

6

BOAT HANDLING

The skills involved in handling a vessel are learned over time and come with practice. A new boat handler will fair better if they understand and can apply some of the principles and basic tools outlined in this chapter.

“The difference between a rough docking and a smooth easy docking is around 900 attempts.”

BOAT HANDLING

CONTENTS

6.0 Introduction	101
6.1 Helm Position	101
6.2 Forces on Your Vessel	103
6.2.1 Winds	103
6.2.2 Waves	103
6.2.3 Current	104
6.2.4 Combined natural forces	104
6.3 Vessel Characteristics	104
6.3.1 Displacement Hulls	104
6.3.2 Planing Hulls	105
6.4 Propulsion and Steering	107
6.4.1 Pivot Point	108
6.4.2 Trim	108
6.5 Propellers	109
6.5.1 Parts of a Propeller	109
6.6 Basic Manoeuvres	110
6.7 Manoeuvring	110
6.7.1 Directed Thrust	110
6.7.2 Twin Engine Directed Thrust	110
6.7.3 Waterjets	112
6.7.4 Non-Directed Thrust and Rudder Deflection	112
6.8 Getting Underway	113
6.8.1 Tips For Success	113
6.9 Station Keeping	114

Exerpts taken from the book “High Seas High Risk”**Written by Pat Wastel Norris 1999**

(The Sudbury II was a legendary offshore salvage tug that had taken a large oil drilling platform in tow during the summer of 1961. This drama occurred in the Caribbean as Hurricane *Hattie* approached.)

The Offshore 55, a towering oilrig, was at that time the largest rig in the world. It was the size and shape of a city block and sat there in the water like a small square island. “And that’s going to be a bugger to tow,” the mate remarked to Harley. The centre of the platform of the Offshore 55 was filled with drilling equipment and, on either side of this machinery, eight huge jack-up ladders rose a hundred feet in the air. When the rig was in place these ladders became the legs that anchored it to the sea bottom. They could be raised and lowered hydraulically and were now in their raised position; even so, they protruded 10 feet below the waterline and created, the Sudbury II crew soon found, enormous drag. “What a lump to tow,” said George Winterburn. “Right off the bat Number Four main engine blew up. We had nothing but grief.” Towboat men count patience among their many virtues...

Next day the Sudbury II’s radio provided the unsettling news that the hurricane, christened *Hattie*, was bearing down upon them at increasing speed. Harley altered course to port. The hurricane veered off to port as well. Now there were long slow swells-rolling away from the disturbance behind them and a line of ominous black clouds forming. As the wind increased it became capricious, blowing first from one direction and then from another.

Harley talked to the alarmed occupants of the Offshore 55, weather worsening as he spoke. The Americans, having those same weather reports, were by now clamouring to be taken off. Harley outlined his plan of action: he would haul in line and when the Sudbury II was close enough he would float a life raft and let it drift back to them on a line. “Right at the crucial moment our towing winch loused up,” said Winterburn. “It was an electric winch with burnt out wiring. We couldn’t retrieve the towline. We cut it.” Two thousand feet of wire dropped into the sea.

Harley circled the rig cautiously and brought his stern up close as he dared. Waves were now breaking over both the tug and the oil rig. Splashing around in this water, the Sudbury II’s deck crew launched the life raft and attempted to guide it to destination. Time after time it slipped past the rig, out of the hands of the four life-jacketed figures that clung to the pipe rail. Then, as those on the Sudbury II watched helplessly, a wave burst over the Offshore 55 and smashed one of the waiting men into the deckhouse. The rig’s formidable bulk was now heaving out of the seas, and then buried in them. Her jack-up ladders were shaking with a noise like garbage day in a can factory, broken pipes and machinery clattering across her decks adding to the din.

Four times the size of the tug and completely out of control, the rig lurched toward the Sudbury II like a menacing drunk. Harley moved the telegraph from Slow Ahead to Half ahead. From the engine room there was instant compliance. The tug’s captain picked up the radio phone that connected him with the oil rig. “How are you guys making out?” Harley’s voice was even. Not so the voice that replied. “For christ sake forget that Jeezely life raft and get us off of here,” it screamed. “Come alongside and get us off. We’ve got a guy here who’s hurt.”

contined page 102

6.0 Introduction

Boat handling requires an understanding of many variables and complex problems. Though you can only develop boat-handling skills through hands-on experience, the information covered in this chapter will provide you with a basic description of principles and practices.

Though good coxswains and captains are familiar with the characteristics of their boat and how it operates, the best coxswains are knowledgeable in the operation of all types of small craft, including sailboats and personal watercraft. They know how varying weather and sea conditions affect the operation of their vessel, and are keenly aware of the limitations that weather and sea impose on other vessels.

Some helpful hints are:

1. Plan your manoeuvres ahead of time. Think of what you will need to do, and what you should have at hand to accomplish the task. Brief your crew on both the hoped-for result and the steps to achieve it.
2. Do things slowly, unless it's obvious that power is needed in a particular situation. Boats have momentum, and every action has a reaction. As you try out different actions at different speeds, carefully observe the effect that the manoeuvres have on your boat. Wait for the reaction because it is rarely immediate. Always practice in a safe location away from other boats.
3. Learn the theory presented here. Practice at every opportunity. Enjoy your developing skill. Good boat handling will make your time on the water safe and productive.



6.1 Helm Position

The person at the helm is responsible for:

- Ensuring and monitoring the positions and safety of crew
- Ensuring all on board are equipped, secure and ready to proceed
- Communicating all intentions to manoeuvre the vessel before manoeuvring
- Wearing a kill switch
- Safe manoeuvring of the vessel through the various evolutions
- Manoeuvring the vessel in the event of a Crew Overboard
- Looking out ahead for traffic, obstacles, objects in the water

- Identifying and altering correctly for all aids to navigation
- Search spotting duties for the forward sector in a search
- Monitoring of the speed, throttles, engine warnings, gauges, pressures, electronics, power and signalling/horn (smaller vessels 20m and under)
- Monitoring fluid levels, especially fuel and oil
- Monitoring the depth sounder
- Listening to engine sounds and machinery space sounds
- Steering a compass course or on a landmark
- Changing the vessels' course smoothly and efficiently
- Observing the SAR operations and watching for hazards



Commands and Signals for Docking & line handling

- Clear** – All crew are clear of lines, gear and machinery that is about to be engaged
- Clear Forward, Clear Aft** – All mooring lines are off the dock and the vessel is clear to proceed
- Standby to...** – Get ready to perform a task
- Let go stern, bow, spring or breast lines** – Untie the line and get it clear of the dock or vessel
- Ready Lines stern, bow, spring or breast lines** – Untie and hold line with on wrap / loop on the rail or cleat and stand by to let go.
- Ready Lines for Port/Starboard tie up** – Break out mooring lines and fenders and rig them for tying up on a designated side.
- Pass the line** – Throw the line or hand it to its destination
- Make fast** – Tie up the line
- Take a wrap** – To control the line without making it fast, wrap it once under the rail or on a cleat and pay out or take in slowly
- Slack the line** – Loosen the line
- Pay out / or surge the line** – Feed more line out in a controlled manner

cont'd from page 100

“I can't get alongside. That thing would smash us to pieces. I'm going to shoot you a line. It'll be coming against the wind so be ready to grab it quick. Fasten it onto that Carley float you've got and then put the Carley's line around your bollard.”

