A MASTER’S GUIDE TO BERTHING

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BERTHING

Ship handling is an art rather than a science. However, a ship handler who knows the science will be better at his art. Knowledge of the science will enable easy identification of a ship’s manoeuvring characteristics and quick evaluation of the skills needed for control. A ship handler needs to understand what is happening to his ship and, more importantly, what will happen a short time into the future. This knowledge is essential in a port environment when a ship encounters close quarter situations, narrow channels and the effects of cross-winds, tides and currents. The tide of course affects the water flow but the change in water level can also change the ship’s side area exposed to the wind when approaching berths and jetties. The culmination of any voyage is usually the controlled coming alongside of the ship to a stationary berth or jetty. Berthing requires precise and gentle control if the ship is not to damage the berth. Such precise control is demonstrated every day by ship handlers in ports all over the world. Most ships dock safely, most of the time – a testament to the skill and ability of pilots, masters, bridge team members, deck and engine personnel – but the outcome of a manoeuvre is not always successful. Ships can, and do, run aground, demolish jetties, hit the berth and collide with other ships with alarming frequency, giving rise to loss of life, environmental pollution and property damage. The master should never rely solely on the pilot's actions to berth his ship. The master must always remain in full control of the operation. The purpose of this guide is to provide some insight into what can go wrong and why; why ships are designed the way they are; why they handle the way they do; and how to berth them. In the final chapter, there is advice on pilotage. On its own, the guide will not teach you how to become a ship handler, but it does provide background material to help a good ship handler become a better one. Throughout the berthing examples, it has been assumed that the ship has a single right-handed propeller and that bulk carriers and tankers have their accommodation aft. The guide is unable to cover all the different ship types. Masters must become acquainted with their own ship configurations.
GOLDEN RULES OF BERTHING

There are certain actions that a master should always take before and during berthing.

The most important rules are:

• slow speed
• controlled approach
• planning
• team work
• checking equipment

Bridge team

• the master must ensure that all ships personnel are familiar with the expected approach to the berth/quay/lock or terminal and what is expected of them. A positive team approach to the task improves efficiency and communication

Passage planning

• always brief the bridge team to ensure the officer of the watch (OOW), helmsman, lookout and pilot are fully aware of the expected manoeuvres and the likely effects of wind, tide and current

• always passage plan from berth to berth. Pay careful attention to the dangers that are likely to be encountered during periods under pilotage

• always fully brief the pilot, making sure that he understands the ship’s speed and manoeuvring characteristics

• always ask the pilot to discuss the passage and berthing plan. Ask questions if anything is unclear

• always check with the pilot that the ship will have under-keel clearance at all times

• always have your anchors ready to let go and forecastle manned in advance of berthing

Equipment check

• ensure main engines and thrusters are fully operational before approaching the berth

Main engines should be tested before arriving at the pilot station ahead and astern. Remote controls checked
• ensure steering gears fully operational. Both steering motors operating. Hand steering mode operational
• ensure all bridge equipment checked including engine movement recorders, VDR, radars, course recorders, echo sounders and all remote read outs. Use a bridge equipment check list

Working with tugs

• consider the use of tug assistance, where wind, tide and current or the ship’s handling characteristics create difficult berthing conditions

• always estimate windage and use this estimate to determine the number of tugs required

• when berthing with a bow thruster, a large ship may need a tug to control the ship’s stern

• when estimating the number of tugs consider their bollard pull and propulsion arrangements

Manoeuvring

• avoid high forward speed particularly when working with tugs, when using a bow thruster, when under-keel clearance is small, when sailing in a narrow channel or when close to other ships

• test astern movement and wait until the ship moves positively astern before stopping

• remember that a kick ahead can be used to initiate and maintain a turn when speed is low

• remember that the ship’s pivot point is forward of amidships when steaming ahead

• remember that a ship will want to settle with the pivot point to the windward of, and in alignment with, the point of influence of wind

• remember that the point of influence of wind changes with wind direction and the ship’s heading

• remember that at low speed, current and wind have a greater effect on manoeuvrability and that high-sided ships will experience a pronounced effect from leeway

• remember draught and trim affect the ship’s manoeuvring characteristics
Finally

• never ring 'finished with engines' until every mooring line has been made fast

• always anticipate well ahead and expect the unexpected to occur

• always brief the officers in charge of the berthing crew fore and aft of what is expected and allow them sufficient time to prepare for berthing. The pilot should always be consulted on the expected ‘tie up’ and the order of running the mooring lines

Remember :
The first rule of berthing is to approach at a slow and controlled speed. The second rule is bridge team work and preparation.
SHIP FACTORS THAT AFFECT MANOEUVRING

Underwater hull geometry
Length to beam (L/B), beam to draught (B/T), block coefficient, prismatic coefficient (ratios of the ship’s volume of displacement against the volume of a rectangular block or a prism) and location of longitudinal centre of buoyancy, all give an indication of how a ship will handle.
High values of L/B are associated with good course directional stability. Container ships are likely to have an L/B ratio of approximately 8, while harbour tugs, which need to be able to turn quickly and where course stability is not required, have a value of 2.5 to 3.
High values of B/T increase leeway and the tendency for a ship in a beam wind to ‘skate across the sea surface’. A B/T ratio of over 4 is large. Most merchant ships have a B/T ratio in the range of 2.75 to 3.75. A 22-metre fast motor yacht will have a B/T ratio of about 5.75.
Ships with large block and prismatic coefficients have poor course stability and a readiness to turn. When turning, they will do so easily. Large tankers have these characteristics.
Ships with a large protruding bulbous bow are likely to have their longitudinal centre of buoyancy far forward. As a result, the ship will show a tendency to turn.

