Water Awareness and Charge Certificate Manual

Module 34: Introduction to Power Boats

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Module Contents

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Outcomes

After completing this module, the certificate holder will:

- Be able to describe the operation of a internal combustion engine
- Be able to operates standard systems on-board a power vessel
- Be able to perform general manoeuvring in a power vessel
- Be able to demonstrate fuelling, launch, recovery and storage of a power vessel.

1 Introduction

In this section, we look at the operation of the internal combustion engine and legal requirements for construction of a power boat. Then, most importantly, we look at operation of said vessels and preventative maintenance that should be performed, particularly on the engine.

This chapter covers two- and four-stroke engines, the propeller, fuel system, cooling system, lubrication, trim and tilt system and ventilation requirements.

2 Engines

Broadly speaking, there are 8 types of marine engine, determined by the combustion cycle (2-stroke vs. 4-stroke), drive setup (outboard vs. stern drive vs. inboard) and fuel (petrol vs. diesel), but in reality you are most likely to encounter 2- & 4- stroke petrol outboards and 4-stroke petrol stern drives. We will concentrate on these 3 engine types

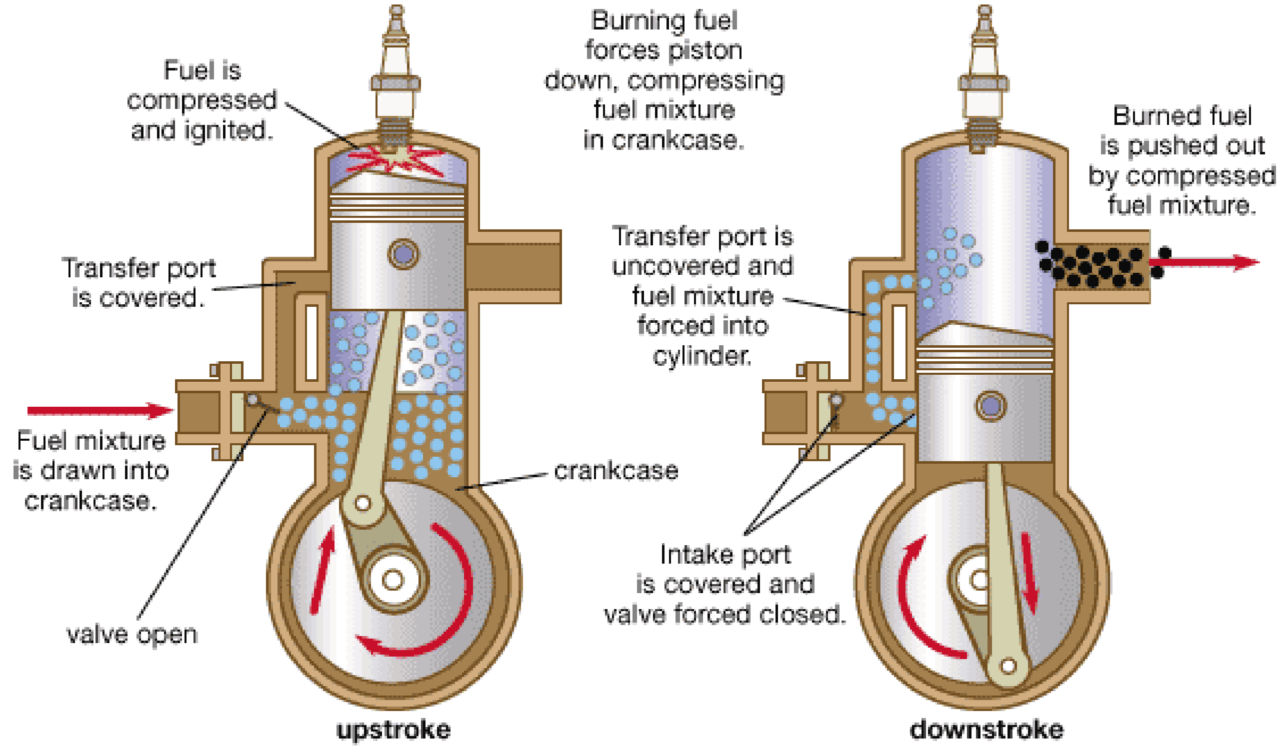
2.1 Combustion Cycle

The steps in the combustion cycle are the same for any internal combustion engine

1. A mixture of fuel and air is forced into the cylinder.
2. The piston rises, compressing the fuel / air mixture
3. The compressed fuel / air mixture is ignited, force the piston down
4. The exhaust gasses are ejected from the cylinder and the cycle begins again

This process can be achieved with 2 movements of the piston (2-stroke) or 4 movements of the piston (4-stroke). The difference is that with a two stroke engine, steps 1 and 4 occur simultaneously using, the force of the incoming fuel / air mixture is used to force the exhaust gasses out. Step 2 has the additional function in the 2 stroke cycle of inducting the fuel air mixture into the respective crankcase compartments. With a 4-stroke engine, each step will be performed separately, one per movement of the piston.