Once more Harley positioned his ship in the heaving seas. From the Sudbury II's stern a line arced through the air and, with more good luck than good management, landed right at the feet of the men at the rail of the rig. A deckhand bent a heavier line onto it. Now, as Harley had instructed, the raft was secured by two lines—one from the tug, the other from the rig. Fighting for balance, the oilmen manhandled their Carley float into the sea and those on the tug's afterdeck hauled in their line. As they pulled it across the 100 feet that separated the two vessels, the waves dropped the raft deep into the troughs and then hurled into the air.

The Sudbury II's chief officer, a young Maritimer name Caldwell, now prepared to ride the raft back to the rig. Balanced on the bulwarks, he timed his exit with exquisite precision: as it flew past him on its upward trajectory he scrambled into it positioning himself carefully in its centre. Now it was the oilmen's turn to pull the raft through the waves. They had secured a lifeline to the injured man and as the raft reached the rig it rose on the crest of a wave, the men threw the coil of the line to Reg. The injured man worked his way onto an exposed section of the deck and then, as a wave washed over it, he let go and went with it. Reg reeled him in until he lay sprawled half in and half out of the raft. Shock and pain made any further effort on his part impossible and Reg, fearing that any attempt to wrestle him into the raft might capsize it, left him there for the few minutes it took them to reach the tug. One by one the others made the perilous journey and clambered over the bulwarks and into the outstretched arms of those on the stern of the tug. Finally Reg, who had supervised their evacuation from the rig, let go the line there and pulled himself across to the tug. Both he and the Carley float were yanked aboard the Sudbury II. The raft remained a souvenir of that day. “We had that Carley around for a long time,” Bob Gray remembers.

All contact with the Offshore 55 had now been severed and, as the tug got clear, those on deck saw the rig drift away and disappear in the maelstrom that surrounded them.

Commands and Signals for Manoeuvring and Steering



Steady – Hold that course

Port/Starboard Easy – Turning to Starboard or Port gently

Hard over – Wheel all the way to Port or Starboard

Come to course 000° – repeat the course. Bring vessel's heading to the course. Report the heading when on course

Sighted Target or Vessel – report the contact using agreed upon sighting methods eg. on the Port/starboard bow, beam, quarter etc.

Steady Bearing – An approaching vessel bearing has not changed and we may be on a collision course

Secure – Ready to proceed underway (In fast response craft it means ready to accelerate onto a plane.)

Stop – Throttles to neutral immediately

Full Reverse – Throttles to reverse

Take way off – Use reverse to gently stop the vessel

Maintain Steerage – Use engines in forward gear to keep the vessel manoeuvrable

Trim up Trim down – Adjust the angle of engines or trim tabs while underway to optimise performance.

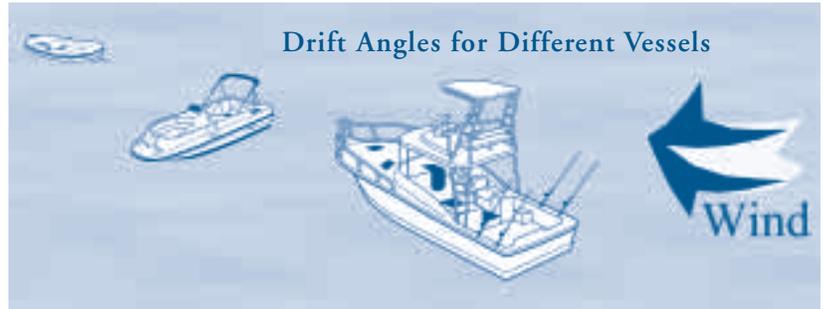
Weight Aft/Forward, Port/Starboard – Move people or gear around the vessel to change trim.

6.2 Forces on Your Vessel

Even on calm days the strength of wind, seas and current can be overwhelming. Ship captains that have thousands of horsepower at their fingertips make a habit of diligently watching the changing natural forces. A huge ship can be rendered helpless at the mercy of a mild current and gentle breeze in minutes resulting in millions of dollars worth of damage to the ship and the environment. When you are on the helm of a small vessel that same responsibility is now yours. You must take the time to observe how the wind, seas and current, alone and together, make differences in your boat's response to helm and thrust. Experienced operators learn to use the natural forces to their advantage.



6.2.1 Winds



Winds will always be a main factor in all manoeuvring. The wind acts on the hull topsides and superstructure, and on smaller boats, the crew. The amount of surface upon which the wind acts is called sail area. The vessel will make "leeway" (drift downwind) at a speed proportional to the wind velocity and the amount of sail area. The "aspect," or angle the vessel takes due to the wind, will depend on where the sail area is centred compared to the underwater hull's centre of lateral resistance. A vessel with a high cabin near the bow and low freeboard aft would tend to ride stern to the wind. If a vessel's draft is shallower forward than aft, the wind would effect the bow more than the stern. A sudden gust of wind from abeam when mooring a vessel like this might quickly set the bow down on a pier.

Knowledge of how the wind affects a vessel is very important in all close quarter situations, such as docking, recovery of an object in the water, or manoeuvring close aboard another vessel. If manoeuvring from a downwind or leeward side of a vessel or pier, look for any wind shadow. The helmsman should account for the change in wind by planning manoeuvres with this wind shadow in mind.

6.2.2 Waves

Waves are a product of the wind acting on the surface of the water. Waves affect boat handling in various ways, depending on their height and direction, and the particular vessel's characteristics. Vessels that readily react to wave motion, particularly pitching, will often expose part of the underwater hull to the wind. In situations such as this, the bow or stern may tend to "fall off" the wind when cresting a wave, as less underwater hull is available to prevent this downwind movement.

FRC Ops:

During high speed operations on a Fast Rescue Craft the navigator or coxswain will give commands by touch signals. Here are examples of signals used in the Canadian Coast Guard's Rigid Hull Inflatable Operators Training (RHOT) School:

Touch Signals

Stop

– Tap the operator on the top of the head or helmet.

Maintain course

– Push the operator in the middle of the back.

Slow down

– Pull on the back of the operator's vest.

Come slightly to port and steady

– Tap the operator's left shoulder.

Turn to port continuously

– Pull on the operator's left sleeve until the desired heading is reached.

Come slightly to starboard and steady

– Tap the operator's right shoulder.

Turn to starboard continuously

– Pull the operator's right sleeve until the desired heading is reached.

6.2.3 Current

When the water under your vessel is moving quickly it takes great skill to make your vessel respond to your helm and thrust corrections. Current will act on a vessel's underwater hull. Though wind will cause a vessel to make leeway through the water, current will cause drift over the ground. A one-knot current may effect a vessel to the same degree as 30 knots of wind. Strong current will easily move a vessel up-wind.

Learn to look for the signs of current flow so that you are prepared when current affects the vessel. Be particularly aware of instances where current shear is present. As with wind, a large, stationary object like a breakwater or jetty will cause major changes in the amount and direction of current. Note the amount of current around floating piers or those with open pile supports. Use caution when manoeuvring in close quarters to buoys and anchored vessels. Observe the effect of current by looking for current wake or flow patterns around buoys or piers. Watch how currents affect other vessels.

6.2.4 Combined natural forces

Environmental conditions can range from perfectly calm and absolutely no current, to a howling gale with a spring tide. Chances are that even if you don't operate at either extreme, some degree of environmental forces will be in action.

Know how your vessel responds to combinations of wind and current and determine which one has the greatest effect on your vessel. It may be that up to a certain wind speed, current has more control over a given vessel, but above that certain wind speed, the boat sails like a kite. Know what will happen if you encounter a sudden gust of wind; will your boat immediately veer, or will it take a sustained wind to start it turning?