The pivot point
A ship rotates about a point situated along its length, called the ‘pivot point’. When a force is applied to a ship, which has the result of causing the ship to turn (for example, the rudder), the ship will turn around a vertical axis which is conveniently referred to as the pivot point.
The position of the pivot point depends on a number of influences. With headway, the pivot point lies between 1/4 and 1/3 of the ship’s length from the bow, and with sternway, it lies a corresponding distance from the stern. In the case of a ship without headway through the water but turning, its position will depend on the magnitude and position of the applied force(s), whether resulting from the rudder, thrusters, tug, wind or other influence. The pivot point traces the path that the ship follows.

Lateral motion
Ships move laterally when turning because the pivot point is not located at the ship’s centre.
When moving forward and turning to starboard, the ship’s lateral movement is to port. When moving astern and turning to starboard, lateral movement is to starboard.
It is important to understand where the pivot point lies and how lateral movement can cause sideways drift; this knowledge is essential when manoeuvring close to hazards.
Propeller and rudder
The rudder acts as a hydrofoil. By itself, it is a passive instrument and relies on water passing over it to give it ‘lift’ to make it more effective. Rudders are placed at the stern of a ship for this reason and to take advantage of the forward pivot point, which enhances the effect. Water flow is provided by the ship passing through the water and by the propeller forcing water over the rudder in the process of driving the ship. The optimum steerage force is provided by water flow generated by a turning propeller. Water flow is vital in maintaining control of the ship. While water flow provided by the ship’s motion alone can be effective, the effect will diminish as speed is reduced. Obstacles that deflect flow, such as a stopped propeller in front of the rudder, particularly when the propeller is large, can reduce rudder effectiveness. Reduced or disturbed flow will result in a poor response to rudder movements.

Conventional rudders are described as ‘balanced’; part of the rudder area is forward of the pintles to help the rudder turn and to ease the load on the steering motor. This arrangement provides for better hydrodynamic loading. A flap (Becker rudder) can be fitted to the rudder’s trailing edge. The flap works to increase the effective camber of the rudder and to increase lift.

Rudders can be defined by what is known as the ‘rudder area ratio’, which is a ratio of the surface area of the rudder divided by the ship’s side area beneath the water level. The rudder area ratio gives an indication of the likely effectiveness of a rudder. Merchant ship ratios range from 0.016 to 0.035. The larger the ratio, the greater the effect the rudder will have.

The balance between headway and lift is dependent on how much of the propeller disc is blanked by the rudder when hard over. This knowledge is important when considering the effect of a ‘kick ahead’. If the optimum rudder angle for a given speed is exceeded the radius of turn will increase because the rudder will generate more drag than lift.

Thrust vectoring devices – Azimuth thrusters
Thrust vectoring devices are fitted as an alternative to a rudder. They operate under the principle that a rudder is effective because it deflects the propeller slipstream, which initiates a turn and maintains a state of balance once the turn is established. Consequently, manoeuvrability is enhanced when all the thrust from a propeller is vectored. Azimuthing ducted thrusters, cycloidal thrusters and pump jets all operate by directing thrust to initiate and to maintain the turn.

Azipods are devices where the prime mover is an electric motor, encased in an underwater streamlined pod, which connects directly to a propeller. Pods are fitted to the outside of a hull. They can be azimuthing i.e. used as a rotational device or used in a fixed position in a similar way as a fixed propeller. Propellers attached to them can push or pull. A propulsion pod acts as both propeller and rudder.
Bow thrusters and their use
Lateral thrusters can be fitted in the bow or the stern.

Bow thrusters
Their objectiveness will depend upon:
• the distance between the thrusters and the ship’s pivot position
• the forward draught
• the ship’s speed

Lateral thrusters are most effective when a ship has neither headway nor sternway. They create a turning effect by providing a side force at their location. Their effectiveness will depend upon the distance between the thruster and ship’s pivot point. When berthing a ship that has a single bow thruster, and no stern thruster, it is important not to become too focused on the bow, because this can be controlled with the thruster. Plan to get the stern alongside as a priority. Remember that pure rotation can only be induced by two lateral thrusters, one forward and one aft, opposing each other, and that a tug may be needed to control the stern of a large ship.

Bow thrusters are used when it is required to ‘breast’ on to or off a berth, to move the ship’s head from a jetty or to turn the ship in a limited space. Modern ships fitted with a bow thruster will often berth without tug assistance.

However, a bow thruster will lose its effectiveness as a ship’s speed increases. Depending on the hull and thrust tunnel design, thrust effectiveness can be lost at between 2 and 5 knots. The reason for this is the merging of the slipstream from the thruster with the general flow around a forward moving hull. When speed increases above 2 knots, local loss of pressure over the hull, downstream from the thruster, creates a turning moment opposite to the moment produced by the thruster. The thruster may become ineffective.

Thrusting when stopped
When stopped and thrusting, a ship’s pivot point is likely to be aft. If a bow thruster is put to starboard on a stopped ship, the ship will turn to starboard.

Thrusting with headway
The pivot point will be forward, so thrusting will be ineffective, especially at high speeds.

Thrusting with sternway
The pivot point is aft and when the bow thruster is put to starboard, the ship’s bow will swing to starboard. The thruster will be effective, and will act as a form of ‘rudder’.
Rudder response
The time it takes for the rudder to respond to a helm order will determine how rapidly a ship gets into a turn. The quicker the rudder responds, the sooner the ship will begin to turn.

Single rudders and twin screw ships
Manoeuvring characteristics at low speeds will generally be poor on twin screw ships fitted with a single centre line rudder. This is because the single centre line rudder may have to be moved to large angles before any part of it becomes immersed in the slipstream of one of the propellers. When not immersed, the lift produced by the rudder at low speeds will be very small, resulting in large turning circles and poor helm response.