Another major difference is that 4-stroke engines are lubricated with oil that is pumped into the crankcase from the sump. Two stroke engines are lubricated by oil that is mixed into the fuel supply. This mix is either created manually by mixing oil and fuel in the tank, or automatically by the engine in the case of an "Auto-lube". **Be sure to use marine outboard oils and not any type of 2 stroke oil**



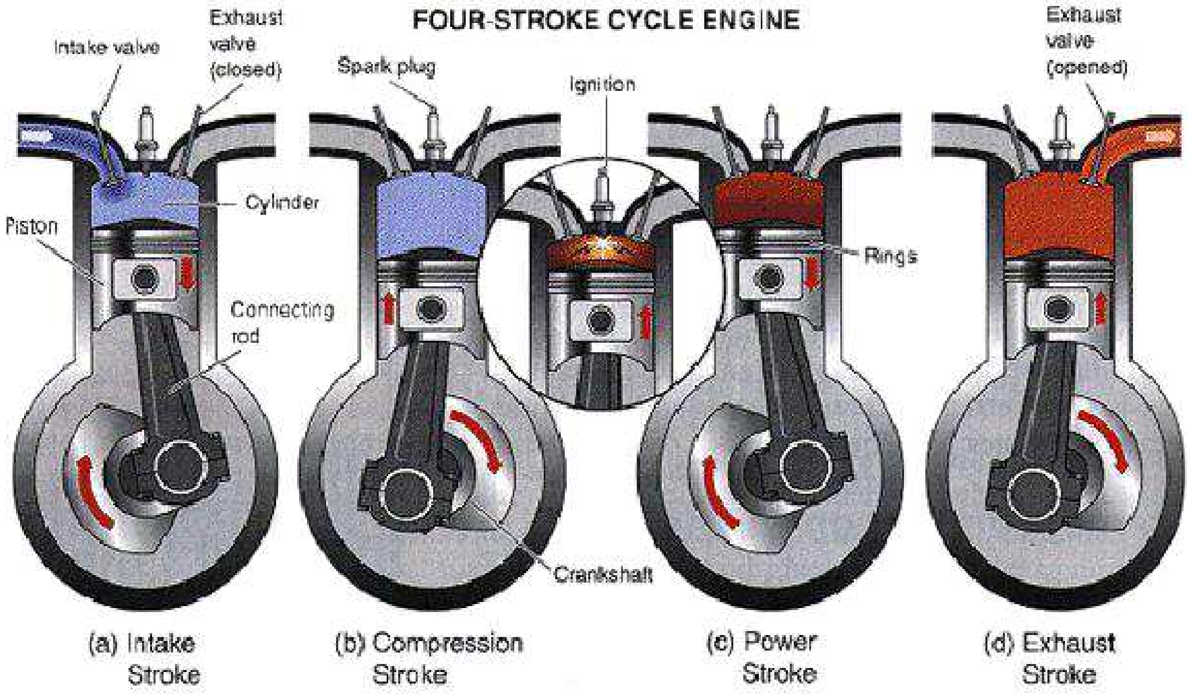


Figure 1: Engine cycles

2.2 Drive setup

The term outboard is defined as outside of the vessel. It follows that an outboard motor would be outside the main body of the vessel. A modern outboard motor is an all in one propulsion unit containing the engine, driveshaft, gearbox, cooling system and propeller in one casing. Smaller outboards may even incorporate the fuel tank.

In typical outboard configuration, the motor is hung from the transom and the battery and fuel tanks (where applicable) are secured in the stern of the vessel. Some vessels also have small outboards in the bow to aid with manoeuvring.

Outboard motors are simple and robust and have many advantages, such as ease of access for service and repair, relatively easy to remove / replace the entire unit and they are relatively inexpensive. But they also have one major disadvantage in that the weight distribution of the vessel is biased towards the stern