When current goes against the wind, the wave patterns will be steeper and closer together. Be particularly cautious where current or wind is funnelled against the other. Tide rips, breaking bars, or gorge conditions frequently occur in these types of areas, and may present a challenge to even the most proficient coxswain.

On the other hand, making leeway while drifting downstream (down current) requires a change in approach to prevent overshooting your landing.

Compensate for wind or current

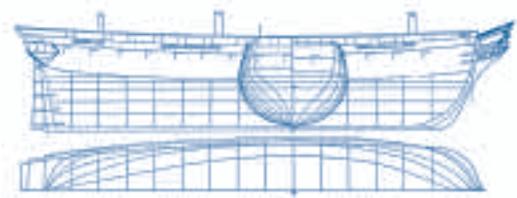
Check the conditions before manoeuvring. Always try to take advantage of wind and current when docking or mooring. To maintain best control, approach against the wind and current and moor on the lee-

ward side of a mooring when possible. Chances are that when you get underway, conditions aren't the same as when you moored.

6.3 Vessel Characteristics

6.3.1 Displacement Hulls

From the slow and steady pace of a seaworthy wooden trawler to the bright orange rescue Zodiac that streaks by us at a dizzying rate, different hull designs behave differently in the water. From another viewpoint, they are the logical extension of an evolutionary progression that began with boats more than 2000 years ago. What limits certain shapes of vessels from moving faster than their hull speed? Why do other vessels not have hull speeds, and are only limited by the size of the engine on the stern?



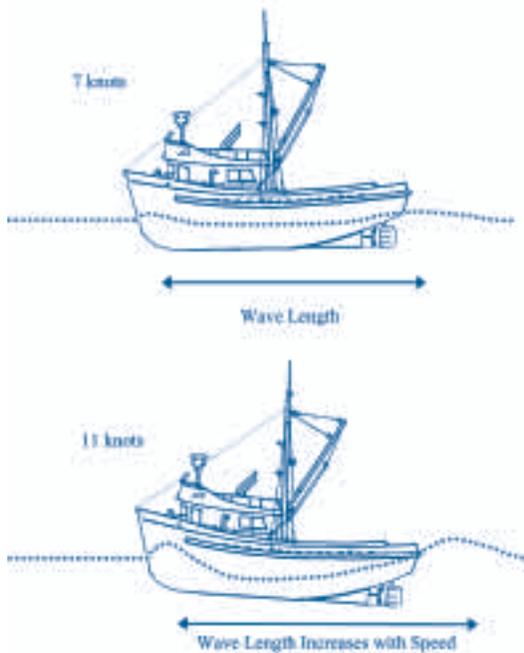
Displacement hulls are common in vessels old and new

Wave Drag and Theoretical Hull Speed

The term "displacement" refers to the fact that at the dock, a boat of any sort displaces a weight of water equal to its own weight. The difference between a displacement vessel and a planing vessel begins when they depart. Underway, a displacement vessel constantly displaces or shoves aside the water in its path, while water from either side closes in behind it. At any given moment, however, the weight of the displaced water continues to equal the weight of the vessel. The planing vessel, on the other hand, uses hydrodynamic lift to push the water underneath the bow downwards. At slow speed it obeys the displacement rule, but when enough power is applied to the leading edge of the hull the boat will climb its own bow wake and escape the slothful confines of the displacement rule. The sheer design of the displacement vessel's bow will never let it escape from the boundaries of its bow wave.

In order to understand why escape is not possible we must elaborate on exactly what occurs at the bow of a displacement vessel. The bow of a moving boat tends to push water both sideways and ahead. In the process, it creates a localised zone of higher pressure

and the water bulges above the average level of the surrounding surface. The result is a bow wave. Near the stern, another bulge forms as the surrounding water surges inward and upward to fill the space that the hull is vacating. The net result is the familiar v-shape wake or wave array that constantly streams away from a displacement vessel - at least, a displacement vessel that is moving smartly. The existence of this self-induced wave system often lowers the average water level in the immediate vicinity of the vessel. When this occurs, the hull will settle a little deeper to maintain the essential equilibrium between its weight and the amount of water it displaces.



Anyone who has watched storm surf breaking on a beach is well aware that waves transmit energy. Storm waves are created by wind energy, while a boat's wake is a manifestation of propulsion from either engine(s) or sails. A bigger wake represents more energy being dispersed, or in other words, more wave-making resistance.

At a speed below the theoretical hull speed, the quarter wave of a typical displacement hull is situated along the flanks of the vessel, well forward of the stern. The length of the arrow in the diagram above indicates the wavelength of the "entrained" wave system.

Physicists tell us that as the speed of this self-induced wave pattern increases, so must the wavelength (for sailors, this is the running distance between the two peaks). The problem is that the two peaks of the first wavelength are holding up the boat. As the speed increases and the second peak moves back the stern will lose its peak to sit on and drop into the trough. The farther away the stern is from the bow (length of the waterline or LWL) the more the wavelength

can increase, (along with its speed), before the stern falls off.

As the vessels' speed and the distance between the two peaks (wavelength) increases the stern drops into the trough. Then the vessel's length limits the speed that the vessel can travel. Why can't the boat go any faster when the stern drops off the hump?

As the vessel reaches theoretical hull speed the bow wave and quarter wave enlarge and separate, with the crest of the quarter wave moving aft to the transom. If the quarter wave moves out from under the stern then the stern loses lift and drops into the hole.

When the stern drops into the trough the boat is now sitting on the back of its own bow wave. This means that the bow is pointed towards the sky and the stern sinks. It is at this point that a planing hull begins to climb up the wake and because of its specially shaped bow and buoyant stern it can actually climb up over top of the wake and take off. The displacement hull does not push the water down and under, creating lift. It simply kicks it aside and therefore is doomed to always inhabit the back of its bow wave. Once the wavelength is exceeded then the more power we add to the throttles the more water we push aside and the larger the wake gets. We don't end up going much faster.

The length between the two humps (wavelength) is directly related to the speed of the two waves travelling along. Since our new boat can only speed up and spread the wavelength apart until the stern drops off of the back hump, then the wavelength of the boat cannot exceed the boat length.

The difference between a displacement vessel and a planing vessel begins when they leave the dock.

The sheer design of the displacement vessel's bow will never let it escape from the boundaries of its bow wave.

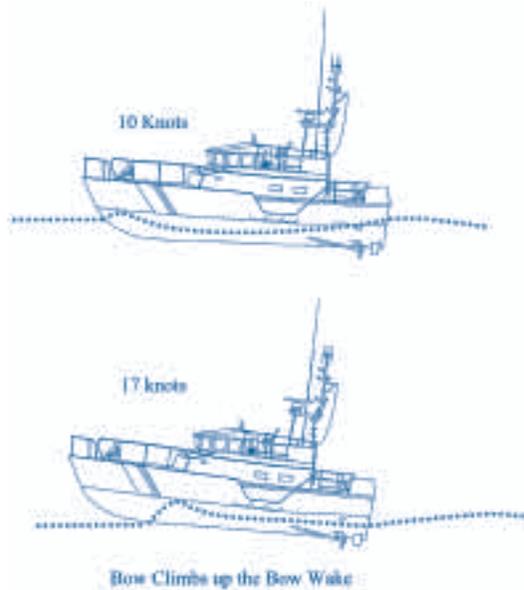
6.3.2 Planing Hulls

Planing

Planing is sliding or skimming over the surface of the water. Any true displacement vessel, including a planing hull at low speed, is sustained - buoyed up - by hydrostatic forces exactly equal to its own weight. The surrounding water pushes inward and upward with equal force. Therefore, when a boat is launched it automatically settles into the water until the weight of the water it displaces exactly equals its own weight.