Transverse thrust
Transverse thrust is the tendency for a forward or astern running propeller to move the stern to starboard or port. Transverse thrust is caused by interaction between the hull, propeller and rudder. The effect of transverse thrust is a slight tendency for the bow to swing to port on a ship with a right-handed propeller turning ahead. Transverse thrust is more pronounced when propellers are moving astern. When moving astern, transverse thrust is caused by water passing through the astern moving propeller creating high pressure on the starboard quarter of the hull, which produces a force that pushes the ship’s stern to port. Rudder angle can influence the magnitude of this force.
Masters should be aware of the variable effect of transverse thrust. As water flow over a ship’s hull changes, so does transverse thrust. The difference is most noticeable in shallow water. For example, a ship that turns to starboard in deep water may well turn to port in shallow water. Also, the magnitude of the force will change and, by implication, there will be a range of water depths for which the bias may be difficult to predict, something that is especially true when a ship is stopping in water of reducing depth.
Transverse thrust is often used to help bring the ship’s stern alongside during berthing.
When a propeller is put astern on a ship moving forward at speed, the initial effect of transverse thrust is slight. However, as the ship’s forward motion decreases, the effect of transverse thrust increases.
It is essential for a master to understand just how much effect transverse thrust has on his particular ship. He should also be aware on how the traverse effect can vary or change due to its currents and depths of water.
Approach speed
Many berthing accidents occur because the speed of approach is too high. The master should advise the pilot of the ship’s stopping distance and general manoeuvring characteristics, giving particular emphasis to speed, corresponding engine revolutions and to the critical range. When close to a dock, speed should be the minimum necessary to maintain control. Masters should plan ahead with the pilot on if, and how many, tugs are to be used.

Control while slowing
It can be difficult to reduce speed and maintain control. This is because reduction in propeller speed reduces water flow over the rudder and the rudder becomes less effective.

The normal procedure for stopping is to put engines astern. However, when a propeller rotates astern, water flow over the rudder is broken and the ship will be less responsive to helm. In addition, there is the disruptive effect of transverse thrust.

For this reason, it is essential to plan a stop by reducing speed in good time. Also, it should be appreciated that putting engines to full astern during an emergency could result in a loss of steerage.

Kick ahead (astern)
The ‘kick ahead’ is used when a ship is moving forward at very slow speed due to minimal water flow over the rudder and the ship is not responding to helm. It is also used to initiate a turn or to maintain a heading. Engines are put ahead for a short burst with the objective of increasing water flow over the rudder, but without increasing the ship’s speed. Engine power is reduced before the ship’s longitudinal inertia is overcome and she begins to accelerate.

When using the ‘kick ahead’, it should be borne in mind that prolonged and frequent kicks ahead will increase the ship’s speed; the master should know his ship and how it reacts to ‘kicks ahead’ or astern. Note for example that ships with hull growth tend to the slower and more ‘sluggish’ at slow speeds. Apply full rudder before initiating the ‘kick ahead’ to provide maximum steering force. Anything less than hard over during turning will allow a greater proportion of the power to drive the ship ahead. It is important to reduce engine power before reducing helm.
BERTHING IN WIND

Wind and its effect
Wind has a significant effect on a ship. It causes heading changes and leeway. Failure to compensate correctly for wind during berthing is a significant cause of berthing accidents. The difficulty in allowing for wind arises from the variable effect that wind can have on a ship because of changes in a ship’s heading and speed. Wind has special significance in the handling of high-sided ships such as car carriers, container ships, bulk and tankers in ballast. The effect will vary with the relative wind direction and the speed of the ship. Although wind force and direction can be estimated from information obtained from a variety of sources, such as weather forecasts, VTS information, the ship’s own wind instrumentation and personal observation, local conditions can change rapidly and with little warning. Control of a ship can be easily lost during the passage of a squall. There is an obvious need to understand how wind will affect your ship, and how this effect can be difficult to predict. For example, it might appear logical that the effect of wind on a tanker stopped in the water would cause the bow to swing towards the wind. However, experience shows that a tanker stopped in the water will usually lie with the wind forward of the beam rather than fine on the bow. It is especially difficult to predict the effect of wind on a partially loaded container ship. Ships with high sides and large windage, car carriers, loaded containers and passenger ships, for example, should always keep an eye on changes in wind direction. Cloud formations to windward can often be an indication of approaching squalls.

The centre of lateral resistance
The force of the wind causes the ship to drift and, by doing so, hydrodynamic forces act on the underwater hull to resist the effect of the wind. The point of influence of these underwater forces is known as the Centre of Lateral Resistance (CLR) and is the point on the underwater hull at which the whole hydrodynamic force can be considered to act. Similarly, there is a point of influence of wind (W) which has an important relationship with the CLR. W is likely to alter frequently as it will change in relation to the wind direction and the ship’s heading. To anticipate the effect wind will have on a ship’s heading, W must be viewed in relation to CLR. Ship handlers prefer to refer to pivot point (P) rather than CLR when discussing the effects of wind on a ship with headway or sternway. However, a stopped ship does not have a pivot point and for this reason CLR should always be used. In the discussion which follows, CLR is used for a stopped ship and P for a ship with motion.

The point of influence of wind
The point of influence of wind (W) is that point on the ship’s above-water structure upon which the whole force of the wind can be considered an act. Unlike a ship’s centre of gravity, the point of influence of wind moves depending on the profile of the ship presented to the wind. When a ship is beam to the wind, W will be fairly
close to the mid-length point, slightly aft in the case of ships with aft accommodation and slightly forward if the accommodation is forward. A ship will always want to settle into a position where the pivot point and point of influence of wind are in alignment.

**Ship stopped – ship with accommodation block aft**
On a stopped ship with the wind on her beam, W will be close to the ship’s mid-length. When stopped in the water, the CLR is also at its mid-length. The difference in location between the two points produces a small couple, and the ship will turn with its head towards the wind. As the ship turns, W moves until it is close to the CLR, when the couple reduces to zero. The ship will settle on this heading, usually with the wind slightly forward of the beam.

