Chapter 8: Boat Characteristics

Introduction

Knowledge of a boat's characteristics is crucial in performing safe boat operations. All crewmembers must be able to recognize and correctly apply boat related terminology. They must also be able to locate any piece of gear quickly and to operate all equipment efficiently, even in the dark. To accomplish these tasks, crewmembers must be familiar with the boat's layout. Each boat has specific operational characteristics and limitations. These are outlined in the boat's standard manuals or for non-standard boats, in the owner's/operator's manual. Some types of characteristics that the boat crew should be familiar with include:

- Maximum speed
- Economical cruising speed
- Maximum range at various speeds
- Maximum endurance of boat at cruising speed
- Minimum required crew size
- Maximum number of people that can be safely carried
- Maximum load capacity

This chapter covers the basic knowledge needed to know a boat. For additional definitions see *Appendix Glossary*.

Section A. Boat Nomenclature and Terminology

A.1. Definitions
As with any profession or skill, there are special terms that mariners use. Many of these terms have a fascinating history. Fellow mariners will expect that these terms will be used in routine conversation. Many of these words will be discussed within this chapter.

The following are common terms used for location, position and direction aboard a boat. **Figure 8-1** provides a diagram of a boat with the more common terms noted.

A.2. Bow
The front of end of a boat is the bow. Moving toward the bow is going forward; when the boat moves forward, it is going ahead. When facing the bow, the front right is the starboard bow, and the front left side is the port bow.

A.3. Amidships
The central or middle area of a boat is amidships. The right center side is the starboard beam, and the left center side is the port beam.

A.4. Stern
The rear of a boat is the stern. Moving toward the stern is going aft. When the boat moves backwards, it is going astern. Standing at the stern looking forward, the right rear section is the starboard quarter and the left rear section is the port quarter.

A.5 Starboard
Starboard is the entire right side of a boat from bow to stern

A.6. Port
Port is the entire left side of a boat, from bow to stern.

A.7. Fore and Aft
A line, or anything else, running parallel to the centerline of a boat is fore and aft.

A.8. Athwartships
A line or anything else running from side to side is athwartships.

A.9. Outboard
Outboard is from the centerline of the boat toward either port or starboard side.

A.10. Inboard
Inboard is from either side of the boat toward the centerline. However, there is a variation in the use of outboard and inboard when a boat is tied up alongside something (e.g., pier or another vessel). In this example, the side tied up is inboard; the side away is outboard.

A.11. Going Topside
Going topside is moving from a lower deck to a weather deck or upper deck.

A.12. Going Below
Going below if moving from an upper deck to a lower deck.

A.13. Going Aloft
Going aloft is going up into the boat's rigging.

A.14. Weather Deck
The weather deck is the deck exposed to the elements (weather).

A.15. Lifelines
Lifelines or railings, erected around the edge of weather decks, are all technically called lifelines, although they may have different proper names.

A.16. Windward
Windward is moving in the direction from which the wind is blowing; toward the wind.

A.17. Leeward
Leeward is the opposite point from which the wind is blowing; away from the wind. The term is pronounced "loo-urd."

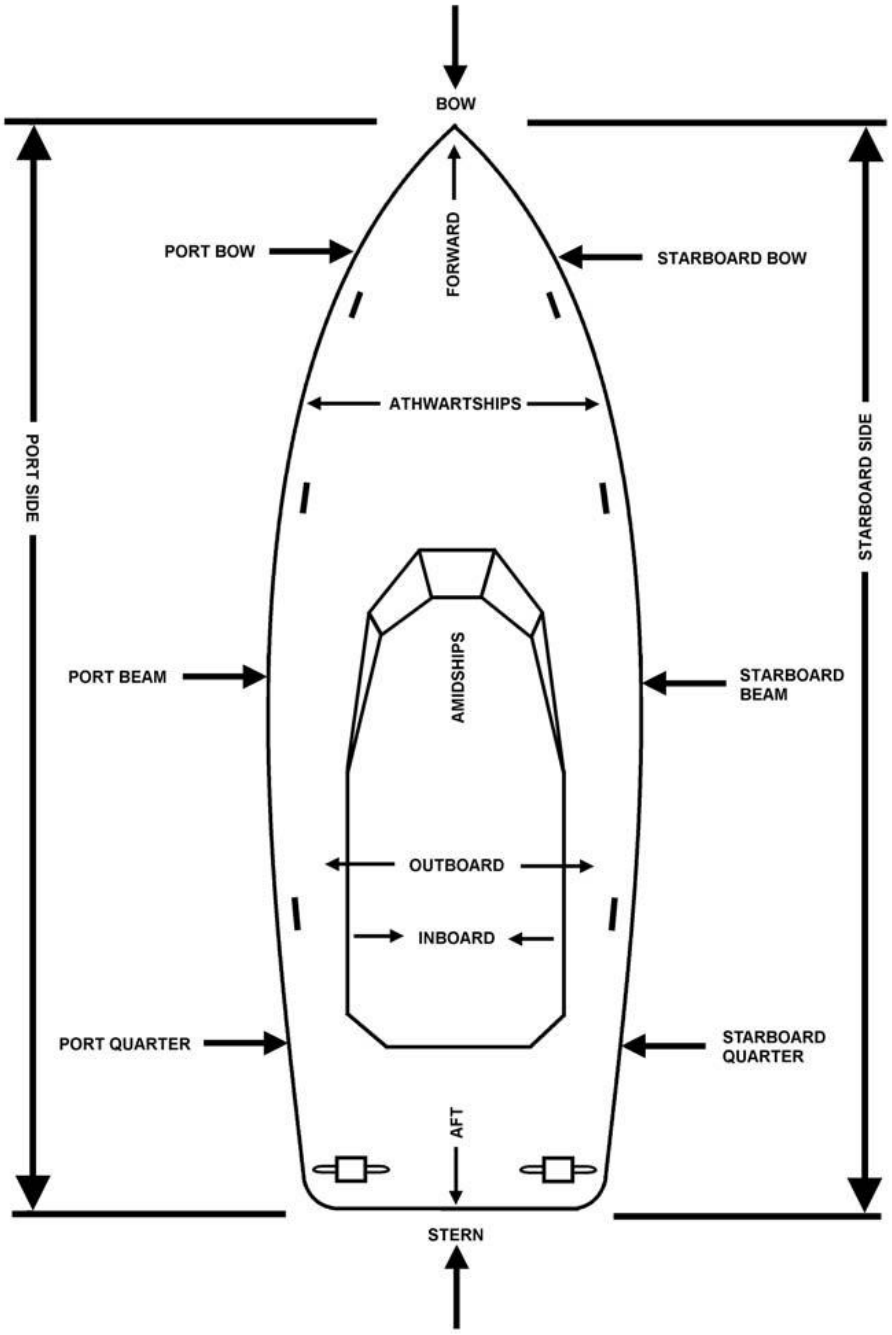

Figure 8-1
Position and Direction Aboard Boats

Section B. Boat Construction

Introduction
Boat construction covers terms that the boat crew will use on a daily basis in normal conversations and in operational situations. Proper understanding of these terms and concepts has importance that an inexperienced sailor may overlook.