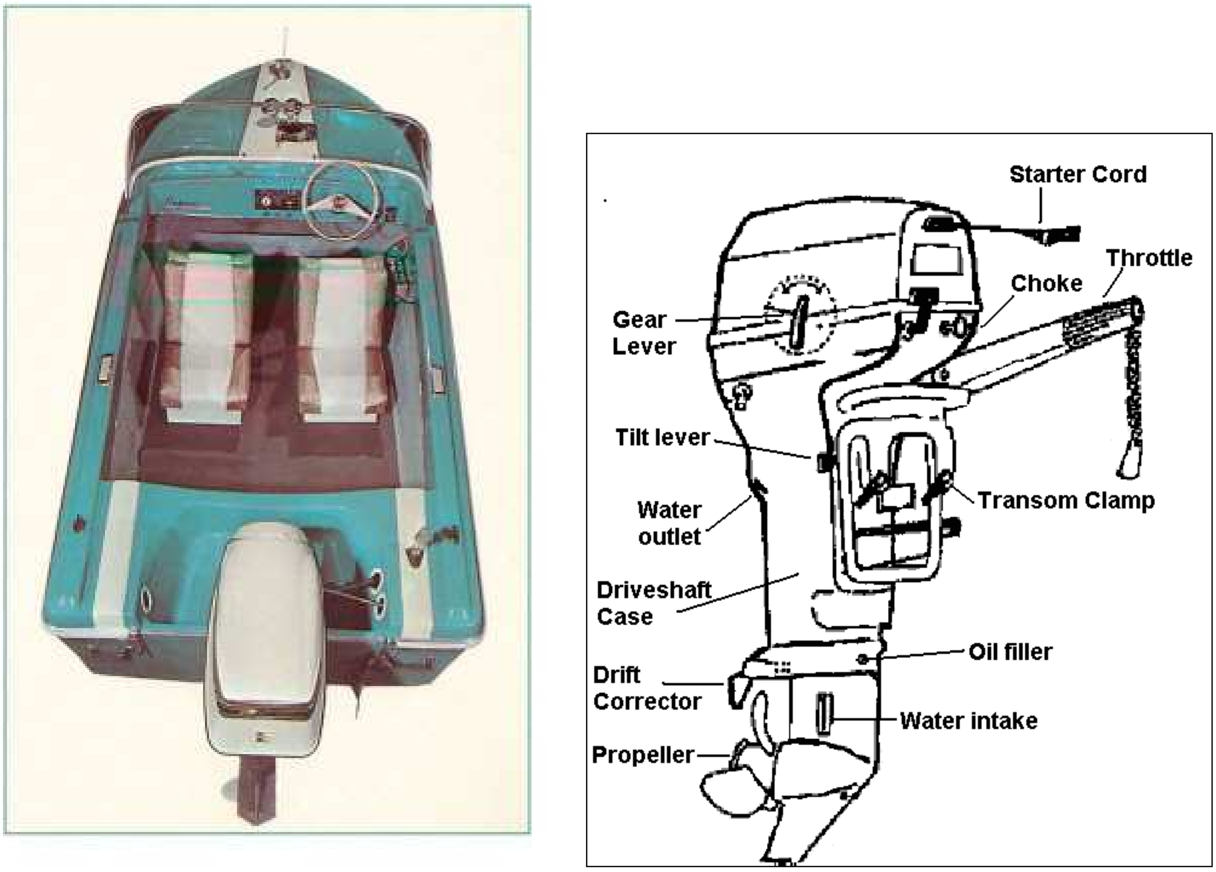


Figure 2: Ski boat and outboard layout

On the other hand, in vessels with an inboard or stern drive configuration, the engine can be placed nearer the centre of the vessel, resulting in better balance. The engines can also be larger and more powerful. However, they are more generally more expensive and may be more difficult to service or repair (depending on the construction of the vessel)

In a typical stern drive configuration, the engine and gearbox will be placed near the centre of the vessel. An inboard configuration, generally only found on larger vessels, will have a drive shaft from the engine that goes through the hull via a stern gland (a.k.a stuffing box) and is attached to the propeller. Smaller craft will have a Z-drive attached to the transom that transfers the power from the engine to the propeller