Underway, many boats, particularly the planing designs, convert some of the energy of their forward motion into vertical lift by deflecting water downward. A flat stone skipped across a pond obtains lift in the same way, temporarily remaining above the water's surface despite the fact that stones are too dense to float. Unlike the skipped stone, which rebounds from the surface at high speed, a planing boat can never obtain enough dynamic lift from the water to lower its displacement all the way to zero, although fast ones come close. (Of course, with the

addition of aerodynamic lift, light racing hydroplanes readily become airborne and, not infrequently, crash as a result).



a boat on a clean plane is perched just behind the crest of the wave it creates by deflecting water downward, forward and outward

Speed potential in a displacement vessel is harshly limited by the inherent speed of the wave system it generates as it shoulders water aside. In simple terms, the displacement vessel lacks the power to climb appreciably up the back face of its own bow wave. On the other hand, a boat on a clean plane is perched just behind the crest of the wave it creates by deflecting water downward, forward and outward. The water shoved down and aside by the passage of the hull, instead of closing in directly behind the boat and forming a distinctive stern or quarter wave, breaks cleanly away at the transom and chines. The faster the boat goes, the longer it takes this water to rebound in the boat's wake. Thus the stern wave of a planing hull, unlike the well defined quarter-wave of a displacement hull, trails a substantial distance behind the transom. The faster the planing boat goes, the further it lags behind.

Trim Angle in Stepless Planing Boats

The vast majority of runabouts, fishing boats, and planing cruisers are flat or v-bottom designs with no transverse steps or discontinuities in their running surfaces. When a boat of this type accelerates from a standstill the trim angle first increases, peaking about the time that planing commences (i.e. the water begins to break cleanly away at the transom and the chines), and progressively levels off as the speed continues to climb. This self-trimming feature is characteristic of all stepless planing hulls.

The drag associated with too large a trim angle (bow in the sky) can prevent a boat from climbing "over the hump" and onto a plane if the available

power is marginal for the load. As any experienced small boat operator knows, a boat struggling to get onto a plane often can be helped along by shifting weight toward the bow. On the other hand, the highest speeds for a given hull, load and power plant are generally attained when the boat's centre of gravity is quite far aft, despite the fact that this load distribution often makes it significantly harder to start planing in the first place.

Planing boats have two main sources of resistance. The first is the energy required to deflect water downward as it encounters the bottom. A steeper trim angle causes water to be deflected abruptly, which not only creates larger lifting forces, but absorbs more energy in the process. Roughly speaking, the work of generating dynamic lift matches the work of a loaded boat hauling up a friction's ramp whose slope equals the trim angle.

The second source of resistance is, of course, skin friction. Frictional drag is determined mainly by wetted area and secondarily by surface finish. Skin friction and trim angle drag are, to some extent, inversely related. For example, if trim angle is increased and speed held constant, wetted surface (and skin friction) will decrease somewhat. Minimising total drag in a planing boat boils down to obtaining the optimal combination of trim angle and wetted surface to carry the chosen load at the desired speed. Obtaining this optimal combination is more a matter of initial hull design than movable weight positioning, trim tab adjustments or the like. Fortunately, the basic elements of sound hull design are by now well understood, thanks to the pioneering work of such naval architects as Lindsey Lord, and later, Raymond Hunt.

The Advantage of V-Bottomed Hulls

V-bottom boats have acquired their overwhelming popularity partly because their extra wetted length along the keel makes them highly resistant to porpoising which is a tendency to pitch and slam. (Two other advantages of v-bottoms, their enhanced ability to negotiate rough water at high speed and bank into turns, will be discussed a bit later.) For a given speed and load, a v-bottom will create more drag and require more power than a flat bottom. In almost all cases, this trade-off is worthwhile.

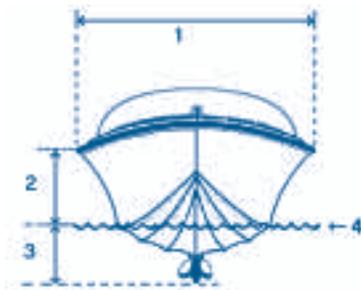
Banking, Heeling and Stability

Good planing hulls, instead of leaning away from turns like displacement boats or automobiles, bank into them like motorcycles. The explanation for this is rooted in the basic principles of planing. When a boat enters a turn, centrifugal force causes it to skid sideways. In the process of skidding, the boat is actually planing sideways as well as forward. As a result, the high lift leading edge area shifts toward the

side of the bottom that is on the outside on the turn, raising it and causing the boat to bank.

V-bottom boats bank harder and more reliably in turns than flat bottom boats. As a v-bottom boat skids sideways, the outer side of the hull meets the water at a large trim angle and develops lots of lift, while the inner side contacts the water at a much smaller angle and may easily develop suction.

Good planing boats are more stable at speed than they are at rest. When weight is shifted to one side of a displacement boat, the boat heels, moving the centre of buoyancy laterally until it is again in vertical alignment with the centre of gravity - this time with the boat heeling to some extent. However, when a boat is planing, the same weight shift will also alter the trim angle on one side of the bottom relative to the other, inducing an additional and comparatively large dynamic righting force.



1. Beam
2. Freeboard
3. Draft
4. Waterline

Terms Referring to Direction on a Vessel

Forward	Towards the bow
Aft	Towards the stern
Abaft	A position behind a reference position on the vessel
Port Side	Left side, when facing the bow
Starboard	Right hand side, when facing the bow
Beam	The boat at its widest point or width
Amidships	The centre of the vessel
Athwartships	Travelling across the breadth of the vessel
Aloft	Above the deck or in the rigging
Inboard	Inside the boat or towards the centre line
Outboard	Outside the boat or away from the centre line

6.4 Propulsion and Steering

Propulsion and steering are considered together here for two reasons. Applying thrust has no use if you can't control the vessel's direction, and often the device providing the propulsion also provides the steering. There are three common methods of transferring power and providing directional control:

- ◆ Rotating shaft and propeller with separate rudder
- ◆ A movable (steerable) combination, such as an outboard motor or stern drive
- ◆ An engine-driven pump mechanism with directional control, called a waterjet

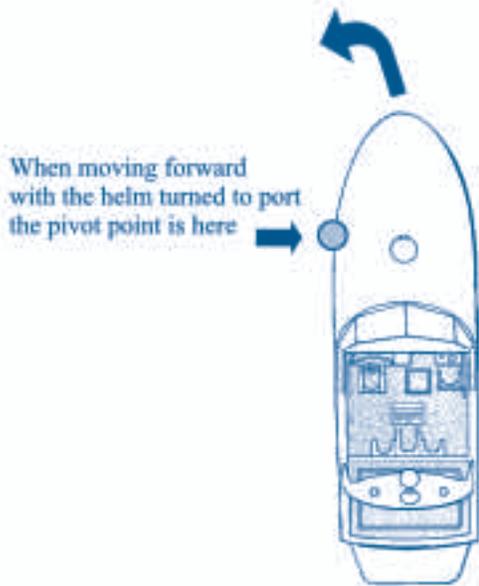
Good planing hulls, instead of leaning away from turns like displacement boats or automobiles, bank into them like motorcycles

All three arrangements have their advantages and disadvantages from the standpoint of mechanical efficiency, ease of maintenance and vessel control. Using one type of propulsion instead of another is often a matter of vessel design and use parameters, operating area limitations, life cycle cost and frequently, personal preference. There is no single "best choice" for all applications. Regardless of which type you use, become familiar with how each operates and how the differences in operation affect vessel movement.