In This Section
This section contains the following information:

Hull Types

B.1. Three Types
The hull is the main body of a boat. It consists of a structural framework and a skin or shell plating. The hull may be constructed of many different materials, the most common being metal or fiberglass. A metal skin is usually welded to the structural framework, although riveting is sometimes used. A vessel could be monohull or multi-hull, such as catamarans and trimarans. The three basic types of hull forms based on vessel speed are:

- Displacement hull
- Planing hull
- Semi-displacement hull

B.2. Factors Influencing Hull Shapes
Many factors influence hull shapes and affect the boat's buoyancy (its ability to float) and stability (its ability to remain upright). Factors that influence hull shapes are discussed as follows:

Factor	Description
Flare	Flare is the outward turn of the hull as the sides of the hull come up from the waterline. As the boat is launched into the water, the flare increases the boat's displacement and creates a positive buoyant force to float the boat
Tumble home	Tumble home is the reverse of flare and is the shape of the hull as it moves out going from the gunwale to the waterline. This feature is most noticeable when viewing the transom of an older classic cruiser.
Camber	A deck usually curves athwartships, making it higher at the centerline than at the gunwales so the water flows off the deck. This curvature is called camber.
Sheer	Sheer is the curvature of the main deck from the stem to the stern. When the sheer is pronounced and the bow of the boat is higher than the main deck at amidships, additional flotation, known as reverse buoyancy, is provided by flare

	and sheer.
Chine	The turn of the boat's hull below the waterline is called the chine. It is "soft" if it is rounded, and "hard" if it is squared off. Chine affects the boat's speed on turning characteristics
Transom	The transom at the stern of the boat is either wide, flat, or curved. The shape of the stern affects the speed, hull resistance, and performance of the boat.
Length on waterline	The boat's length on waterline (LWL) is the distance from the bow to the stern, measured at the waterline when the boat is stationary. Note that this length changes as the boat rides high or low in the water.
Length overall	The boat's length overall (LOA) is the distance from the foremost to the aftermost points on the boat's hull measured in a straight line. It does not change according to the way the boat sits in the water.
Beam and breadth	Beam and breadth are measures of a boat's width. Beam is the measurement of the widest part of the hull. Breadth is the measurement of a frame from its port inside edge to its starboard inside edge. Molded beam is the distance between outside surfaces of the shell plating of the hull at its widest point.
Draft	Draft is the depth of the boat from the actual waterline to the bottom of its keel
Draft appendage	Draft appendage is the depth of the boat from the actual waterline to the bottom of its keel or other permanent projection (e.g., propeller, rudder, skeg, etc.), if such a projection is deeper than the keel. The draft is also the depth of water necessary to float the boat. The draft varies according to how the boat lies in the water.
Trim	Trim is a relative term that refers to the way the boat sets in the water and describes generally its stability and buoyancy. A change in trim may be defined as the change in the difference between drafts forward and aft. A boat is trimmed by the bow hen the draft forward increases and the draft is greater than the stern draft. A boat is trimmed by the stern if it is down by the stern.

Displacement

B.3. Measurement
Displacement is the weight of a boat and is measured in long tons (2,240 lbs) or pounds.

B.4. Gross Tons
A gross ton is the entire cubic capacity of a boat expressed in tons of 100 cubic feet.

B.5. Net Tons
A net ton is the carrying capacity of a boat expressed in tons. One ton = 100 cubic feet. It is calculated by measuring the cubic content of the cargo and passenger spaces.

B.6. Deadweight
Deadweight is the difference between the light displacement and the maximum loaded displacement of a boat and is expressed in long tons or pounds.

B.6.a. Light Displacement
Light displacement is the weight of the boat excluding fuel, water, outfit, cargo, crew, and passengers.

B.6.b. Loaded Displacement
Loaded displacement is the weight of the boat including fuel, water, outfit, cargo, crew, and passengers.

CAUTION! When towing a vessel, be careful not to tow beyond the vessel's designed speed.

B.7. Displacement Hull
A displacement hull boat pushes away (displaces) water allowing the hull to settle down into the water. Underway, the hull pushes out this water, creating waves. (See **Figure 18-2**) The water separates at the bow and closes at the stern. Tremendous forces work against a displacement hull as the power pushing it and the boat's speed both increase. At maximum displacement speed, there is a distinct bow and stern wave. The length of these waves depends upon the boat's length and speed. (The longer the boat, the longer the wave length.) The bow and the stern ride lower in the water while increasing speed, and the water level alongside, amidships becomes lower than that of the surrounding water.

The lower water level is caused by the increase in the velocity of the water flowing under the boat and its interaction with the bow and stern wave. As the boat travels along, it rides in a depression created by its own passage. The displacement hull vessel's maximum speed is determined by the vessel's waterline length. Heavy displacement hulls cannot exceed a speed of 1.34 times the square root of their waterline length without requiring excessive power. This speed is known as critical speed. For details on towing displacement hulls, see *Chapter 17, Towing.*