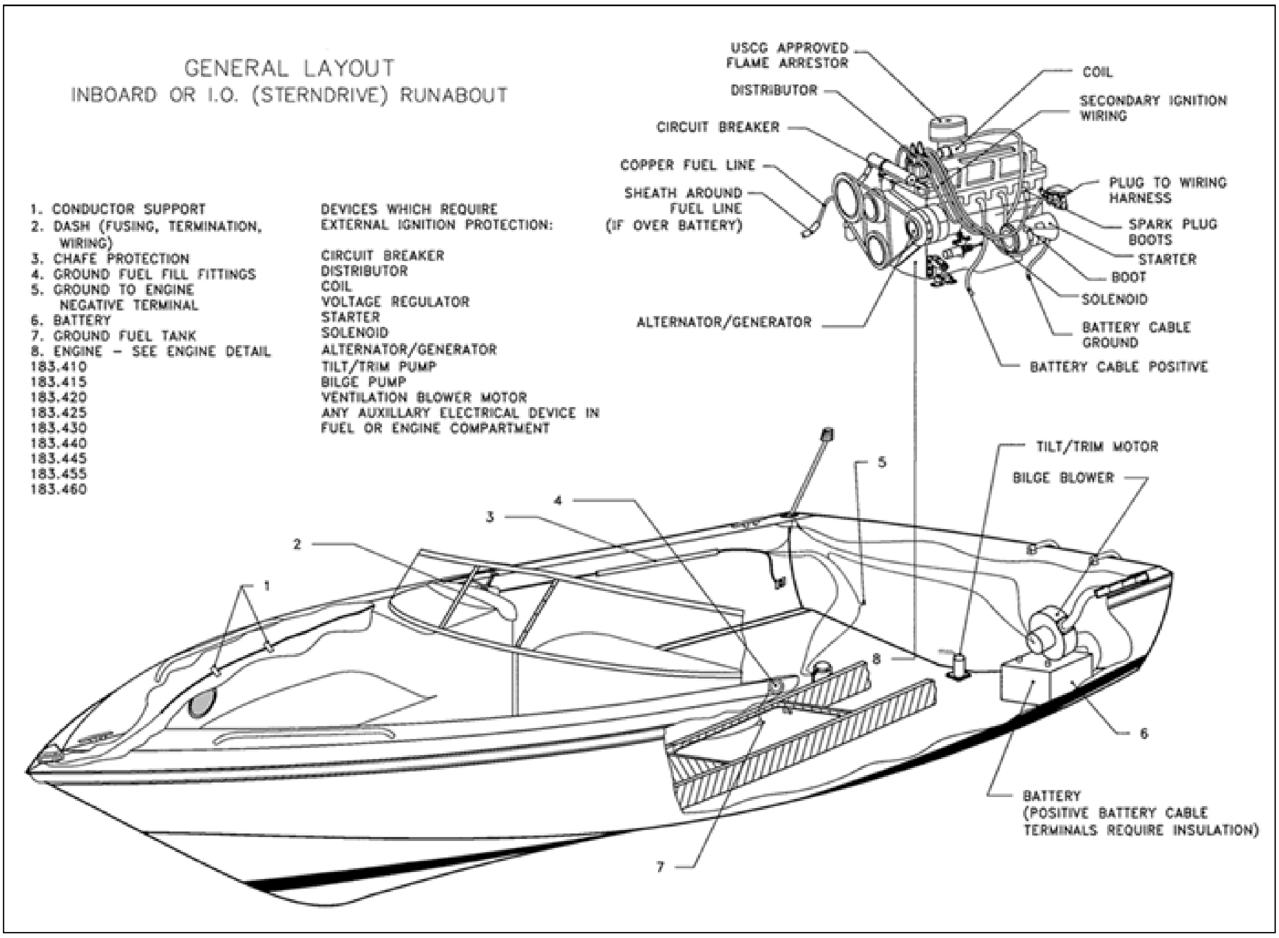


Figure 3: General inboard engine layout

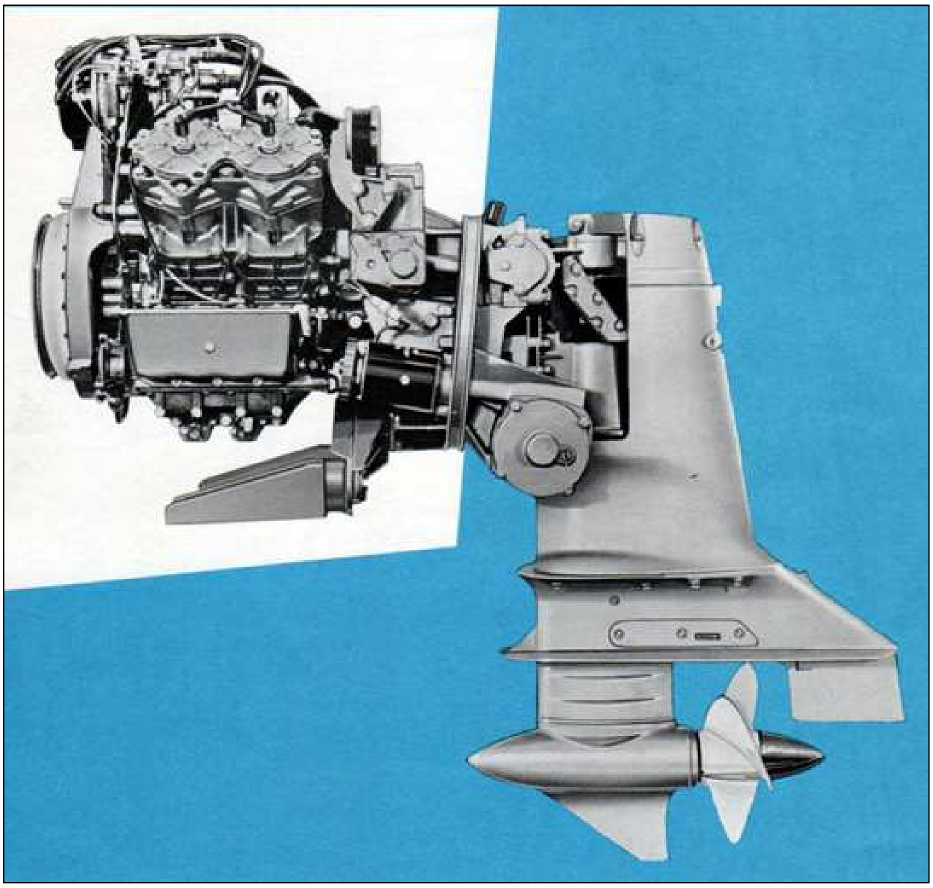


Figure 4: Sterndrive

2.3 Fuel

The options for this category are petrol and diesel. The major difference between petrol and diesel is the method of ignition. In the case of a petrol engine, the compressed fuel / air mixture is ignited by a spark from the spark plug. For a diesel engine, the fuel is atomised by injecting it into the cylinder at extremely high pressure and the piston compresses the mix to such an extent that it self ignites. Other important differences are the fuel efficiency, torque and revolutions per minute.

In the case of a petrol engine, you need electric connections to provide the spark to the plug, which is not required on diesel engines. Diesel engines also have the advantage of producing more torque and using less fuel than petrol equivalents. Petrol engines gain the advantage of being lighter and being able to rev higher.

A couple of manufactures have attempted to produce diesel outboard motors, but they are extremely rare. The engine block must be made heavier and stronger to deal with the higher compression ratio and they rev slowly in comparison to petrol motors. To move through the water using a small propeller, the propeller must spin rapidly and a diesel engine cannot spin the propeller fast enough

Diesel engines are most often used, and are ideally suited, for larger vessels, where large propellers turn at a slower rate.

2.4 Cooling System

The combustion of fuel within the engine causes a build up heat in the engine. Some heat is necessary as a warm engine runs more smoothly and more efficiently than a cold engine, but too much heat will result in damage to the piston rings, valve seats and engine head. The excess heat can be removed from the engine in 1 of 3 ways

1. Air Cooling – in this case, the engine is designed to allow the free flow of air around the block. Heat is transferred to the air as it passes by, there by cooling the engine. This method is not very effective and is generally only found on small capacity outboard motors.
2. Open circuit water cooling – In an open circuit, water is drawn into the motor from the water floating the vessel. Using a specific pump or an impellor, the water is forced through cooling channels in the block and head. As the water passes through the channels, heat is transferred to the water, and then the water is expelled from the engine back into the main body of water. This method is more effective than air cooling as the water absorbs more heat and is constantly being forced around the engine. Most small marine engines and specifically outboards make use of this method.
3. Closed circuit water cooling – Much the same principle as the open circuit, except that the cooling water remains in the system. This method requires the use of a radiator or heat exchanger to remove heat from the water. These systems are more complex than open circuit, but have a major advantage in reducing salt water corrosion in the engine. For this reason, most large sea going vessels use closed circuit cooling systems.

2.5 Propellers

Whether using an outboard or a stern-drive, the selection of the correct prop is vital. A correct prop will allow the engine to maintain its recommended R.P.M. under load. An incorrect prop may result in abnormal fuel consumption, slow top speed and sluggishness to plane.

Your prop should be free of nicks, chips, pitting or bent edges to allow it to develop an even thrust across the entire aft surface of each blade. Wear, pitting or an uneven bite may result in visible "hot spots" on the surface of the blades, indicating that the prop needs to be repaired or replaced.