**Ship with headway – ship with accommodation block aft**
If a ship has headway, P is forward and the lever between W and P is large. The resultant force will cause the ship’s head to turn to the wind.
Ship with sternway – ship with accommodation block aft
If a ship has sternway, P is aft of W and the ship’s stern will seek the wind. However, and for the majority of ships, the complexity of the aft-end accommodation structure can cause W to move further aft as the ship turns. Eventually, the ship may settle with the wind broad on the quarter rather than the stern.

![Diagram of wind direction and turning lever]

**Force of the wind**
This calculation below gives an estimate of the total force of wind on a ship’s side. It will give an indication of the total power that tugs will need in order to overcome this force. Wind force can be estimated by the formula:

\[ F = \left( \frac{V^2}{18,000} \right) \times \text{windage area} \]

where F is the wind force in tonnes per square metre, V is the wind speed in m/s (metres per second) and windage area is the area of ship exposed to the wind in square metres. Estimate windage area for a beam wind by multiplying length by freeboard and adding the side area of the accommodation housing. For a head wind, multiply beam by freeboard and add the area of the bridge front. As a ‘rule of thumb’, double the figure obtained for F and order an additional tug with a suitable bollard pull. This calculation gives an estimate of the total force of wind on a ship’s side. It will give an indication of the total power that tugs will need in order to overcome this force. It should be remembered that a ship will always want to settle on a heading where the ship’s pivot point is in alignment with the position of the wind’s point of influence. When navigating on such a course, a ship will show good course-keeping properties. As a result, it is preferable to berth with head to wind with headway or to berth with stern to wind with sternway. In addition, knowledge of the location of W, compared with P, makes it possible to predict whether the ship’s head or stern will ‘go to wind’ as a ship is stopped. The ship will want to settle with P in alignment with and to windward of W. High-sided ships may suffer more from leeway than from heading change.
Berthing in wind
A ship is most vulnerable when presenting its broadside, the area of greatest windage, to the wind. In strong winds, it may be difficult to counteract the effect without tug assistance or the use of a thruster. If close to a berth, it is essential that mooring lines are set as quickly as possible. Ideally, plan the manoeuvring so as to present the minimum profile to the wind, that is, head to wind, or at least reduce to a minimum the time the wind is at a broad angle to the ship.

Points to remember:
• ensure that conditions are safe and suitable for the envisaged manoeuvre. It will be cheaper to delay the ship until the wind moderates than to deal with the aftermath of an accident

• wind force acting on a ship increases with the square of the wind speed. Doubling the wind speed gives four times the force. Sudden gusts of wind are therefore dangerous

• if berthing in high winds, take evasive/corrective action early. Attach tugs early and before they are needed. Bow thrusters effectiveness can be limited

• tugs should be of sufficient strength to counteract the effects of wind and to get the ship to the required destination

• the berthing plan should be devised to minimise the adverse effect of wind and to maximise its assistance

• thrusters are more effective at slow speed

• a ship is more vulnerable to wind at slow speed. As speed reduces, hydrodynamic forces reduce, and the effect of wind on heading and leeway increases

• take corrective action as soon as it becomes obvious that it is needed. The earlier that action is taken, the less that needs to be done. The longer things are left, the more drastic will be the action needed to correct the situation

• ‘kicks ahead’ can be effective in controlling a ship in windy conditions

• consider any special circumstances where wind may affect ship handling. Trim, freeboard and deck cargo can vary the position of W and the force of the wind on the ship, and change the ship’s natural tendency in wind. For example, significant trim by the stern can cause W to move ahead of P. In these circumstances the bow will have increased windage. Consequently, if the ship is heading into wind, the bow may show a tendency to blow downwind, even if the ship has headway. This is very noticeable with small ships in ballast and trimmed by the stern enclosed bridges can lead to a false impression of wind strength, as opposed to open bridge wings where the wind strength will be obvious
• the windage area, and hence the force of the wind on the ship, will vary with the relative heading to the wind, the maximum force on the ship is when the ship is broadside to the wind

• the windage profile considerably changes when in a loaded or ballast condition. The windage effect of the bow and forward area can be significant when trimmed well by the stern

• good control is easier to achieve when the ship’s head is to wind and the ship has headway. Control is difficult when wind is following

• consider that wind speed increases with height above sea level. The speed provided by the port/terminal control or tugs will be lower than the wind speed recorded on the ship’s mast

• consider that on high sided ships, 85% of the beam windage can act when the ship is only 20° off the wind

• high freeboard ships are more difficult to berth. When berthing high freeboard ships such as car carriers, it is essential to pay extra attention in windy conditions

• keep spatial awareness of the vicinity including other ships and those moored, shore cranes and overhead obstructions

• apply large passing distances when it is windy. Draught and sea room permitting, always pass any obstructions downwind or well upwind. Gusts and squalls can arrive very rapidly and with little warning. When wind has caused a ship to move rapidly to leeward, it can be difficult to overcome the motion and return to a position of safety

• allow plenty of distance from the berth for approach manoeuvrings when wind is onshore. If berthing in an onshore wind, it is best practice to stop half a ship’s length from the berth and then come alongside in a controlled manner. An uncontrolled landing on a downwind berth can result in damage to both the ship and the berth
EFFECT OF CURRENT

Current and its effect
A feature of any river berth is the current. It is common for a river berth to lie in the same direction as the prevailing current so that the current can assist with berthing. In this case, a berth can be approached bow into the current in order to give the advantage of relatively high speed through the water with a reduced speed over the ground. Consequently, steerage at low ground speed is improved by the good water flow over the rudder. The ship will be easier to stop.

Another advantage of berthing into a current is that it can be used to push a ship alongside. Position the ship off the intended berth but at a slight angle towards it. Then allow the current to produce a sideways movement of the ship towards the berth. Masters should note that currents are usually complex, with varying rates and directions that can change hourly. For safe navigation, local knowledge is essential.