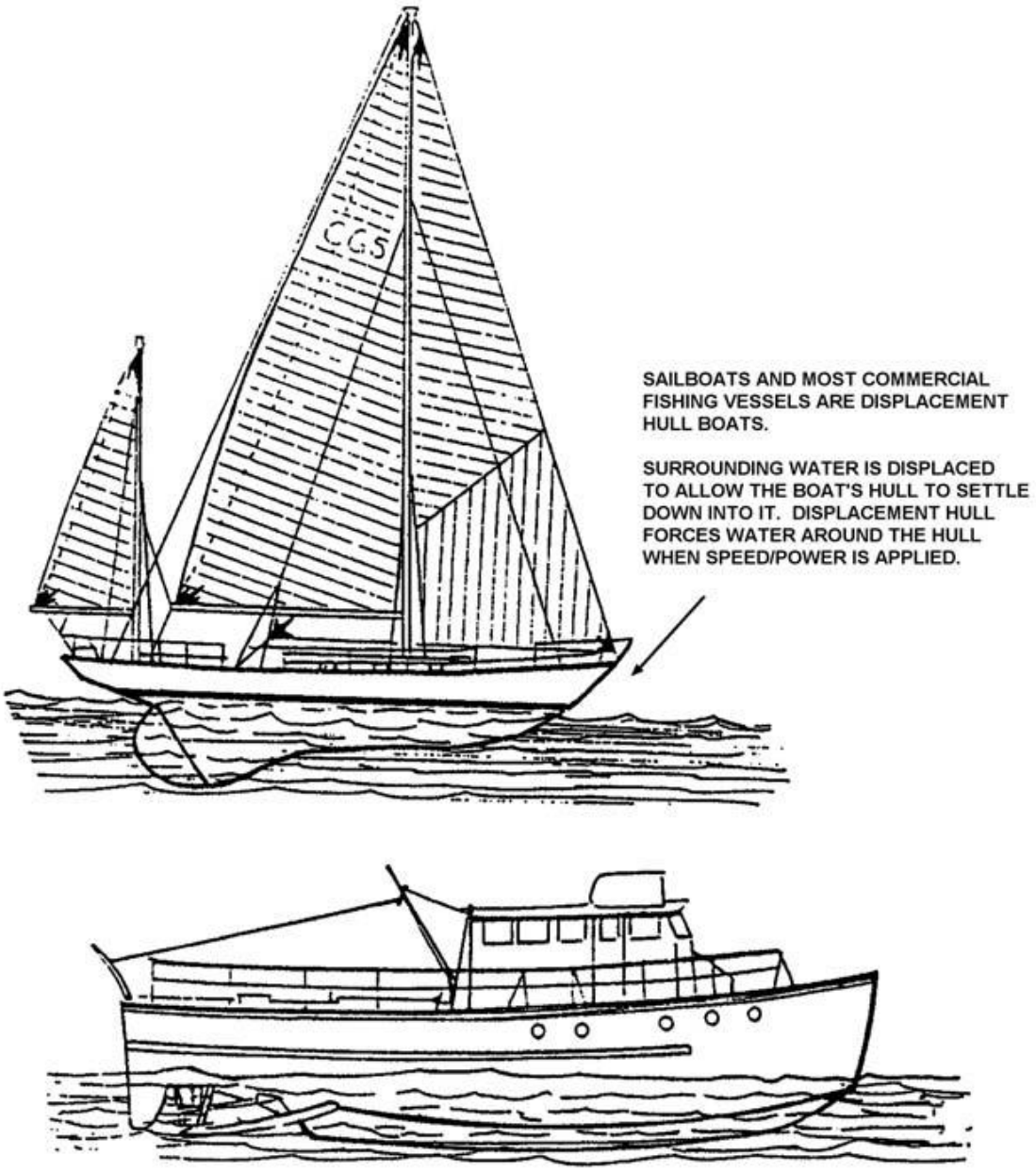

Figure 8-2
Displacement Hulls

B.8. Planing Hull

At rest, the planing hull and the displacement hull displace the water around them. The planing hull reacts nearly the same as a displacement hull when it initially gets underway – it takes considerable power to produce a small increase in speed. However, at a certain point, external forces acting on the shape cause an interesting effect – the hull is lifted up onto the surface of the water. (See **Figure 8-3**) The planing hull skims along the surface of the water whereas the displacement hull always forces water around it. This is called planing.

Once “on-plane,” the power/speed ratio is considerably altered – very little power increase results in a large increase in speed. Crewmembers must apply or reduce power gradually when going from the displacement mode to the planing mode or form planing mode to the displacement mode. When the power is decreased gradually, the hum makes an even, steady transition, like slowly moving the hand from above the water’s surface, through it, and into the liquid below. However, if power is rapidly decreased, the transition will be a rough one, for the hull will slap the surface of the water like the slap resulting by hitting a liquid surface with the hand.

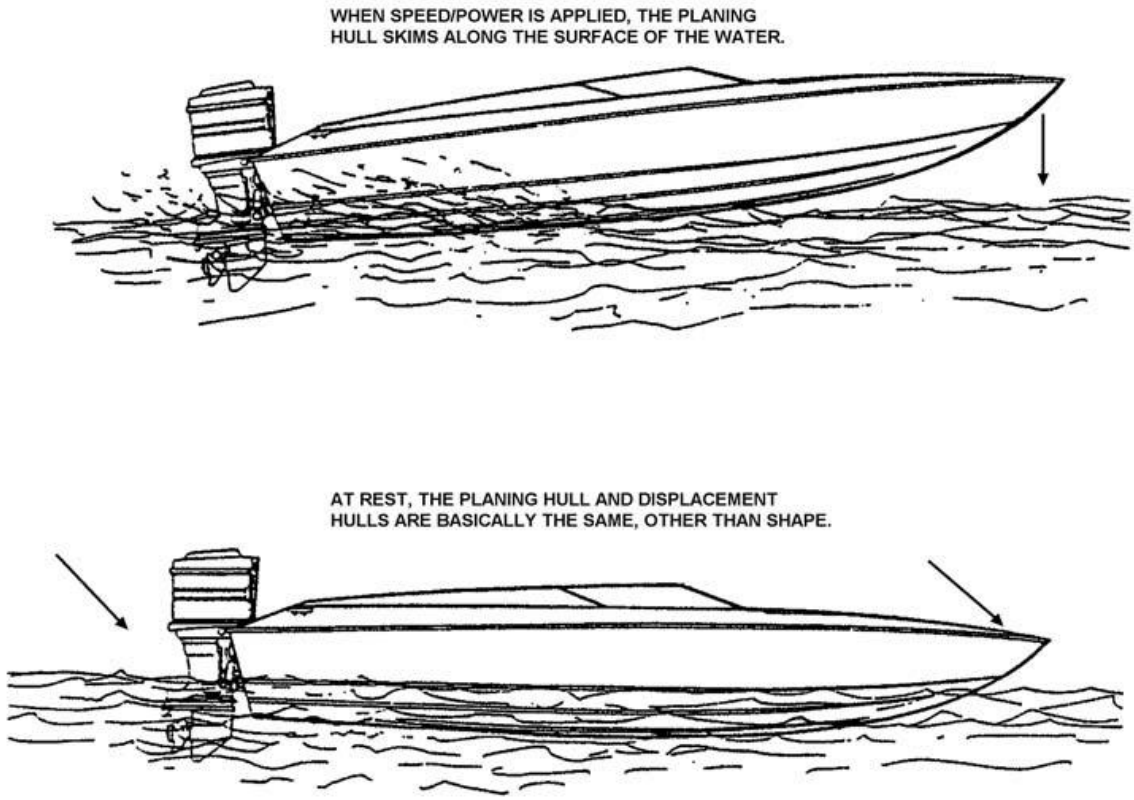

Figure 8-3
Planing Hulls

Additionally, the rapid “re-entry” into the displacement mode from above the surface, through the surface, and back into the water causes rapid deceleration as the forces in the water exert pressure against the hull. The effect is like rapidly braking an automobile.

