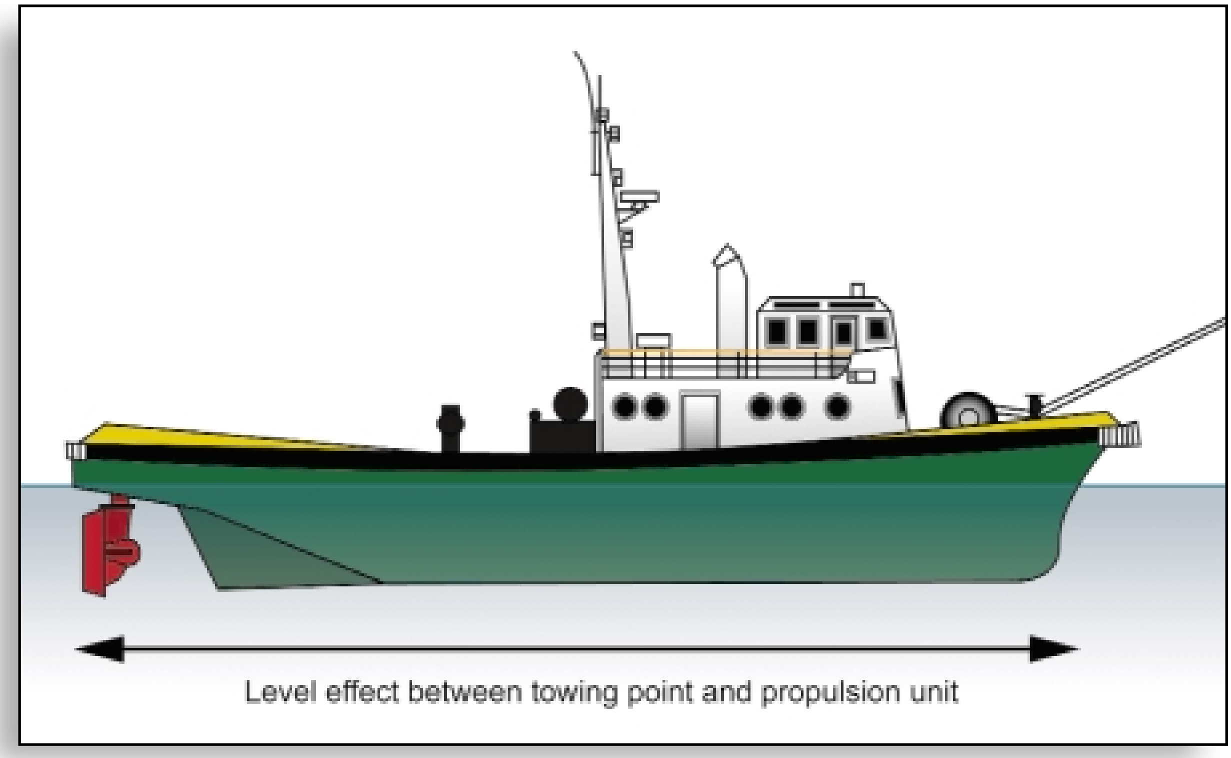

Figure 3.44 – Azimuth Stern Drive Tug

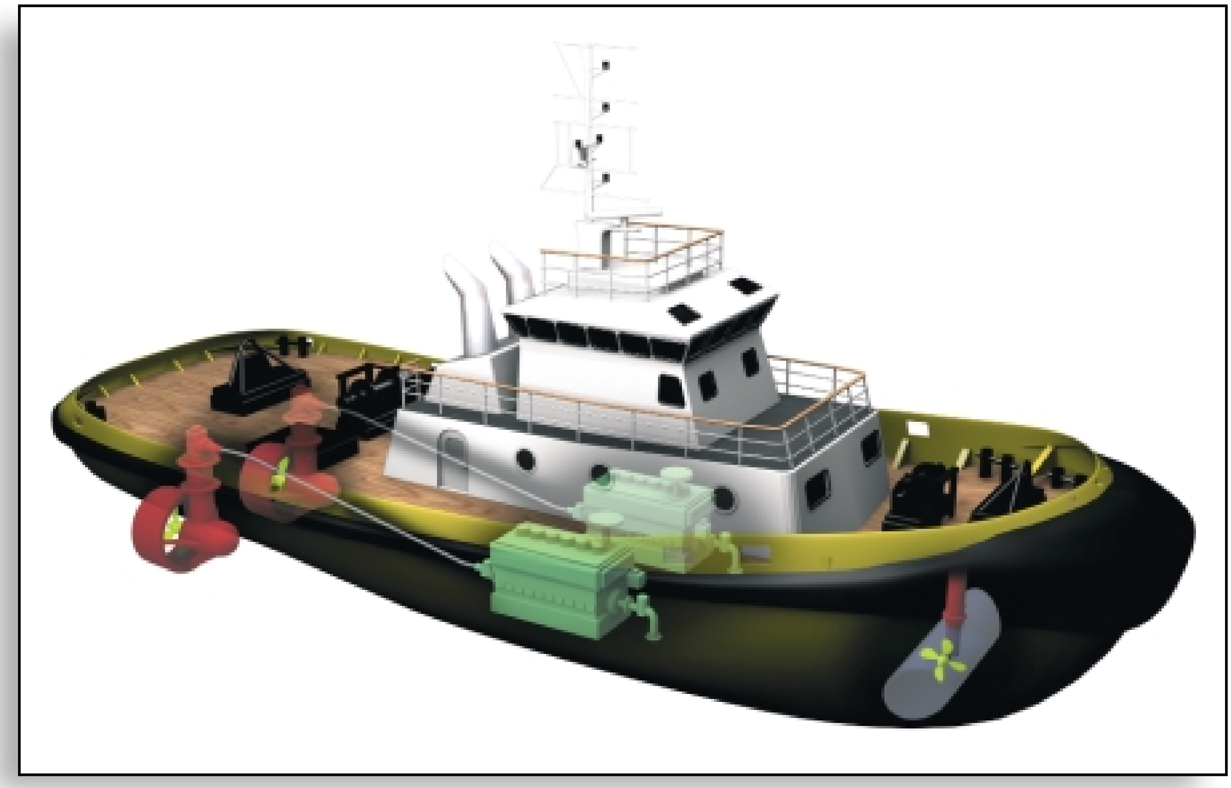

Figure 3.45 – Azimuth Stern Drive Tug

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