2.6 Cavitation

- As a propeller rotates, the water pressure increases on the face of the blades and reduces behind the blades. Water pressure can be increased infinitely, but as the R.P.M. increases, the pressure behind the blade drops below the vapour point of the water. At this point, the water vaporises forming cavities and you have the beginning of cavitation. It can also be caused by a propeller operating too close to the surface and drawing in air. This type of cavitation will be visible as a mass of bubbles around the propeller and sudden increase in RPM. The function of the flat horizontal blades on Z drive and outboard drive legs just above the propeller, called the cavitation plate is to prevent air being sucked down into the propeller via the trailing edge of the drive leg.
  Cavitation decreases the efficiency of the propeller and causes the engine to race. The collapsing of the cavities can also cause pitting on the blades and produce uncomfortable levels of noise and vibration.
- Exhaust gasses can be drawn back into the outboard propeller when going full astern in an emergency, and thus reduce available power.

Selection of propeller depends on the purpose for which it will be used, but in any application, the prop should deliver maximum power under maximum load at the top recommended R.P.M. of the engine. The two factors to consider are the number of blades and the pitch of the blades.

2.7 Number of Blades

- A 5 blade prop is used on large vessels to minimize vibration while delivering maximum thrust at low R.P.M.
- A 4 blade prop is used on medium size vessels to minimize vibration while delivering maximum thrust at low R.P.M.
- A 3 blade prop is used for small H.P. engines to provide good acceleration and planning ability
- A 2 blade prop is used in racing to prevent cavitation where the engine speed exceeds 4000 R.P.M.

2.8 Pitch

The pitch of the blade is defined as the theoretical amount of forward travel per revolution of the prop and is very important. For example, a boat with a single engine may be fitted with a 12 pitch prop, but the same boat with the same load may use a 13 pitch prop with a twin engine setup.

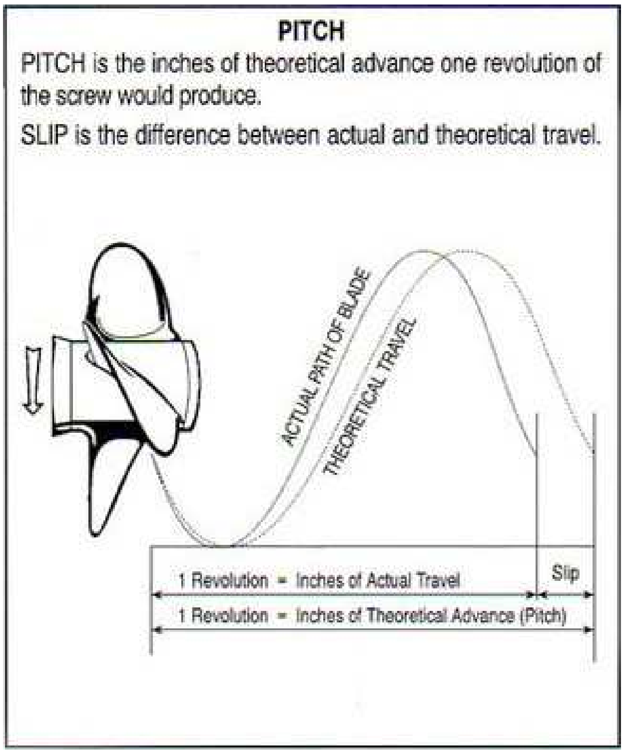


Figure 5: Propeller pitch

Most small craft have constant pitch props, but it is also possible to get propellers where the pitch changes across the face of the blade. These are known as progressive pitch blades and offer superior planning performance

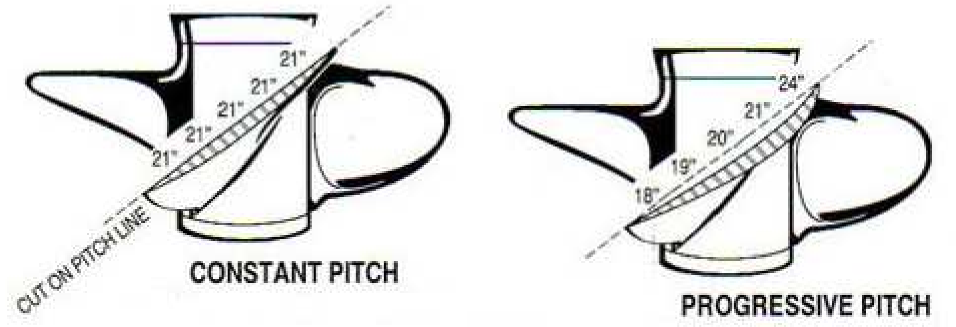


Figure 6: Propeller Pitch

On some large vessels it is possible to adjust the pitch to suite the requirement while at sea. These are known as variable pitch propellers.

2.9 Propeller thrust

As a propeller spins it exerts force on the vessel in 3 ways.

- Axial thrust is produced in the line of rotation of the propeller. This the thrust that propels the vessel forward or aft
- Transverse thrust, also known as propwalk, is produced at 90° to the axis of rotation. With a right handed propeller, turning clockwise, the torque of the propeller will slowly turn the vessel to starboard. When the engine is put astern, the stern of the vessel will shunt across to port. On some vessels this can be so positive that it becomes a primary manoeuvring tool; in others it is barely perceptible
- Rotational force from the propeller described above will cause the boat to cant slightly to port.

3 Construction

The following are the construction requirements as set down by SAMSA for vessels longer than 9 metres or with more than 6hp.

3.1 Buoyancy

The law states that all vessels must have sufficient built-in buoyancy to keep the vessel afloat while fully loaded and swamped. It must also be capable of keeping a capsized vessel afloat in a way that provides a platform on which the full crew complement can reside. The built-in buoyancy must be a material that is not affected by oil based products. The volume displaced by the buoyancy (i.e. the reserve buoyancy) is required to represent a figure of 30% of the gross weight of the vessel.