B.9. Semi-Displacement Hull

The semi-displacement hull is a combination of characteristics of the displacement hull and the planing hull. This means that up to a certain power level and speed (power/speed ratio), the hull remains in the displacement mode. Beyond this point, the hull is raised to a partial plane. Essentially, the semi-displacement hull, like the displacement hull, always remains in the water; it never gets “on-plane.” When in the displacement mode, the power/speed ratio is similar to the power/speed ratio described above for the displacement hull. When in the semi-planing mode, it is affected by a combination of forces for the displacement mode and some for the planing mode. This, while a small power increase

will increase speed, the amount of resulting speed will not be as great as the same power increase would produce for a planing hull.

Keel

B.10 Location
The keel is literally the backbone of the boat. It runs fore and aft along the center bottom of the boat.

B.11. Keel Parts
The following are all integral parts of the keel:

- Frames
- Stem
- Stempost

B.11.a. Frames
Frames are attached to the keel, which extend athwartships (from side to side). The skin of the boat is attached to the frames. The keel and the frames strengthen the hull to resist external forces and distribute the boat's weight.

B.11.b. Stem.
The stem is an extension of the forward end of the keel. Although there are a number of common stem shapes, all are normally slanted forward (raked) at an upward angle to reduce water friction.

B.11.c. Stempost
The Stempost is a vertical extension of the aft end of the keel.

B.12. Keel Types
There are many types of keels. But for the purpose of this manual we will only discuss Non-sailing keels and sailboat keels as these are the two most common types found in Utah's waters.

B.12.a. Non-Sailing Keels
In non-sailing vessels the keel helps the hull move forward, rather than side-slipping. It gives the bottom of the vessel greater directional control and stability.

B.12.b. Sailboat Keels
In sailboats, keels use the forward motion of the boat to generate lift to counteract the leeward force of the wind. A second purpose is to provide ballast. Keels are made of heavy materials such as lead or steel that stabilize the boat. Keels may be fixed (non-movable) or they may retract allowing the sailboat in shallower waters. Retractable keels come in a *retractable* form or a *swing keel* form.

Principle Boat Parts

B.13. Bow
The shape of the boat's bow, its profile, form, and construction determine hull resistance as the boat advances through the water. Hull resistance develops from friction and from the wave the hull makes as it moves in the water. Wave-making resistance depends on the boat's speed.

The bow of a boat must be designed with enough buoyancy so it lifts with the waves and does not cut through them. The bow flare provides this buoyancy.

Boats intended for operation in rough seas and heavy weather have "full" bows. The bow increases the buoyancy of the forward part of a boat and deflects water and spray. When a boat is heading into a wave, the bow will initially start to cut into the wave. It may be immersed momentarily if the seas are rough. As the bow flare cuts into the wave, it causes the water to fall away from a boat's stern, shifting the center of buoyancy to move forward from the center of gravity. The bow lifts with the wave and the wave passes under the boat, shifting the center of buoyancy aft. This action causes the bow to drop back down and the vessel achieves a level attitude.

B.14. Stern
The shape of the stern affects the speed, resistance, and performance of the boat. It also affects the way water is forced to the propellers.

The design of the stern is critical in following seas where the stern is the first part of a boat to meet the waves. If the following waves lift the stern too high, the bow may be buried in the sea. The force of the wave will push the stern causing it to pivot around toward the bow. If this is not controlled, the result can be that a boat broaches or pitch poles.

B.15. Rudder
The rudder controls the direction of the boat and may vary widely in size, design, and method of construction. The shape of the stern, the number of propellers (if any), and the characteristics of the boat determine the type of rudder.

B.16. Propeller
Most power driven vessels are driven by one or more screw propellers, which move in spirals somewhat like the threads on a screw. That is why the propeller is commonly referred to as a screw. The most common propellers are built with two, three or four blades. The propeller on a single-screw boat typically turns in a clockwise direction (looking from aft forward) as the boat moves forward. Such screws are referred to as right-hand. On twin-screw vessels, the screws turn in opposite directions, rotating outward from the centerline of the boat. The port screw is left-handed and turns counterclockwise. The starboard screw is right-handed and turns clockwise.

B.16.a. Propeller Parts
A propeller consists of blades and a hub. The area of the blade down at the ub is called the root, and its outer edge is called the tip. (See **Figure 8-7**)

B.16.b. Propeller Edge

The edge of the blade that strikes the water first is the leading edge; the opposite is the following edge. The diameter of the screw, the circle made by its tips and its circumference, is called the tip circle. Each blade has a degree of twist from root to tip called pitch. (See **Figure 8-7**

B.16.c. Pitch

Pitch is the distance a propeller advances in one revolution with no slip. (See **Figure 8-7**) Generally, less pitch in the same diameter propeller makes it easier for the engine to reach its preferred maximum RPM; thus, like putting a car in first gear, more power, and sometimes more speed, is available. Similarly, like third gear in a car, more pitch may give more speed, but lower RPMs give less power. Optimum performance is obtained when pitch is matched to the optimum design speed (RPM) of the engine.