The following assumptions will apply to our discussion of propulsion:

- ◆ If a vessel has a single-shaft motor or drive unit, it is mounted on the vessel's centreline
- ◆ When applying thrust to go forward, most propellers turn clockwise (the top to the right or a "right-handed" propeller), viewed from astern. When going astern it turns counter clockwise viewed from astern when making thrust to go astern
- ◆ If twin propulsion is used, most vessels have counterrotating drives in the following configuration: starboard propeller, when going ahead, operates as above (right-hand turning), while the port unit turns counter clockwise (left-hand turning)

6.4.1 Pivot Point



On almost every boat, the propulsion and steering arrangement is designed to operate more efficiently and effectively when going ahead than when going astern. When turning, a vessel will rotate on a specific point, called the pivot point. The fore and aft location of the pivot point varies from boat to boat, but is generally just forward of amidships when the boat is at rest. As a hull moves either ahead or astern, the effective position of the pivot point moves either forward or aft respectively. A sense of the location and behaviour of

the pivot point is a critical component for boat handling at slow speed.

6.4.2 Trim

Trim is the angle of the hull in reference to the water's surface; there are a few ways to adjust this angle:

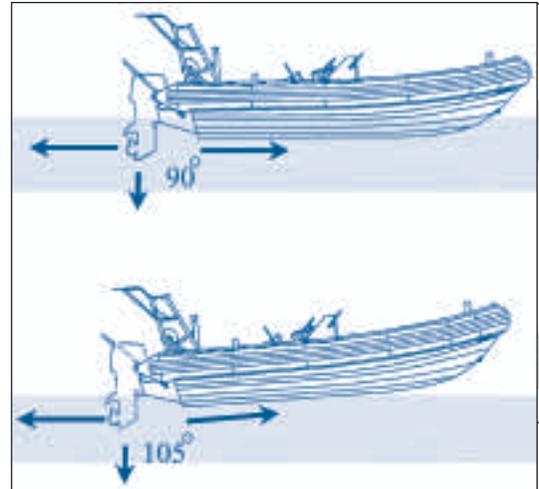
- ◆ Adjust the angle of propulsion
- ◆ Adjust the weight onboard the vessel
- ◆ Use trim tabs or fins attached to the hull or engine leg to create lift (stern up) or suction (stern down) from the water travelling along the hull surface.

The angle of propulsion in reference to the angle of the transom can affect trim

When moving on to a plane, the boat is actually climbing up its own bow wave. Displacement mode describes the vessel at slow speed displacing its weight in the water. During the transition between displacement mode and planing mode, the vessel must overcome its bow wave and ride on the after part of the hull, suspended on a cushion of air and water it develops dynamic lift. In order for the transition to occur smoothly, the boat must be properly trimmed.

Adjust the angle of propulsion

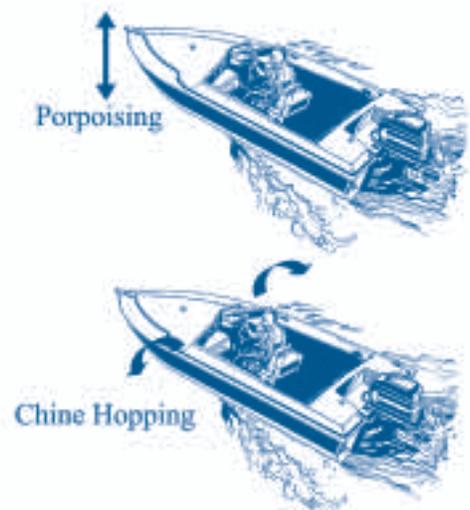
The angle of propulsion in reference to the angle of the transom can affect trim. This is most commonly achieved by adjusting the a trim ram on a drive mount. Trimming up increases the angle and drives the stern down while lifting the bow up. Trimming down does the opposite. The ideal trim angle vs. power ratio is when the boat is stable, but has a



minimum amount of hull surface in the water. As the angle of trim is increased or "trimmed up," more horsepower is required to hold the hull out of the water. If there is a lot of horsepower and too much of the hull is lifted out, then the boat becomes unstable. There are two indications of being trimmed up too high:

- Porpoising:** When the bow bobs up and down, even in calm water;
- Chine Hopping:** Violently hopping; when the boat sways from one side to the other, with increasing frequency.

The boat is not trimmed high enough when the steering is stiff and sluggish and the bow wake is still up at the bow. The boat will be pushing a lot of water along like a snowplough, rather than gliding along.

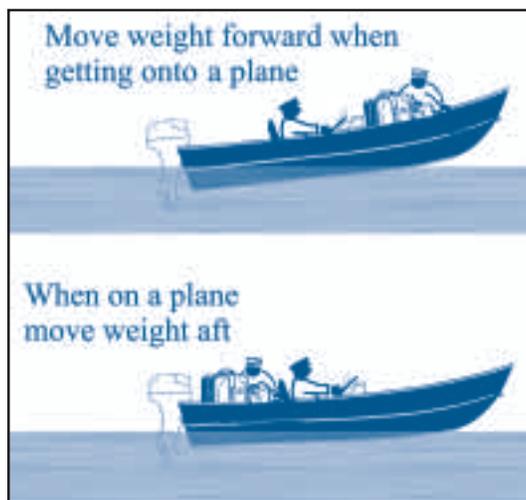


Optimum Trim

A good trim angle is characterised by responsive steering, and the feeling that the boat is floating on a cushion of air. At this angle, the boat is using less fuel, is more stable, steers easier, and is going faster.

Adjusting the Trim with Weight

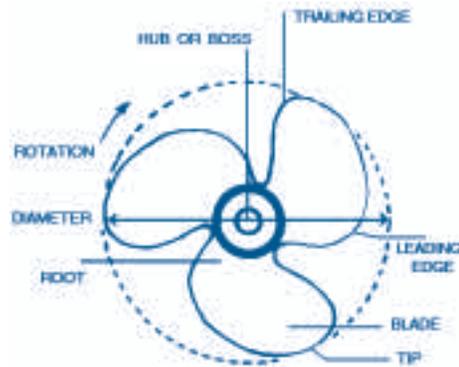
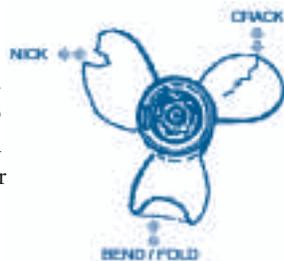
With small boats, we usually have portable ballast (people) that we can move around to balance out the boat. When first accelerating, move weight forward to help the bow climb the wake. Once up on a plane, move the weight aft to trim up the bow. If you have power trim, then trim down first. When up on a plane, trim up to the optimum.



6.5 Propellers

A boat is only as good – or bad – as its prop. With the right prop, your boat is a joy. Fast, smooth, comfortable, fuel-efficient and just plain fun. With the wrong prop, your boat will feel rough, or slow, or sluggish or lacking in top end. The wrong prop can even damage your engine through lugging or over-revving.