For solid hull vessels when life rafts are not carried, the vessel must have sufficient buoyancy in the form of foam or approved plastic bottles.

Inflatable or Semi-rigid vessels must have at least 3 separate inflated buoyancy chambers. The vessel must be able to stay afloat with any two of the chambers deflated. Ensure that vessels with wet decks have large enough scuppers drain the water in the event of the vessel being swamped.

In accordance with the regulations, vessel owners are required to be able to prove that their vessels have suitable and adequate buoyancy. This can be proven by:

- A manufactures certificate.

- Weighing the vessel and calculating the appropriate amount of buoyancy
- By pulling the plugs or swamping the vessel in calm water. This method is not recommended.

The buoyancy must be capable of keeping the craft with all passengers, motors and equipment afloat for 48 hours in any emergency.

3.2 Hatches

Hatches must have lockable watertight covers. When fastened down, all watertight hatches should be able to withstand a hose test. A hose test involves playing a jet of water along the cross joints and perimeter seals of the hatch covers at a certain minimum pressure and distance from the structure.

3.3 Guard Rails

All walking space should be protected by guard rails. On vessels <9m, the rails should be 450mm high

3.4 Towing bollards

Every vessel must have a towing bollard or bow eye, as well as a stern eye.

3.5 Engine Power

The engine must be capable of propelling the craft at least five (5) knots when fully loaded

3.6 Fuel Tanks

Only approved tanks constructed of steel or another suitable non-corrosive material may be used. The tanks must be efficiently secured and outlets must have shut off valves or approved automatic shut off or anti-siphoning devices. The valves should be operated remotely if not readily accessible.

Filler pipes must have threaded plugs or caps and breather valves should not leak if heeled to 50°. Fuel levels must be able to be determined and gauge glasses, where fitted, must have self closing valves. All fuel tanks and lines containing petrol must be fitted outside the battery compartment. Fuel lines should be heavy duty steel or copper or heavy duty hose with metal braiding.

The fuel tanks may not be installed inside the engine compartment

3.7 Electrical Installation

As more and more modern technology is being used on board vessels, the electrical systems are becoming more vital. However, seldom is any thought given to the capacity of the battery or recharging system.

The law required that batteries must be isolated from engine and secured in a separate watertight compartment and a suitable charging appliance must be fitted. Batteries should be placed as high in the boat as is practical and be well secured.

All circuits should be protected by a fuse of the appropriate rating. All wiring should be kept clean and tidy and well secured.

Boats restricted to daylight operation need only have one bank of batteries, where the engine has a hand start mechanism. The single bank must be capable of providing 12 hours of auxiliary power for navigation lights, electric bilge pumps and fixed radio equipment, if applicable. All other vessels require 2 banks of batteries be capable of providing 48 hours of auxiliary power

3.8 Bilge Pumps

Vessels less than 5m must be fitted with a hand operated pump (capacity 2000 litres per hour) if the vessel has a split deck or cabin below deck. Vessels over 5m must be fitted with a power driven pump (driven electrically or by the main engine) with a capacity of 3000 litres per hour. In addition, the vessel must be fitted with a hand operated pump situated above the main deck. All bilge pump outlets should be fitted with non-return valves

3.9 Inboard motors

A vessel with an inboard petrol engine shall have

- A water and vapour tight engine compartment
- A bilge pump in the engine compartment
- A gas detector fitted in the engine compartment.
- A flame proof alternator and starter
- An extractor fan drawing from the engine compartment
- An ignition system that runs the fan for 30 seconds before starting the engine
- The exhaust system must be lagged to reduce heat transfer and run clear of any bodywork that is liable to catch fine.

3.10 Kill Switch

Inflatable vessels have a tendency to throw the skipper overboard, and for this reason they must be fitted with a Kill Switch a.k.a. Dead Man Switch. This switch is an electronic plug attached to the skipper’s arm via elastic cord and will cut the engines if pulled out.

3.11 Visibility at steering position

There must be clear visibility from two points abaft the beam on each side forward. Screens must be constructed from non-opaque or non-starred plastic or armour-plate glass

4 Operation of a Power Driven Vessel

In the wrong hands, a power vessel can be extremely dangerous, to the people onboard and those in the surrounding water. Almost every week there is a news item about people being injured by power vessels. For this reason, the skipper of any such vessel must have a licence (Certificate of Competency) certifying that they can safely operate a power driven vessel.

4.1 Before Launching

Check that:

- The fire extinguisher(s) are in place and charged
- The bilges are clear of water, oil, fuel and rubbish and the bilge pump system is working.
- The drain plugs are fitted
- The steering system is operational and turns the motor or Z-drive fully to either side
- The fuel tank is secure and the fuel lines are properly connected, unkinked and that there are no leaks
- The breathers and fuel valves are open and the engine is primed
- You have sufficient fuel for your journey, plus a reserve of at least 25%
- The oil level in the engine and gearbox if applicable
- The engine compartment contains no fuel or oil and has been thoroughly ventilated (inboard engines)
- The motor is securely fastened to the transom (outboards)
- The engine cover is securely in place.
- Trim and tilt is functioning (if fitted)
- The battery is secured in place and the terminal connections are tight
- Connect the cord to the kill switch so the engine can be stopped quickly in an emergency.
- A quick start of the engines is advisable to check that they fire, but do not run for more than a few seconds as this may cause the engine to overheat and damage the impeller