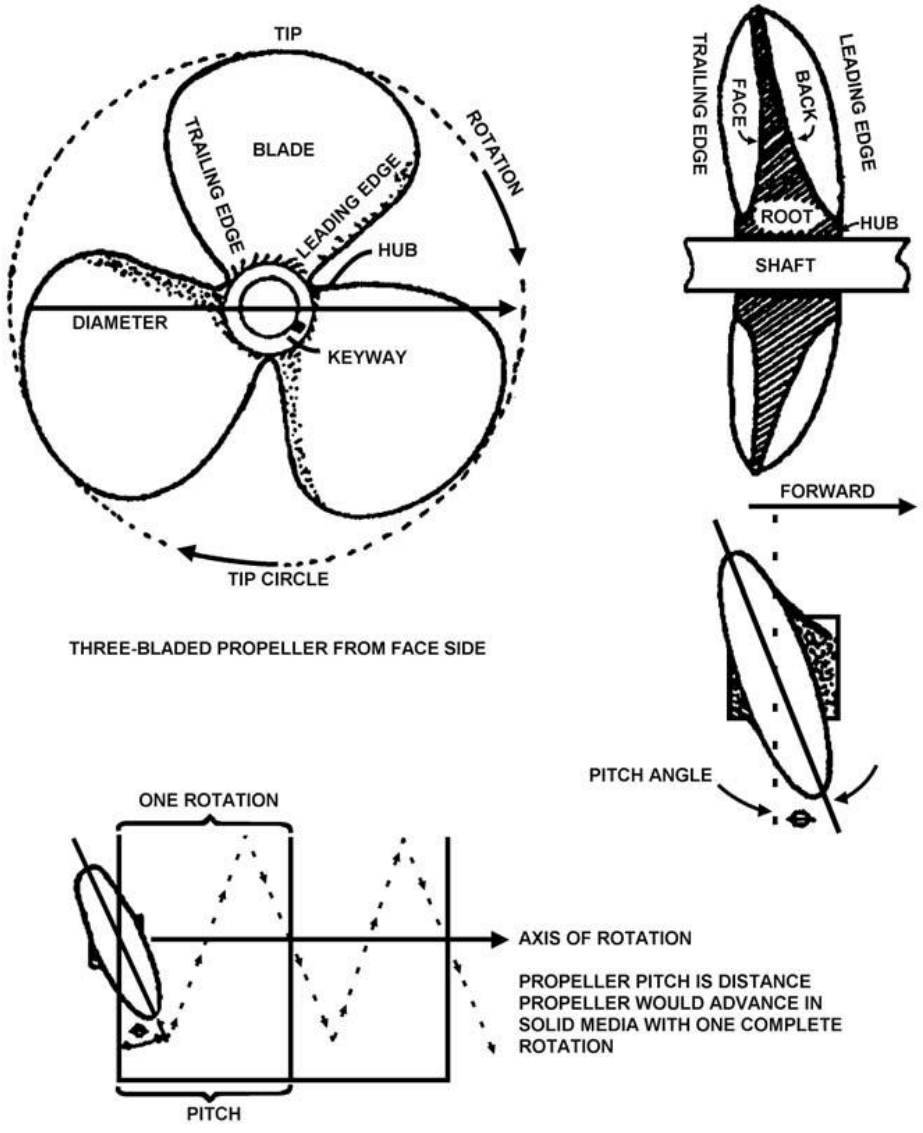

Figure 8-7
Parts of a Propeller

B.17. Frames

As previously stated, it is the framing that gives the hull its strength. Frames are of two types:

- Transverse.
- Longitudinal.

B.18. Decks

A deck is a seagoing floor and provides strength to the hull by reinforcing the transverse frames and deck beams. The top deck of a boat is called the weather deck because it is exposed to the elements and is watertight. In general, decks have a slight downward slope from the bow. The slope makes any water taken aboard run aft. A deck also has a rounded, athwartship curve called camber. The two low points of this curve are on the port and starboard sides of the boat where the weather deck meets the hull. Water that runs aft down the sheer line is forced to the port or starboard side of the boat by the camber. When the water reaches one of the sides, it flows overboard through holes, or scuppers, in the side railings.

Hatches and Doors

B.19. Hatches

In order for a deck with a hatch in it to be watertight, the hatch must be watertight. A weather deck hatch is made watertight by sealing it into a raised framework called a coaming. Hatches operate with quick-acting devices such as wheels or handles, or they may be secure with individual dogs. (See **Figure 8-10**)

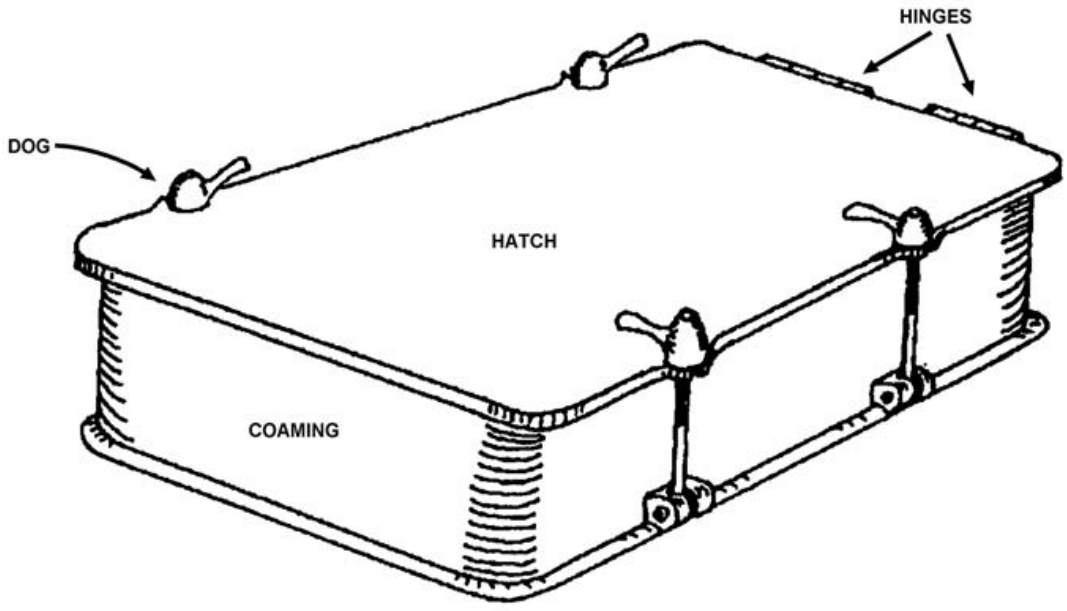

Figure 8-10

Watertight Hatches

B.20. Scuttles

Scuttles are small openings. A scuttle cover, fitted with a gasket and dogs, is used to secure the scuttle. A tool called a "T-handle wrench" is used to tighten down the scuttle cover dogs.

B.21. Doors

Watertight doors are designed to resist as much pressure as the bulkheads through which they provide access. Some doors have dogs that must be individually closed and opened; others called "quick-acting watertight doors" have handwheels or a handle, which operate all dogs at once.

B.22. Gaskets

Rubber gaskets form tight seals on most watertight closure devices. These gaskets, mounted on the covering surface of the closure device (e.g., door, hatch, scuttle cover), are pressed into a groove around the covering. The gaskets are sealed tight by pressing against a fixed position "knife edge."

CAUTION! Scuttles and hatches must be secured at all times to maintain watertight integrity except when they are open for inspection, cleaning, or painting. They must never be left open overnight or when crewmembers are not actually working or passing through them.