A ship making headway into a current, but stopped over the ground, will have a forward pivot point. Berthing in a current Berthing with a following current is difficult, since the ship must develop sternway through the water in order to be stopped over the ground. In these circumstances, control of a single screw ship will not be easy. Use a tug to hold the stern against the current. Care is needed when berthing into a current, because too large an angle between the berth and the direction of the current will cause the ship to move rapidly sideways. Unless corrected, contact with the berth may be unavoidable. If a controlled approach is not possible assistance of tugs should be considered.

If during berthing the bow’s angle to the berth is over-corrected then the ship could move away from the berth as the wedge of water between ship and berth becomes established. This may cause the ship’s stern to strike the berth. A controlled and slow speed approach to the berth allows time to assess if the angle of approach is correct. Consideration should also be given to the effect of currents on solid quays/berths or open quays. Masters should be prepared to abort an approach if the ship is incorrectly aligned.

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Once alongside, care must be taken to prevent the ship dropping astern before back springs and head lines are set.

**Points to remember:**

- In many places a counter current flows in the opposite direction to the main current close to the bank. Only local knowledge will provide this information.
- Current can vary with depth of water and large deep draught ships can experience different current effects at differing parts of the hull. Caution is needed.
- When close to the berth in a head current, there is a danger that flow inshore of the ship becomes restricted and the ship is subject to interactive forces (see page 28). These forces can cause the ship to either be sucked towards or pushed away from the berth. Local knowledge will help anticipate this phenomenon.

- As speed is reduced, take care that the increased proportion of the ship’s vector which is attributable to current does not set the ship close to obstructions.

- Always make a generous allowance for current. Its effect on the ship increases as the ship’s speed reduces. A mistake made during berthing is often difficult to correct. Remember that current predictions are just predictions and meteorological conditions may result in a greater or lesser rate than forecast. Local VTS information will normally advise of any significant anomalies.
HYDRAULIC EFFECTS

Water depth
Water depth has a profound effect on manoeuvring. In a harbour, water depth may vary from deep water to conditions in which there is danger of touching bottom. The behaviour of the ship changes with changes in water depth. A ship’s resistance increases as water depth reduces. The increase becomes significant when the water depth is less than twice the mean draught. The effect of this increased resistance is a reduction in speed, unless engine revolutions are increased.

As well as speed, water depth affects manoeuvring, and as depth and under-keel clearance reduce, turning ability deteriorates, virtual mass increases (increase in a ship’s mass resulting from water being dragged along with the ship) and the effect of the propeller’s transverse thrust on yaw alters. As a result, a ship can become difficult, if not impossible, to control during a stopping manoeuvre as the rudder loses the beneficial effects of the propeller slipstream, and the bias off-course may become more pronounced. The increase in virtual mass is most noticeable when a ship is breasting on to a quay or jetty. Virtual mass in sway motion is invariably large, increasing as under-keel clearance reduces. Consequently, any impact with a quay wall jetty or fender will be much more severe if under-keel clearance is small.

Similarly, when a large ship moored in shallow water is allowed to move, the momentum can be considerable. Fortunately, the situation is alleviated by the considerably increased damping of any movement that is a consequence of shallow water and small under-keel clearance.

Water depth limits a ship’s speed. There is a maximum speed that a conventional displacement ship can achieve in shallow water which can be less than the normal service speed. This is called the ‘limiting speed’. Limiting speed needs to be considered during passage planning. Knowledge of areas where ship’s speed is limited by water depth is important because any increase in engine power to overcome the limiting speed will greatly increase wash. In simple terms, the limiting speed can be calculated from the formula: \( V_{lim} = 4.5 \sqrt{h} \)
where \( h \) is the water depth in metres and \( V_{lim} \) is speed in knots. In shallow water, and because of insufficient engine power, a conventional ship may be unable to overcome the limiting speed. However, some powerful ships such as fast ferries can overcome limiting speed but in doing so produce dangerous wash.

Squat
Squat is the increase in draught and trim that occurs when a ship moves on the surface of the sea. At low speed, a ship sinks bodily and trims by the head. At high speed, a ship bodily lifts and trims by the stern. At especially high speed, the ship can plane. However, squat is greatest in shallow water where the resulting increase in draught and trim can cause grounding. This, of course, provides a further limit on speed in shallow water, consideration of grounding due to squat being especially important if the under-keel clearance is 10% or less of the draught and the speed is 70% or more of the limiting speed. In shallow water, squat can be estimated by adding 10% to the draught or 0.3 metres for every 5 knots of speed. High speed in shallow water can also adversely affect a ship’s course ability to steer. Squat effect will vary from ship to ship.
Waterway width
If the waterway is restricted in width as well as depth, this can also have an effect on performance. If the underwater midship area of the ship is significant compared to that of the waterway (for example over 20%) then this ‘blockage’ will further increase resistance, increase squat and create a ‘backflow’ of water between the ship and the waterway. This will cause silt to go into suspension or deposit on the bed of the channel, and may erode the waterway. It may also cause bank material to be transferred to the bed of the waterway. A further effect may also occur. If the banks are high relative to the water depth, the ship may steer away from the bank. This ‘bank effect’ is due to backflow between the bank and the ship creating a low-pressure region amidships. This causes the ship to be ‘sucked’ towards the bank, and a pressure wave between the bow and the bank (the ‘bow cushion’) pushes the bow away from the bank and the stern is drawn in.

Bank effect increases with increases in speed, blockage (that is when the cross-sectioned area of the ship is large relative to the cross-sectioned area of the bank) and low under-keel clearance. If speed is too high, bank effect can be severe and sudden, catching the ship handler unaware. It is advisable to slow down and to steer towards the bank. By so doing, it may be possible to strike a balance, with the ship running parallel to the bank. Bank effect is also felt on bends in a waterway when proximity to the outer bank may ‘help the bow round’ a tight bend.