4.2 Launch Procedure

- Disconnect the trailer electrics from the tow vehicle and remove tailboard (if fitted)
- Release the chains / tie down straps and remove the support bracket from the engine
- Back the trailer into the water until the boat can be pushed off. Use the winch or painter to prevent the boat floating away.
- Secure the boat to a jetty or mooring and move the trailer to the designated trailer park

4.3 After Launching

- Start the engine and check that the cooling water is being circulated through the engine and discharged.(on outboard motors commonly called the tell tale).
- Visually check the engine for leaks, excessive vibration or any signs of overheating
- Never over rev a cold engine. Run the engine at low throttle openings (not more than 1500rpm) using the warm up levers (if fitted) for a few minutes until the engine has warmed up

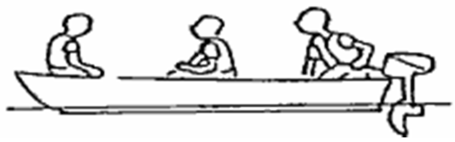
- Ensure the engine responds to the throttle. Be sure that your prop is not stuck on the bottom before engaging gear, as this will cause the motor to stall and damage the prop and gearbox

4.4 Balancing the Vessel

- Never exceed the ratio of 10kg of all up weight for every 3kg of reserve buoyancy.
- Distribute the weight to keep the boat balanced according to the conditions. In a following sea, move the weight forward to allow the bow to rise. In a bow sea, move the weight aft to allow the bow to rise over the waves.

Poor: Too much weight in front

Poor: Too much weight in back



Correct: Load is evenly distributed and ensures optimal performance

- Never overload the vessel with either people or equipment. An overloaded vessel will have less freeboard and be less responsive to the helm and to general sea conditions. The vessel will tend to push through wave crests instead of rising over them.
- Overloaded vessels also have a higher centre of gravity and are more susceptible to capsizing. Once a vessel has capsized, it is actually more stable as the buoyancy is on the surface and the weight is below.

4.5 Springing Away from a Berth

At the beginning we noted that you can't just 'drive' a boat from an alongside berth. This is because if you try to steer out, the dock prevents her stern from pivoting in, with the result that you bash your stern along the dock and don't succeed. Shoving the bow off is the simplest solution to this difficulty, but this isn't always practical, particularly in strong onshore winds, or where larger boats are concerned. What you require is a method that falls between pushing off and hauling the bow out using a kedge. The answer is to spring off, as shown in below.

Springing off involves removing all your lines except one spring line, then motoring against it so that the opposite end of the boat is levered off the wall.

To spring the bow out, motor astern against the stern spring and the bow will waltz round to seaward as if by magic. If this doesn't work, springing the stern out is even more effective. Leave the bow spring on, motor ahead against it, and turn your rudder in towards the wall as though you wanted to steer your bow in. The propeller wash is blown inwards by the rudder. The bow spring levers the stern out as well and, before you know it, you are far enough out to let go and motor astern into open water.

Don't forget to use your fenders intelligently while springing off, and always be sure that you can let go the spring line without leaving one of your crew on the pontoon.

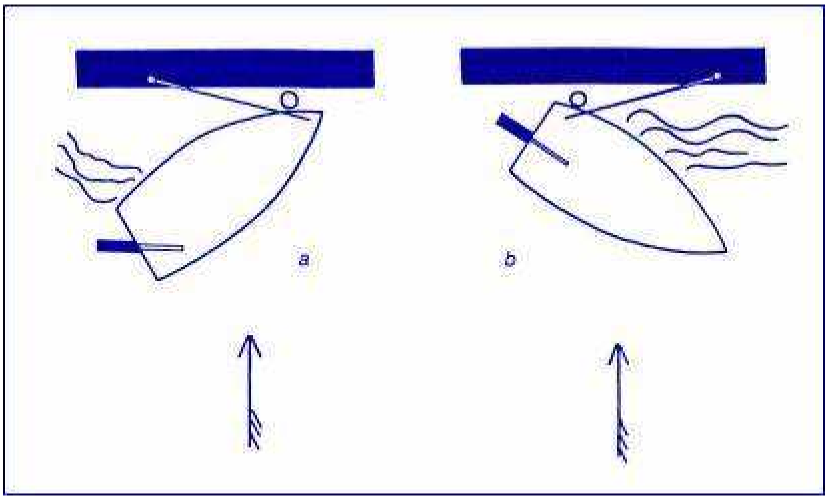


Figure 7: Springing away from a berth

4.6 Accelerating and Planing

Accelerating is an easy process, but it is easy to make mistakes.

During acceleration, always increase throttle smoothly. The acceleration will cause the stern to squat and rapid increase in RPM will cause the propeller to cavitate.

Acceleration tends to make a boat leave the water and hydroplane on the surface; this movement is triggered by the wash of the motor. It lifts the boat by several degrees. This seriously diminishes the operator's visibility in front of the boat and makes it more difficult to effectively use the motor's propulsion force. To correct this situation, simply accelerate slightly to pass over the wave onto the plane and regain a relatively horizontal trim.

Most motor vessels operate most efficiently when planning.

4.7 Turning

A vessel is turned by moving the rudder from side to side. In vessels with outboard motors and Z-drives, there is no rudder and turning is accomplished by altering the angle of axial thrust of the propeller.

A rudder will be effective as long as the vessel is making way. An outboard motor does not operate as a rudder and the vessel will have no steerage if the motor is in neutral or switched off.

When turning, a vessel pivots around the pivot point of the vessel. This point is dependent on hull shape and boat speed, but is approximately 1/3 of the vessel's length aft of the bow. The higher the speed, the further forward the pivot point, up to the planning, when the pivot point is some distance in front of the bow.