B.23. Knife Edges

Watertight closures must have clean, bright, unpainted, smooth knife edges for the gaskets to press against. A well-fitted watertight closure device with new gaskets will still leak if knife edges are not properly maintained.

B.24. Interior

The interior of a boat is compartmentalized by bulkheads, decks, and hatches. With the doors and hatches closed, the space between them becomes watertight and is called a watertight compartment. (See **Figure 8-11**) These watertight compartments are extremely important. Without them, the boat has no watertight integrity and a hole anywhere in the hull will cause it to sink. By dividing the hull into several watertight compartments, the watertight integrity of the boat is significantly increased. One or more of these compartments may flood without causing the boat to sink. A boat could be made unsinkable if its hull could be divided into enough watertight compartments. Unfortunately, excessive compartmentation would interfere with the engineering spaces and restrict movement in the interior spaces.

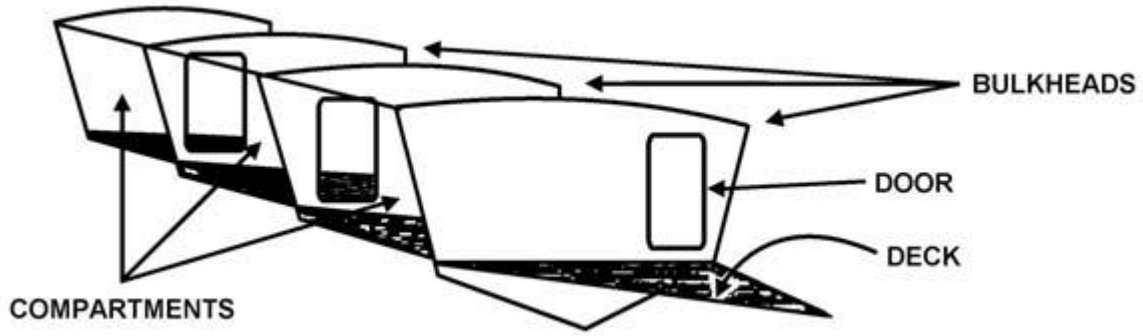

Figure 8-11
Watertight Compartment

Section C. Watertight Integrity

Introduction
Watertight integrity describes a compartment or fitting that is designed to prevent the passage of water into it. An important concern in boat operations is to ensure the watertight integrity of the vessel. A boat may sustain heavy damage and remain afloat if watertight integrity is maintained. Doors, hatches, and scuttle covers must be securely dogged while the boat is underway and while it is moored and unattended by crewmembers.

C.1. Closing and Opening Watertight Doors and Hatches
Watertight doors and hatches will retain their efficiency longer and require less maintenance if they are properly closed and opened.

CAUTION! Extreme caution is always necessary when opening compartments below the waterline near hull damage.

C.2. Entering a Closed Compartment After Damage
Watertight doors, hatches, and scuttle covers on a damaged boat must not be opened until the following is determined:

- Flooding did not occur or, if flooded,
- Further flooding will not occur if the closure is opened.

NOTE: Suspect flooding if air escapes when the dogs on a door or hatch are released.

Section D. General Boat Equipment

Introduction
All boats should carry basic equipment for the routine procedures, such as tying up, or anchoring. There is also equipment that is needed to conduct specific operations, such as SAR, towing, or LE patrols. Crewmembers must be familiar with the use of the equipment carried onboard and where it is located.

A complete listing of required equipment is contained in the *Appendix A - Required Equipment Aboard Division Vessels.* Each type of boat has its own outfit list.

D.1. General Boat Equipment List

The table below is a list of general boating equipment and the purpose for that equipment. Some of the items on the list are required to be carried aboard Division vessels. Others on the list are required on Division vessels conducting SAR activities. And, in addition to the equipment required for SAR vessels, there are other required equipment for SAR vessels on Great Salt Lake.

* Denotes required on Division Vessels
** Denotes required on Division SAR vessels
*** Denotes required on Division SAR vessels at Great Salt Lake Marina

Table 8-1
General Boat Equipment List

Item	Purpose
Anchors *	For anchoring in calm, moderate, and heavy weather
Anchor Lines *	Provides scope to prevent the anchor for dragging. Enables retrieval of the anchor. Serves as an additional towline if necessary. And can act as a makeshift drogue if necessary.
Chafing Chain *	Assists in preventing chafing of the anchor line on the bottom.
Screw Pin Shackle *	Attaches chafing chain to shank of anchor
Swivel	Allows anchor line to spin freely
Thimble	Prevents chafing of anchor line at connection point with associated hardware
Towline *	Used for towing astern
Alongside Lines **	Used for alongside towing, joining or kicker hooks, passing a pump, etc.
Heaving Lines (75' to 100') ***	Used for passing a towline when a close approach is not possible
Bridle Lines ***	Used for creating a bridle for tow operations
Bridle Shackles ***	Used for connecting bridles and tow lines
Boat Hooks **	Used to retrieve objects from the water or to pull two vessels closer together
Skiff Hook ***	Used to attach a tow line to a small skiff, john boat, airboat or daysailor equipped with a trailer bow eye.
Monel Seizing Line ***	Used to seize shackles
Lead Line (sounding Pole)	Used in determining water depth and bottom type
First Aid Kit **	For emergency treatment of injuries suffered by crewmembers or survivors
Ready Bags	Used by crewmembers to stow personal items and PPEs
Binoculars	Used for SAR applications, dead reckoning or identifying objects
Safety Harness ***	Used by crewmembers to attach themselves to the vessel
Jack Lines ***	Used by crewmembers in conjunction to safety harness to keep crewmembers safely aboard vessel

Tool Kit **	Used to make simple repairs to vessels
Manual Bilge Pump ***	Used to pass to other boats taking on water or flooding
Spare Engine Oil ***	Used as a reserve of oil (remember that most two-stroke motors will use their capacity of oil before exhausting their capacity of fuel
Paddle *	Used as a spare means of propulsion
Type I PFD's **	Used for the transport of prisoners on Division Vessels
Ring Buoy (Type IV) *	Throwable device designed to be thrown to a person in the water, grasped and held by the user until rescued.
Fenders*	Used to protect the vessel at dock or during tows
Boarding Ladder*	Used to retrieve someone from the water
Fire Extinguishers*	For extinguishing fires. ABC recommended, BC required

Section E. Troubleshooting Basic Mechanical Problems

Introduction

Troubleshooting mechanical problems is typically the responsibility of the VO or the Boat Shop. But Boat Crewmembers should be able to provide basic troubleshooting for themselves and those vessels that they are trying to assist. Often, a simple mechanical fix can avoid a long tow (especially on the larger lakes of Utah) or the loss of use of a Division rescue vessel. The primary source for a boat's maintenance and repair requirements should be the manufacturer's service manuals that come with the boat.