Interaction with other ships
Just as ships can interact with banks, they can also interact with other ships. The same basic physical factors are involved: shallow water, speed and distance. When one ship comes too close to another at high speed, then one or more things can happen. The ship may turn towards, or be drawn towards the other ship, or both ships may sheer away from each other, or the ship may turn towards (across) the other’s bows. These hydrodynamic effects are collectively known as ‘interaction’. They can, and do, lead to collisions or contact. Interaction is accentuated by shallow water when a large hydrodynamic effect can render a ship almost impossible to control. To minimise their effect, it is essential that masters anticipate the situation, that speed is reduced before the encounter, if practicable, and that the maximum passing distance is maintained. This is especially true when overtaking.

Interaction is more of a problem when overtaking than when crossing on a reciprocal course, because the forces have more time to ‘take hold’ of the other ship. But it should be remembered that both ships are affected by the interaction and both should take care to minimise its effect. Research has shown that mariners accept closer passing distances for overtaking ships than for crossing ships.

Approach channels
Approach channels allow a deep-draught ship to enter an otherwise shallow port and may provide many of the external factors that affect manoeuvring.
The width, depth and alignment of many approach channels are now subject to rigorous analysis at the design stage so that they provide the minimum hazard to ships that move along them. They are designed for single or two-way traffic and their width, depth and alignment are an optimised compromise between acceptable marine risk on the one hand and economic acceptability (with regard to dredging costs) on the other.
BERTHING WITHOUT TUGS

When berthing without tugs, it is essential that the effects of lateral motion are fully understood.
When a ship moving forward turns by use of engines and rudder alone, the effect of centrifugal force is to push the ship laterally away from the direction of the turn. When turning by use of bow thrusters alone, the thruster simply pushes the bow to port or starboard. There is no centrifugal force or lateral motion.

Port-side berthing
The following sequence assumes a fixed pitch right-handed single screw ship without tug assistance. Approach the berth at an angle, because astern thrust will be used to stop the ship and swing the bow to starboard and the stern to port. This will parallel the ship to the berth. Once stopped, the ship can be manoeuvred into the final position using astern power, which gives transverse thrust and kicks ahead with appropriate rudder as required. The actual sequence will depend on the available berthing space. Normal port-side berthing with headway – lateral motion to port.

If sternway is developed and transverse thrust causes stern to swing to port, lateral motion will be to starboard and away from the berth. This may be useful if a new approach is required. If sternway develops – lateral motion is to starboard.
What can go wrong:

• Approach speed too high The ship can hit the berth with her bow before stopping, or if a large astern movement is used to stop the ship, the resulting transverse thrust can cause the stern to hit the berth.

• Kicks ahead go wrong If a sharp kick ahead is made close to the berth then excessive forward motion can result and the ship’s bow can strike the berth.

• Lateral motion ignored When approaching port-side to the berth, the ship’s lateral motion is to port. Insufficient awareness of lateral motion can cause a ship to land heavily against the berth.

• Stopping too far from the berth The ship settles off the berth with her bow moving away from the berth, a situation that is difficult to remedy. The action of applying port rudder and a kick ahead and initiating a swing to port, in order to bring the bow towards the berth, is likely to cause lateral motion of the ship, which will drive her away from the berth. Lateral motion is always at right angles to the direction of motion and away from the direction of turn. This apparently logical action may actually make the situation worse. Careful planning of the approach can often prevent this situation from arising. Depending on the circumstances using an anchor to dredge may solve the situation or assistance of tugs may be required. If berthing against a knuckle, it is important to land flat against the straight part of the quay, not on the knuckle.

Starboard-side berthing
The following sequence assumes a single screw ship with a fixed pitch right-handed propeller. The ideal approach should be to balance forward speed against the astern power needed to stop. The greater the forward speed, the greater the astern power required to stop the ship and, consequently, the greater the effect of transverse thrust, which will bring the bow close to the berth and throw the stern off. Aim to approach the berth with the ship parallel. The effect of transverse thrust will swing the bow towards the berth.

To stop the ship, it will be necessary to put the engine astern. Transverse thrust will probably push the stern to port and bow to starboard. To correct the effect of the transverse thrust, initiate a port swing of the bow before applying astern power.
What can go wrong:

- **Approach speed too high**
  The need to use a large astern movement could cause the bow to swing towards the berth and strike the berth.

- **Ship stops close to the berth with her bow towards the berth**
  Forward engine movement could cause the bow to strike the berth if too much power is used. Transverse thrust generated by an astern movement can cause the bow to swing towards the berth and strike the berth.

- **Ship stops some distance from the berth but parallel to it**
  A kick ahead with full starboard rudder could result in the bow striking the berth at almost 90°. The situation can be made more difficult because the stern is driven away from the berth.

**Berthing between two other ships**

It is normal to berth a ship between two other ships with little more than the ship’s length of clear space. Procedures for berthing between two ships will depend upon local conditions. However, the textbook approach is to stop the ship in the required fore and aft position, but clear of the other two ships, and then work it alongside using thrusters. Alternatively, the bow or stern could be put alongside the berth first.

Although this chapter concerns berthing without tugs, larger ships that are not fitted with a bow thruster will require tug assistance for this manoeuvre.

**Points to remember:**

- **Current has a greater effect at slow speed**
  As speed is reduced approaching the berth, the current exerts a proportionally greater influence which may cause the ship to start to drop astern with the danger of contacting the ship astern.

- Other forces can cause a ship to move
  The ship can pick up headway or sternway when working alongside, either through the effects of wind, current, or asymmetrical lead of fore and aft springs.