- When using a tiller, move the tiller in the opposite direction to the intended direction of turn. With a wheel, turn the wheel in the intended direction of turn
- After the rudder / axial thrust is turned, the vessel continues straight for a short period due to momentum and inertia

- Once the rudder / axial thrust takes hold, the stern of the vessel swings out as it enters the turn.
- The vessel turns about the pivot point, bow inside the path of turn and stern outside the path.

On vessels with multiple engines, the boat can be made to swivel by reversing the thrust on one side.

4.8 General Manoeuvring

- Within 50m of any shore or moored vessel is a "No Wake Zone"
- Reduce speed sooner rather than later – motor boats do not have brakes.
- The radius of the turning circle is proportional to the speed of the vessel – the faster the speed, the larger the turning circle.
- Reduce speed slowly from full throttle to avoid being caught by your wake.
- Never follow in the wake of a skier, wake snake etc.
- After operating the engine at full power, allow it to idle for a minute to cool down before switching off.

4.9 Stopping

Since boats do not have brakes, a skipper must think far ahead when needing to stop.

- Move the throttle smoothly back to the neutral position, allowing the boat to gradually slow down.
- Be aware of the waves in your wake. Do not allow them to break over the transom
- Only engage reverse at low speeds to scrub off the last bit of head way

4.10 Coming Along Side

- Bearing in mind that a motorised vessel is steered from the rear, aim the bow of the vessel at the point where you want the vessel to stop
- Come in as slow as possible, maintaining on enough way for steerage
- Just before reaching the dock, turn bow away from the dock. This will bring the rear in and you can stop alongside.
- You may want to put your engine astern to drag off the last of your way. If this seems at all likely, bear in mind what your propwalk will do. If it is going to pull your stern into the dock, so much the better. If the contrary will be the case, be ready to check the stern using mooring lines and don't use reverse at all if you can avoid it. If there is no tide and not much breeze, you should always choose to put the side to the dock which the boat naturally favours. A right-handed propeller will slide you sweetly into a port-side to berth, for example.

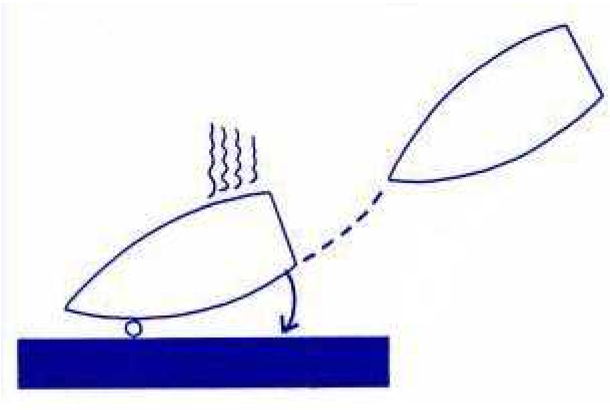


Figure 8: Coming along side

4.11 Tying Up

Under most circumstances, a boat of any length under 17m is best tied up with four ropes. These are the bow line, the stern line, the bow spring and the stern spring. Assuming the boat is 'head up' to the tide or the wind is blowing along the dock, she will be secure enough lying to a bow line only, but she will not be tidy. She will lie bows-in to the dock, risking damage to her pulpit, and bow in general. Putting on a stern line which leads away aft will do little to remedy this situation. However, if you rig a stern spring from well aft to run out parallel to the bow line she will settle back on the pair of ropes and lie sweetly beside the dock.

The position can be firmed up by rigging a stern line to hold the boat back against the other two lines. Should she now ride forward, of course she will hang from the stern only and will finish up grinding against the wall, but this situation is neutralised by deploying a bow spring to act as a pair with the stern line.

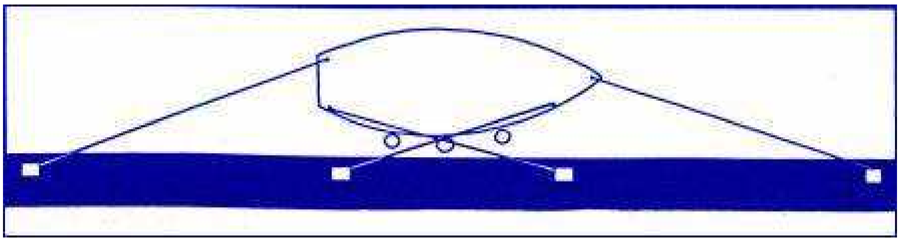


Figure 9: Berthing lines

4.12 Refuelling

- Be aware of static electricity when refuelling
- Avoid spillage to prevent pollution at sea or on the shoreline

4.13 Recovery

- Back the trailer into the water to until the rails and keel rollers are just below the surface.
- Drive the boat onto the trailer at slow speed, using the engine to push the boat as far on as possible. Then attach the winch and winch the boat fully onto the trailer
- Raise the engine
- Slowly pull the trailer from the water, checking to see that the boat stays centred on the trailer
- Remove drain plugs
- Lower motor to allow it to drain
- Secure boat on trailer and secure motor.

4.14 Flush the Motor after Use

- Lower the motor and ensure it is in neutral
- Connect a fresh water source by fitting flush muffs over the water intakes or placing the leg of the motor in a drum of water
- Run the motor at low revs for a few minutes.
- Wash any salt, sand or mud off the exterior of the motor.

4.15 Long Term Storage

If you will not be using the engine for an extended period:

- Connect a fresh water supply using flush muffs

- Start the engine and then cut off the fuel supply by either disconnecting the tanks or closing the fuel shut off values.
- Wait until the engine dies from fuel starvation
- Spray the engine with a water displacement spray
- Disconnect the batteries and cover motor.