NOTE: If an incident command has been established in SAR/Recovery operations, keep the IC advised of the problem and updates of changing status. If in restricted water, consider anchoring

NOTE: This section is not intended to make you a mechanic of Division vessels. That is done by the trained mechanics at the Division boat shop. This section is designed to help you with BASIC mechanical items of Division vessels or to act as a guide for you to help a recreational or commercial vessel that may be having problems on the water. As stated before, this could save you having to do a long tow on Utah's larger lakes.

In This Section

This section contains the following information:

Troubleshooting Diesel Engines

E.1. Problems, Causes, and Solutions

Diesel engines are common as inboard engines for boats. They are very reliable when properly maintained. Typical problems, their possible causes, and potential solutions are provided in **Table 8-2**.

Table 8-2
Diesel Engine Problems, Causes, and Solutions

Problem	Cause	Solution
Engine will not turn over when starter button is pushed	1. Main power switch if off 2. Battery cable loose or corroded 3. Starter motor cable loose or corroded 4. Batteries are low or dead 5. Engine seized due to hydraulic lock (fuel or water in cylinders) 6. Misalignment of controls, neutral safety switch 7. Non-operating or chattering solenoid switch	1. Turn main power switch on 2. Tighten, clean, or replace cable terminals 3. Tighten, clean, or replace cable 4. Charge or replace batteries 5. Remove injectors, bar engine over by hand after (to relieve pressure and prevent internal damage). 6. Make appropriate adjustment, realign controls 7. Replace, repair cable. Replace solenoid. Check battery voltage
Irregular engine operation (engine runs unevenly or stalls)	1. Strainers and fuel filter clogged 2. Lines and fittings leaking. 3. Insufficient fuel/aeration of fuel 4. Binding fuel control linkages 5. Insufficient intake of air	1. Clean, replace, or purge air (bleed) 2. Check fuel lines and fittings for leaks; tighten or replace 3. Sound tanks-shift suction, refuel if necessary 4. Inspect and adjust 5. Inspect intake for obstructions from air silencer. Check emergency air shutdown for possible restriction
Engine over-speeds or overruns	Loose or jammed linkage (If engine RPMs increase, an internal engine malfunction has occurred. A stuck injector, a clutch that slipped into *neutral*, a lost prop or a ruptured lube oil seal could be the cause. Most engines over-speed after someone has performed maintenance. For this reason, it is most important that the operator promptly assess what is occurring. Regardless, when the engine over-speeds, follow the procedures in the next column).	➢ If an engine appears to be operating normally at *cruising* speed but fails to slow down as the throttle is being returned to *neutral*, do not place the throttle in *neutral* until a determination is made that the engine is in fact out of control (i.e., check for throttle linkage that became detached). Keeping the engine in gear will prevent it

		from being destroyed. Secure the engine by following the steps below: ➢ If over-speed continues pull engine stops, (kill switch). ➢ If engine RPMs still over-speed, shut off fuel supply ➢ If problem continues, stuff rags against air silencer. ➢ As a last resort, shoot C02 into the air intake.
Engine oil pressure high	Incorrect grade of oil	Monitor, and if pressure becomes too high, secure engine
	Oil filters dirty	Change filters
	Relief valve stuck	Adjust, remove and clean, or replace
	External oil leaks	• Check and correct • Add oil, monitor and secure engine if necessary
Engine surges	Air in fuel system	• Secure engine • Bleed air out of fuel system • Check and correct leaks
	Clogged fuel strainers/filters	Switch and replace
	Governor instability	• Adjust the buffer screw (G.M.). • Check free movement of flywheights.
	Loose throttle intake	Tighten linkage
Marine (reduction) gear fails to engage	Loss of gear oil	• Add gear oil • Check and correct leaks
	Strainer/filter clogged	Clean strainer, replace filter
	Loose, broken maladjusted linkage	Inspect and correct, as necessary
Unusual noise in reduction gear	Loss of gear oil	• Secure engine, check gear oil • Refill and resume operation for trial
	Worn out reduction gear	Secure engine
	Misalignment of gear	Secure engine
Loss of gear oil pressure to reduction gear	Loss of gear oil	• Inspect all high-pressure lines for leaks and repair • If unable to repair, secure engine
Temperature of engine coolant higher than normal	Thermostat faulty, expansion tank cap faulty, leaky hoses, etc.	• Inspect all lines for leaks and repair • For tank cap, replace if possible; and monitor coolant level

		• For thermostat, secure engine
Engine smokes		•
• Black or gray smoke	Incompletely burned fuel	• High exhaust backpressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel • High exhaust backpressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with manometer; a metal gauge which measures differential pressure • Replace faulty parts • Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner, or blower air inlet screen. Clean these items. • Check the emergency stop to make sure that it is completely open and readjust if necessary.
	Excessive fuel or irregular fuel distribution	• Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate tune-up. • Replace faulty injectors if this condition continues. Avoid hugging the engine as this will cause incomplete combustion.
	Improper grade of fuel	Check for use of an improper grade of fuel.
• Blue smoke	Lubricating oil being burned (blow by valves/seals).	• Check for internal lubricating oil leaks • Conduct compression test • Check valve and rings • Check for use of improper grade of fuel
•	• Bad oil seals in the turbocharger • Faulty intercooler • Faulty after cooler	• Throttle engine back. Call for assistance • Monitor engine (secure if

		necessary) • Return to marina
• White smoke	Misfiring cylinders	Check for faulty injectors and replace as necessary
	Cold engine	Allow engine to warm under a light load
	Water in fuel	• Drain strainers/filters • Strip fuel tank(s)

Troubleshooting Gasoline Inboard Engines

E.2. Indicators

Normal operation indicators are:

- Ease of starting
- Engine reaches specified RPMs a full throttle
- Correct shift and reverse RPMs
- Smooth idle
- Correct operating temperatures
- Adequate cooling water discharge and kill switch
- Smooth acceleration from idle to full RPMs

E.3. Basic Troubleshooting

An initial quick check of the following may reveal a simple fix for a problem that does not appear simple at first:

- Visually inspect for obvious damage
- Check the spark plugs for fouling
- Check ignition system for spark
- Check linkages for adjustments
- Check NEUTRAL/START switch
- Check gear case and lubricants in the engine

E.4. Repairs

The manufacturer's technical manual should be consulted for all adjustments and specifications. Use the following examples in **Table 8-3** as a guide, but always follow the specific engine's technical manual.