Even the right prop, when damaged, can drastically reduce performance and fuel efficiency. Just running a prop through silt or sand can damage it enough to affect how your boat runs. In one test, a damaged prop dropped top speed more than 13%, acceleration 37%, and optimum fuel miles were reduced 21%. So you can see why you should check your prop often and have a damaged prop checked and repaired by an authorised dealer or repair station.



6.5.1 Parts of a Propeller

To understand how propellers work, we have to familiarise ourselves with the parts of the propeller. We have chosen a complex propeller to illustrate a high-performance design. Smaller outboards have simpler designs with fewer parts. This is also true with displacement hull propellers.



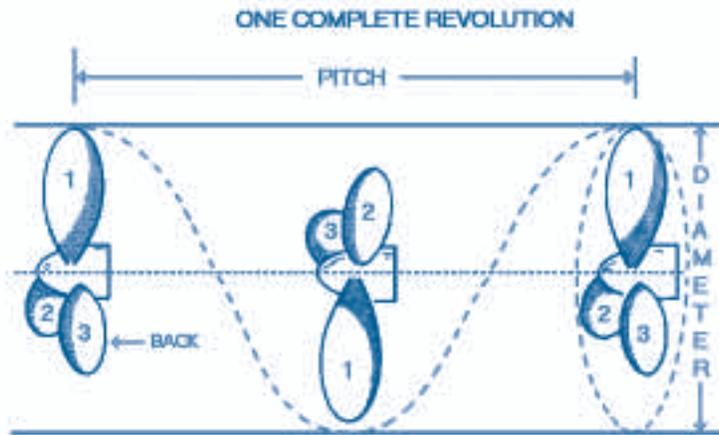
Common outboard engine propeller

Pitch is the theoretical forward distance the prop would move in one full revolution if it were moving through a solid.

1. **Blade Tip:** The maximum reach of the blade from the centre of the propeller's hub
2. **Leading Edge:** The part of the blade that leads as it rotates
3. **Trailing Edge:** The part of the blade that trails
4. **Inner Hub:** This contains the slip hub (usually rubber). The forward end transmits the drive from the shaft to the propeller body
5. **Outer Hub:** This contains the open exhaust passage, suspending the inner hub with spokes

Pitch

Pitch is the theoretical forward distance the prop would move in one full revolution if it were moving through a solid. To get maximum efficiency from your engine, the pitch should be matched to engine power, gross weight and intended use of the boat. The diameter of a propeller is the diameter of the circle through which the blades turn.



Directed thrust steering is only effective when the engine is in gear and directing thrust. If you are in neutral your vessel will not respond to helm changes. This is especially true with jet drives.

Propellers may have two or more blades on a hub. The hub size is dependent on the shaft size and is bored to fit the shaft. Propellers are specified by diameter, pitch, number of blades, direction of rotation, and bore. Diameter and pitch are usually stamped on the hub, for example: 12 X 14RH means 12 inch diameter, 14 inch pitch, right-hand rotation

Best all-around engine performance is achieved when the prop is matched to give just under the top recommended full-throttle rpm. Generally, the heavier the boat, the lower the prop pitch. The right prop allows the motor to operate in its optimum rpm range. The same horsepower motor on a lighter boat needs a higher pitched prop than on a heavier boat to give it more speed and to efficiently use the rpm.

Cavitation

Even slightly chipped blade edges can cause surrounding water to boil (“cavitate”). Gas bubbles then collapse elsewhere on the blade, releasing energy that causes metal erosion or “cavitation burn.”

Ventilation

Air from the water surface or exhaust gases from the exhaust outlet being drawn into the prop blades causes ventilation. This reduces normal water load, causing the prop to over-rev and lose a lot of thrust. Ventilation is most common with high transom mounting, extreme trim-out and sharp turns.

6.6 Basic Manoeuvres

Often the presence of other craft or obstructions will complicate the clearing of a berth, or any simple manoeuvre. Wind and/or current can also become a factor. Before manoeuvring, evaluate the options in order to take full advantage of the prevailing conditions.

Fenders

Never attempt to fend a boat off a pier, float, etc., by hand or foot always use a fender. Always keep the proper sized fenders handy.

Mooring/off-dock wind

When mooring with an off-dock wind, the approach should be made at a sharp angle

Mooring/on-dock wind

When mooring with an on-dock wind, approach parallel with the intended berth and rig the fender in appropriate positions. Ensure that the boat has no fore and aft movement when contacting the dock.

Protecting the stern

Keep the stern away from danger. If your propellers and rudder become damaged, you are crippled. If the stern is free to manoeuvre, you can work your boat out of trouble.

6.7 Manoeuvring

Directed thrust is used in the following types of drives:

- ➔ Jet boats;
- ➔ Outboard drives; and
- ➔ Inboard/outboard drives.

6.7.1 Directed Thrust

When the drive unit is turned to the port or starboard, the thrust is applied to that direction. The stern will swing around the pivot point and the boat will turn.

Thrust and directional control

Outboards and stern drives have a small steering vane or skeg below the propeller. The housing above the gear case (below the waterline) is foil shaped. Though these features help directional control, particularly at speed, the larger amount of steering force from an outboard or stern drive is based upon the ability to direct the screw discharge current thrust at an angle to the vessel's centreline. This directed thrust provides extremely effective directional control when powering ahead.

6.7.2 Twin Engine Directed Thrust

Use the outside arc engine

The engine on the outside of the arc of a turn provides a better thrust angle than the inside engine. When trying to turn in a tight space, the operator can apply power to the outside arc engine. The engine on the outside of a turning arc will provide the most effective directional thrust. This works for both

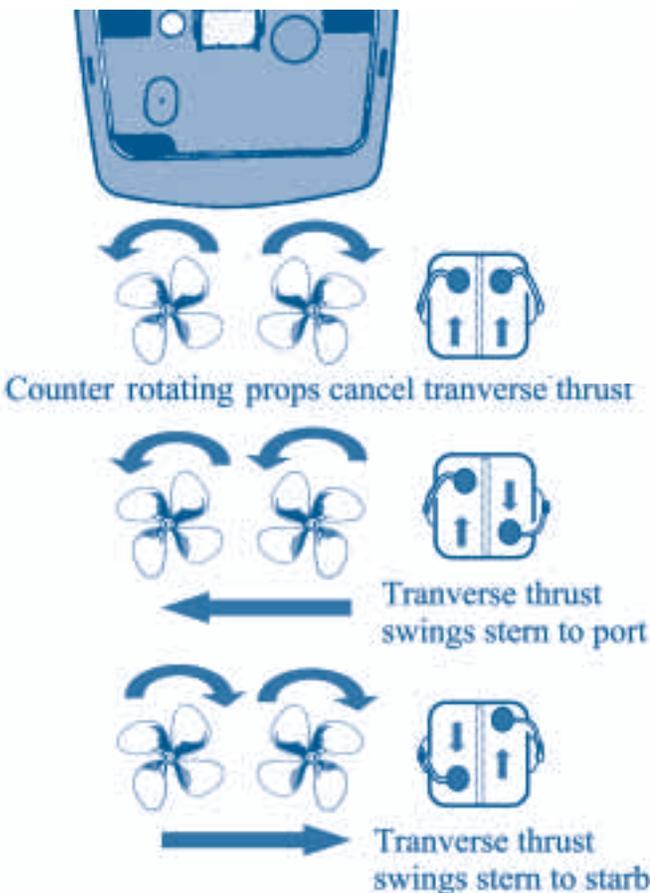
forwards and reverse. If you imagine a wrench stretching from the pivot point (dot) to the engines then the engine that is farthest away from the pivot point provides the better lever. Out of the two wrenches port or starboard the starboard one is the farthest away and it is on the outside of the arc. When manoeuvring in confined spaces, always use your outside arc engine.