- The ship’s propeller may not have zero pitch
  Residual pitch on a controllable pitch propeller ship can cause headway or sternway. This is potentially problematic when berthing in a confined space.

- Use of bow thrusters may not always help
  In some ships and depending on thrust tunnel design, the bow thruster can impact headway.
BERTHING WITH ANCHORS

Anchors are an effective berthing aid. Anchors can be used for berthing without tug assistance on ships without bow thrusters and, in an emergency, to stop any ship.

Dredging anchors (sometimes known as ‘kedging’)
A dredging anchor will hold the bow steady while allowing a ship to move forward or aft. A bow anchor can be dredged from a ship going forward or astern. The advantages of dredging an anchor when moving forward are principally that the ship’s pivot point moves to the position of the hawse pipe and, to overcome the anchor’s drag, propulsive power is used giving good steering at low speed. When going forward, corrective action will be needed to prevent the bow from swinging to port or starboard. The intention is for the anchor to drag and not to dig in. If the anchor does dig in, it could cause the ship to stop and necessitate breaking the anchor out again. Digging in can also damage the ship, anchor or windlass. It is therefore important to use as little cable as possible; typically a length of cable that is between one and a half and two times the depth of the water.

Local knowledge regarding the nature and condition of the seabed is important to avoid dredging in an area where the bottom is foul. Dredging an anchor can be used to control the bow when manoeuvring into a downwind berth.

Emergency anchoring
In an emergency, anchors can be very effective in stopping a ship, provided the anchor is lowered to the seabed and the cable progressively paid out. Initially, the anchor should be allowed to dredge and gradually build up its holding power until its braking effect begins to reduce the ship’s speed. This is why only experienced personnel should be posted forward on stand-by. Care should be taken when trying to stop any ship in this way, especially a large ship, as the anchor and its equipment may ‘carry away’ causing damage or injury particularly if the anchor should snag.

Planning
The key to any port approach is planning and both anchors should be made ready before a port approach or river transit. A part of the passage plan and/or pilot exchange should be the use of anchors and where the dangers are in relation to sub-sea pipe lines and cables. These should be highlighted on the charts. It is too late to check in an emergency.
MASTER/PILOT RELATIONSHIP

The master has the ultimate responsibility for the safe navigation of his ship. He must be cooperative with the pilot, yet assertive. He must remember that he is in command not the pilot. He must be confident that the pilot is doing his duties correctly and he must be ready to take over if the pilot is not fulfilling his duties.

In most occasions, pilotage is compulsory. The majority of accidents during berthing occur with a pilot on the bridge. No berthing guide would be complete without reference to the master/pilot relationship. With kind permission of the International Chamber of Shipping, Intertanko and OCIMF we have reprinted the following text from their guide ‘International Best Practices for Maritime Pilotage’.

International Best Practices for Maritime Pilotage
These recommendations are for the guidance of masters, their supporting personnel and pilots in laying down the minimum standards to be expected of the pilotage service given on board ships in pilotage waters worldwide and aims to clarify the roles of the master and the pilot and the working relationship between them. Such guidance is designed to supplement existing regulations and standard references on pilotage which include, but are not limited to, those listed in Section 10.

1.0 Principles for the safe conduct of pilotage
1.1 Efficient pilotage is chiefly dependent upon the effectiveness of the communications and information exchanges between the pilot, the master and other bridge personnel and upon the mutual understanding each has for the functions and duties of the others. Ship’s personnel, shore based ship management and the relevant port and pilotage authorities should utilise the proven concept of “Bridge Team Management”. Establishment of effective co-ordination between the pilot, master and other ship’s personnel, taking due account of the ship’s systems and the equipment available to the pilot is a prerequisite for the safe conduct of the ship through pilotage waters.
1.2 The presence of a pilot on the ship does not relieve the master or officer in charge of the navigational watch from their duties and obligations for the safe conduct of the ship.

2.0 Provision of information for berth to berth passage planning
2.1 Ships should provide the relevant port or pilotage authority with basic information regarding their arrival intentions and ship characteristics, such as draught and dimensions, as required by the port or other statutory obligations. This should be completed well in advance of the planned arrival and in accordance with local requirements.
2.2 In acknowledging receipt of this information, the appropriate port or pilotage authority should pass relevant information back to the ship (either directly or via agents) as soon as it becomes available. Such information should include as a minimum: the pilot boarding point; reporting and communications procedures; and sufficient details of the prospective berth, anchorage and routing information to
enable the master to prepare a provisional passage plan to the berth prior to his arrival. However, masters should recognise that not all of this information may be available in sufficient detail to complete the passage plan until the pilot has boarded the ship.

3.0 Master pilot information exchange

3.1 The pilot and the master should exchange information regarding the pilot’s intentions, the ship’s characteristics and operational parameters as soon as possible after the pilot has boarded the ship. The ICS Master/Pilot Exchange Forms (Annexes A1 and A2 of the ICS Bridge Procedures Guide) or the company equivalent format, should be completed by both the master and pilot to help ensure ready availability of the information and that nothing is omitted in error.

3.2 The exchange of information regarding pilotage and the passage plan should include clarification of:
• roles and responsibilities of the master, pilot and other members of the bridge management team
• navigational intentions
• local conditions including navigational or traffic constraints
• tidal and current information
• berthing plan and mooring boat use
• proposed use of tugs
• expected weather conditions

After taking this information into account and comparing the pilot’s suggested plan with that initially developed on board, the pilot and master should agree an overall final plan early in the passage before the ship is committed. The master should not commit his ship to the passage until satisfied with the plan. All parties should be aware that elements of the plan may change.

3.3 Contingency plans should also be made which should be followed in the event of a malfunction or a shipboard emergency, identifying possible abort points and safe grounding areas. These should be discussed and agreed between pilot and master.