Transverse Thrust

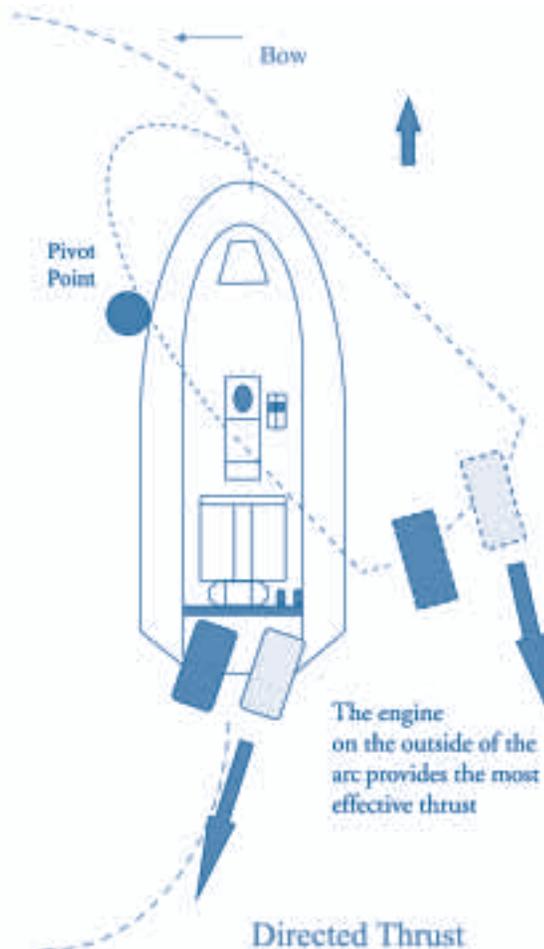
Transverse thrust is the sideways force generated by the propeller blades paddling through the water. The propeller will push water through the blades to create thrust ahead. But the turning blades will also wash water sideways and create a small amount of sideways motion. With many single screw vessels a large propeller will create enough transverse thrust to render your helm ineffective when backing up. The result is a vessel that will only back one way (to port).

Using opposing engines can help manoeuvre in tight spots

With counter rotating screws (propellers) power vessels can use transverse thrust to advantage and get the stern to slide sideways. By using one throttle ahead and one in reverse the vessel can turn on its own length. This is very handy in tight spots.



If the vessel's propellers are not counter-rotating (not spinning in opposite directions when both ahead), then using opposing engines (one ahead and one astern) will not be as effective as on a counter-rotating propped boat. Splitting the engines moves the pivot point of the vessel back between the two engines drastically reducing your leverage and increasing your required power. We can still use opposing engines to help manoeuvre in tight spaces, but often in conjunction with the wheel.



Pivot Points

The dot on the port bow indicates the spot where the boat will pivot in a port hand turn. As the boat turns around the pivot point the stern travels most of the distance. When trying to judge what the boat is doing at any one time, it is better to look at the stern then the bow. The stern will give the operator a better gauge for the movement of the boat. When operating in reverse, the pivot point moves aft, just ahead of the engine well, and the bow will tend to swing more than the stern. The change in pivot point is the reason

that vessels are so difficult to manoeuvre in reverse. If the wind catches your bow when you are backing in, be careful, because it will swing.

When backing to starboard, the side force tends to cause an element of astern motion and also tries to offset the initial starboard movement. Many lower units are fitted with a small vertical vane, slightly offset from centreline, directly above and astern of the propeller. This vane also acts to counter side force, particularly at higher speeds.

6.7.3 Waterjets

A waterjet is an engine-driven impeller mounted in a housing. The impeller draws water in and forces it out through a nozzle. The suction (inlet) side of the waterjet is forward of the nozzle, usually mounted at the deepest draft near the after sections of the hull. The discharge nozzle is mounted low in the hull, exiting through the transom. The cross-sectional area of the inlet is much larger than that of the nozzle. The volume of water entering the inlet is the same as that being discharged through the nozzle, so the water flow is much stronger at the nozzle than at the intake. This pump-drive system is strictly a directed-thrust drive arrangement. A waterjet normally does not extend below the bottom of the vessel hull, allowing for operation in very shallow water.

Thrust and directional control

Vessel control is through the nozzle-directed thrust. To attain forward motion, the thrust exits directly astern. For turning, the nozzle pivots (as a stern drive) to provide a transverse thrust component that moves the stern. For astern motion, a bucket-like deflector drops down behind the nozzle and directs the thrust forward. Some waterjet applications include trim control as with a stern drive or outboard. With this, thrust can be directed slightly upward or downward to offset vessel loading or improve ride.

From time-to-time, you might see a waterjet with a small steering vane, but in most cases the only vessel control is by the nozzle-directed thrust. If a waterjet craft is proceeding at high-speed, power brought down quickly to neutral, and the helm put over, no turning action will occur. Of the three drive arrangements discussed, the waterjet alone has no directional control when there is no power.

No side force

Since the waterjet impeller is fully enclosed in the pump-drive housing, no propeller side force is generated. The only way to move the stern to port or starboard is by using the directed thrust.

Cavitation

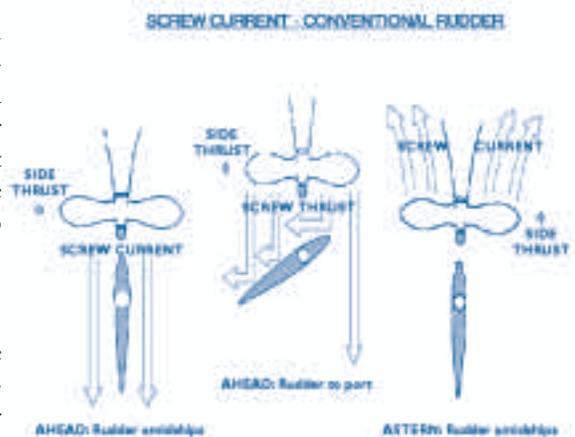
Waterjet impeller blades revolve at an extremely high speed. A much higher degree of cavitation normally occurs than that associated with external propellers without a loss of effective thrust. In fact, a telltale indicator of waterjet propulsion is a pronounced aerated-water discharge frequently seen as a rooster tail astern of such craft.

As the impeller rotation does not change with thrust direction, frequent shifting from ahead to astern motion does not induce cavitation. However, as the thrust to make astern motion reaches the waterjet inlet, the aerated water is drawn into the jet, causing some reduction of effective thrust. As with all types of propulsion, slowing the impeller until clear of the aerated water reduces cavitation effects.

6.7.4 Non-Directed Thrust and Rudder Deflection

If a vessel is moving through the water (even without propulsion), you normally use the rudder to change the vessel's heading. As a hull moves forward and the rudder is held steady, amidships, pressure on either side of the rudder is relatively equal and the vessel will usually keep a straight track. When you turn the rudder to port or starboard, pressure decreases on one side of the rudder and increases on the other. This force causes the vessel's stern to move to one side or the other. Because a vessel rotates about its pivot point, as the stern moves in one direction, the bow moves in the other.