4.0 Duties and responsibilities

4.1 The pilot, master and bridge personnel share a responsibility for good communications and mutual understanding of the other’s role for the safe conduct of the ship in pilotage waters. They should also clarify their respective roles and responsibilities so that the pilot can be easily and successfully integrated into the normal bridge management team.

4.2 The pilot’s primary duty is to provide accurate information to ensure the safe navigation of the ship. In practice, the pilot will often con the ship on the master’s behalf.

4.3 The master retains the ultimate responsibility for the safety of his ship. He and his bridge personnel have a duty to support the pilot and to monitor his actions. This should include querying any actions or omissions by the pilot (or any other member of the bridge management team) if inconsistent with the passage plan or if the safety of the ship is in any doubt.
5.0 Preparation for pilotage

5.1 The pilot should:
- ensure he is adequately rested prior to an act of pilotage, in good physical and mental fitness and not under the influence of drugs or alcohol
- prepare information for incorporation into the ship’s passage plan by keeping up to date with navigational, hydrographic and meteorological information as well as traffic movements within the pilotage area
- establish communication with the ship to make arrangements for boarding

5.2 In supporting the pilot, the master and bridge personnel should:
- ensure they are adequately rested prior to an act of pilotage, in good physical and mental fitness and not under the influence of drugs or alcohol
- draw upon the preliminary information supplied by the relevant port or pilotage authority along with published data (for example, charts, tide tables, light lists, sailing directions and radio lists) in order to develop a provisional passage plan prior to the ship’s arrival
- prepare suitable equipment and provide sufficient personnel for embarking the pilot in a safe and expedient manner
- establish communications with the pilot station to confirm boarding details

6.0 Pilot boarding

6.1 The boarding position for pilots should be located, where practicable, at a great enough distance from the port so as to allow sufficient time for a comprehensive face-to-face exchange of information and agreement of the final pilotage passage plan. The position chosen should allow sufficient sea-room to ensure that the ship’s safety is not put in danger, before, during or directly after such discussions; neither should it impede the passage of other ships.

6.2 The pilot should:
- take all necessary personal safety precautions, including using or wearing the appropriate personal protective equipment and ensuring items are properly maintained
- check that boarding equipment appears properly rigged and manned
- liaise with the master so that the ship is positioned and manoeuvred to permit safe boarding

6.3 In supporting the pilot, the master and ship’s personnel should:
- ensure that the means of pilot embarkation and disembarkation are properly positioned, rigged, maintained and manned in accordance with IMO recommendations and, where applicable, other port requirements
- the master should liaise with the pilot station/transfer craft so that the ship is positioned and manoeuvred to ensure safe boarding

7.0 Conduct of passage in pilotage waters

7.1 It is essential that a face-to-face master/pilot exchange (MPX) described in section 3.1 results in clear and effective communication and the willingness of the pilot, master and bridge personnel to work together as part of a bridge management team. English language or a mutually agreed common language or the IMO Standard Marine Communication Phrases should be used, and all members of the team share a responsibility to highlight any perceived errors or omissions by other team members, for clarification.
7.2 The master and bridge personnel should:
• within the bridge management team, interact with the pilot providing confirmation of
  his directions and feed back when they have been complied with
• monitor at all times the ship’s speed and position as well as dynamic factors
  affecting the ship (for example, weather conditions, manoeuvring responses and
  density of traffic)
• confirm on the chart at appropriate intervals the ship’s position and the positions of
  navigational aids, alerting the pilot to any perceived inconsistencies
7.3 The pilot should:
• ensure that the master is able to participate in any discussions when one pilot
  relinquishes his duty to another pilot
• report to the relevant authority any irregularity within the passage, including
  deficiencies concerning the operation, manning, or equipment of the ship

8.0 Berthing and unberthing
8.1 The necessity of co-operation and a close working relationship between the
master and pilot during berthing and unberthing operations is extremely important to
the safety of the ship. In particular, both the pilot and the master should discuss and
agree which one of them will be responsible for operating key equipment and controls
(such as main engine, helm and thrusters).
8.2 The pilot should:
• co-ordinate the efforts of all parties engaged in the berthing or unberthing operation
  (for example, tug crews, linesmen, ship’s crew). His intentions and actions should be
  explained immediately to the bridge management team, in the previously agreed
  appropriate language
8.3 In supporting the pilot, the master and bridge personnel should:
• ensure that the pilot’s directions are conveyed to the ship’s crew and are correctly
  implemented
• ensure that the ship’s crew provide the bridge management team with relevant
  feedback information
• advise the pilot once his directions have been complied with, where an omission
  has occurred or if a potential problem exists

9.0 Other matters
9.1 The pilot should:
• assist interested parties such as port authorities, national authorities and flag
  administrations in reporting and investigating incidents involving ships whilst under
  pilotage, subject to the laws and regulations of the relevant authorities
• in observing the recommendations within this document pilots should meet or
  exceed the requirements set down in IMO Assembly Resolution A.485(XII) and its
  annexes
• should report to the appropriate authority anything observed which may affect
  safety of navigation or pollution prevention, including any incident that may have
  occurred to the piloted ship
• refuse pilotage when the ship to be piloted is believed to pose a danger to the
  safety of navigation or to the environment. Any such refusal, together with the
  reason, should immediately be reported to the appropriate authority for further action
9.2 The master, having the ultimate responsibility for the safe navigation of the ship has a responsibility to request replacement of the pilot, should he deem it necessary.

10.0 Standard References
• IMO Resolution A.485(XII), Annexes I and II and subsequent amendments “Recommendations on Training, Qualifications and Operational Procedures for Maritime Pilots other than Deep Sea Pilots”
• IMO Resolution A.893(21) “Guidelines for Voyage Planning”
• IMO Resolution A.889(21) “Pilot Transfer Arrangements”
• SOLAS Chapter V, Regulation 23 “Pilot Transfer Arrangements”
• ICS Bridge Procedures Guide