The speed of the water flowing past the rudder greatly enhances the rudder's force. The thrust or screw discharge current from a propeller while operating ahead increases the water flow speed past the rudder. Also, if you turn the rudder to a side, it directs about one-half of the propeller thrust to that side, adding a major component of force to move the stern.



Because a vessel rotates about its pivot point, as the stern moves in one direction, the bow moves in the other

When operating astern, the rudder is in the screw suction current. The rudder cannot direct any propeller thrust, and since the screw suction current is neither as strong nor as concentrated as the screw discharge current, water flow past the rudder does not increase as much. The combined effects of screw current and rudder force when operating astern are not nearly as effective as when operating ahead.

As rudder force is determined by water flow along it, a rudder loses some of its effectiveness if the propeller cavitates and aerated water flows along the rudder.

6.8 Getting Underway

Starting the Engine

Before starting the engine, be sure that it is in Neutral. Different engines have different requirements for start-up and warm-up. Most outboards require some type of choke or priming before they start. Larger outboards have a priming pump that injects extra fuel into the carburettor. Small outboards have a choke on the carburettor that can be engaged while starting, and disengaged after ignition. Read the engine manufacturer's "Operating Instructions."



Vessel Start up Procedure

- ✓ Make sure that the vessel is secure, and that the crew is ready.
- ✓ Check small outboard's transom mounting and back-up cord.
- ✓ Check fuel line attachments and fuel level.
- ✓ Do not proceed if you detect the smell of gasoline or there is evidence of any fuel leaks.
- ✓ Turn on battery power or ignition switch.
- ✓ Pump prime bulb (if applicable).
- ✓ Attach Kill Switch lanyard.
- ✓ Check throttles (in neutral) or in Start position.
- ✓ Prime engine or engage choke.
- ✓ Pull Start cord or turn key until ignition.
- ✓ Bring RPMs to recommended warm-up speed.
- ✓ Warm-up for 2 to 3 minutes (in neutral).

Leaving the Dock

Most vessels are better off backing out when leaving a berth alongside, due to the position of the pivot point. In larger vessels, if there is a problem getting the stern away from the dock, you can go ahead on

the forward spring to swing the stern out. After the stern has swung well away, then reverse out of the berth. If you have to power out forwards, then the bow should be pointing away from the dock first. To manoeuvre the bow out, let go all the lines except the after spring, and back on it until the bow swings out.

To manoeuvre out without using lines or a push:

- 1) Turn the wheel hard at dock and give a shot in forward. Let stern swing out.
- 2) Turn the wheel hard away from the dock and reverse out, manoeuvring the wheel as you do, to bring the vessel to parallel the dock.
- 3) You should now be far enough away from the dock to drive forward away without clipping your stern on the dock



6.8.1 Tips For Success

Rig and lead mooring lines and fenders early

Rig and lead mooring lines and fenders well before the approach. Get the noise and confusion over with long before the coxswain must concentrate and manoeuvre to the dock.

Though common practice is to leave mooring lines attached to the home pier, always have a spare mooring line and moveable fender on the boat and at the ready while approaching any dock, including the home pier.

Control, not speed

Keep just enough headway or sternway to counteract the winds and currents to allow steerage while making progress to the dock. Keep an eye on the amount of stern or bow swing. With a high foredeck, the wind can get the bow swinging much easier than it is to stop. In higher winds, a greater amount of manoeuvring speed may be needed to lessen the time exposed to the winds and currents, but be careful not to overdo it.

When requiring precise control, keep the boat's heading into the predominate wind or current, or as close as possible. When manoeuvring the boat so that the set from the wind or current is on either the starboard or port bow, the boat may "crab" (move sideways) in the opposite direction.

Use clear line handling commands and signals

Line handling is extremely important when docking. Give specific line-handling instructions in a loud, clear voice. Ensure commands are understood, by any helpful individuals near the dock. Poor line handling can ruin the docking at the end of a perfect

STP

Speed: Using too much speed in a confined space.

Throttles: Forgetting whether the throttles are engaged (ahead, in neutral, or in reverse).

Position of Helm: Looking at the bow and forgetting whether the rudder is hard over or amidships

approach. Ideally, try to have the boat stopped alongside the pier before putting lines over.

Steering is more effective when thrust is applied

Directed thrust (turning the angle of the propeller to steer), offers quick and responsive manoeuvrability in most situations. Outboard engines act as a rudder, and even when in neutral (no directed thrust) will steer the boat slightly. But don't count on this to turn you at slow speed.

Don't add more power if things go wrong

Adding more power to a troubled docking is usually a recipe for disaster. If the coxswain is patient enough to use short bursts of power, and wait to see the outcome before manoeuvring again, then a crash may be avoided.

Turn the wheel first, then apply power

If you want to turn your car in a tight spot, you crank the wheel hard over and then step on the gas. If you step on the gas first, then you run out of room. When manoeuvring your vessel in a confined space, the same rules apply.

Use the outside arc engine with twin screw vessels

The engine on the outside of the arc of a turn provides a better thrust angle than the inside engine. When trying to turn in a tight space, the operator can apply power to the outside arc engine.

6.9 Station Keeping

(Definition: The ability to keep the vessel stationary relative to a reference point.)

Station keeping is a learned skill. Understanding the principles of particle motion and wave theory helps in effectively manoeuvring a vessel in tight areas near shore or at sea.



Waves at sea are energy in motion. The water does not flow or move with the wave, it just goes up and down. As the energy moves through the water, the particle motion in the wave is circular. The largest circle is near the surface, getting smaller in size toward the bottom. The wave will remain constant, or nearly constant, as long as there is no object or current present to alter it.

As the wave approaches shore, the circular motion is squashed flat as it nears the sea bed. The circular motion becomes elongated to the point that the wave is now water flowing ashore and then back to meet the next incoming wave.



As you near shore, you must use this understanding of particle motion to anticipate the movement of your vessel, thus being able to use your vessel's power to counter the forces of the wave. As the wave approaches, the vessel will be pulled toward it. As the wave reaches the vessel, the vessel will lift and be carried in the direction of the wave until the wave passes the vessel, at which time the next approaching wave's circular motion will pull the vessel back toward the incoming wave.

To be able to maintain station, the vessel operator has to counteract each of the forces that the circulation motion of the wave applies to the vessel. You must be able to react to each wave as it approaches, anticipating how much force it will carry. Once you understand how your vessel will react to the approaching energy, then you can apply the counter power necessary to remain in one position relative to a fixed object.

Always SAP (STOP, ASSESS, and PLAN) before entering the area where you will be required to station keep.



Stop and Assess the following:

- ▶ Observe wind, tide and current.
- ▶ Observe water colour.
- ▶ Identify shallows, ledges and aerated/turbulent water, and stay away from these areas.
- ▶ Assign a lookout to maintain a sea watch. Discuss with your lookout which are the small, medium and large waves of the series, and have your lookout notify the operator of these large waves before they reach you. Remember that there is always the rogue or extra large wave that will come ashore from time to time. Be on the lookout for the larger waves and move out of the area before they reach too close to shore or your position.
- ▶ Approach slowly, the reverse power is not sufficient to overcome vessel momentum when combined with the surge force of a wave.
- ▶ The vessel is always easier to control when the bow is kept to seaward or toward the incoming wave or current. Do not allow your vessel to get turned beam to an incoming wave near shore. Any wave taken on your beam puts the vessel in a hazardous circumstance, usually difficult to manoeuvre away from.
- ▶ Choose two exits for your vessel. Do not get caught with a boat or debris blocking your path to safety if you get too close to something. Always have an alternate in mind.