Table 8-3
Repair Advice

Problem	Check
Engine stops suddenly after a period of operation	• Inspect for obvious damage of engine components such as loose wires, leaking fuel lines, leaking of coolant, excessive heat. • Check ignition system for broken or loose parts such as wiring, distributor cap, points, or coil. • Check for clogged fuel filters, quality/quantity of fuel.
Engine stops suddenly with no spark to spark plugs	• Inspect for obvious damage, check the ignition system for broke or loose parts such as wiring, distributor cap, points, or coil.
Engine stops, restarts when cool and stops again when hot	• Have the ignition coil and condenser checked out; they may be breaking down when hot

Engine runs by spurts, and stops with the fuel filter clean	• Check the fuel tank and fuel lines • Check the ignition system for obvious damage • Check ignition timing and points • Check the fuel pump for proper operation
Engine stops after a period of rough, uneven operation	• Inspect for obvious damage • Check the ignition system for broken or loose parts such as wiring, distributor cap, points, or coil. • Check the battery, ignition timing, and the fuel filter
Engine runs by spurts and stops, water is present in the fuel filter	• Drain, clean and replace fuel filter • Check the fuel tank for presence of water and drain if necessary • If the carburetor is filled with water, it must also be drained • Take appropriate safety precautions to avoid fire or explosion
WARNING	Beware of fuel vapors before starting engine
Engine misses, gallops, spits, backfires, and has a loss of power	• Inspect for obvious damage • Carburetor may be dirty • Check ignition system for broken or loose parts such as wiring, distributor cap, rotor points and coil • Check fuel filter and fuel lines • Check for plugged vent
Engine starts hard, especially in cold weather	• Battery voltage may be low • Check ignition timing and points • Check ignition system for obvious damage • Exhaust valve may be burned • May have to change to a lighter engine oil
Engine pops and pings in exhaust pipe at all speeds	• Exhaust valves may be burned, worn piston rings or worn valve guides. • Timing may be off. • Fuel octane may be too low • Time for engine overhaul.
Starter turns engine, but engine will not start	• Check fuel level • Inspect for obvious damage to ignition system, broken or loose parts such as wiring, distributor cap, rotor, points, or coil • Check ignition timing and points • Check fuel pump • Check spark plugs

Casualties Common to Both Diesel and Gasoline Engines

E.5. Problems, Causes, and Solutions

Diesel and gasoline engines, though both run on a type of petroleum, operate in different ways. Common problems, causes, and solutions that apply to both are provided in **Table 8-4.**

WARNING! Let the engine cool down before working on it to avoid being burned or getting splashed by fluids that may be under pressure. Never work on a pressurized fluid system. Use appropriate PPE

NOTE: For all high temperature situations, the immediate action is to place the throttle in neutral then look for the probable cause. When an overheated engine must be secured, torn the engine over periodically to keep it from seizing.

Table 8-4
Diesel and Gasoline Engine Problems, Causes, and Solutions

Problem	Cause	Solution
Starter whines, engine doesn't crank over or doesn't engage, starter relay may chatter	Defective starter, Bendix is not engaged. Defective starter relay	• Call for assistance • Replace or repair starter or relay • Check bendix on return to dock
	Low battery voltage	• Check battery cables for loose connection (or corrosion) to starter. • Clean or replace cables • Charge or replace battery
Engine fails to start with starter turning over	• Fuel stop closed • Fuel shutoff valve closed • Clogged air cleaner • Fuel supply exhausted • Clogged strainer • Fuel filters clogged • Clogged/crimped restricted fuel line • Inoperable fuel pump • Emergency air shutdown tripped (type specific) • Clogged air intake • Low battery voltage causes slow cranking • Cold engine	• Open fuel stop • Open fuel shutoff valve • Remove and clear or replace air cleaner • Refill fuel tanks, bleed and prime system • Shift strainer and clean, bleed off • Shift and replace filters, bleed air off • Replace or repair fuel line • Replace fuel pump • Reset shutdown trip mechanism • Remove, clean, or replace • Charge or replace battery • Check hot start
Engine temperature high	Closed or partially closed sea suction valve	• Check raw water overboard discharge; if little or none, check sea suction valve • Open valve
	Dirty, plugged raw water strainer. (Especially	• Replace strainer

	in shallow water.)	• Check all strainers, clean as necessary
	Broken raw water hose	Secure engine, replace hose
	Broken or loose raw water pump drive belt	Secure engine, replace or tighten belt
	Faulty raw water pump	Secure engine
	Clogged heat exchanger	Inspect heat exchanger, clean as necessary
	No/low water in expansion tank (fresh water system)	• Handle the same as for a car radiator – open with caution releasing pressure before removing cap. • With engine running add fresh water
	Broken fresh water hose	Secure engine, replace hose, add fresh water
	Broken belts/drive fresh water system	Treat same as raw water system
	Faulty water pump, fresh water system	Secure engine
	Water in lube oil	Check lube oil for “milky” color. If found, secure engine.
	Broken head gasket	Secure engine, lock shaft, return to mooring
	Engine overloaded (towing too big a vessel or towing too fast.)	Reduce engine speed
	Ice clogged sea strainers (especially during operations in slush ice on Great Salt Lake.)	Shift sea strainer, open deicing valve
	Air bound sea chest	Open/clear sea chest vent valve
	Rubber impeller on raw water pump is inoperable	Replace impeller
Engine lube oil pressure fails (loss or increase)	Lube oil level low	• If above parameters, check oil, add if needed. • If below parameters, secure engine
	External oil leak	Do not tighten fittings under pressure. Secure engine. Tighten fittings if possible.
	Lube oil dilution	Secure engine if fuel dilution is beyond 5% or 2.5% (type specific; refer to Specific Boat Type Operators Handbook.
	Lube oil gauge defective	Take load off engine, if applicable, check to confirm if gauge appears to operate normally
	Mechanical damage to engine	Secure engine

No oil pressure	Lube oil pump failure	Secure engine
	Defective gauge	Verify that failure is only in gauge. Otherwise, secure engine
Loss of electrical power	Short circuit/loose connections causing tripped circuit breaker or blown fuse.	Check for shorts/grounds. Reset circuit breakers, replace fuses as necessary
	Corroded wiring connections	Clean or replace cables/wires
	Overloaded circuit	Secure all unnecessary circuits, reset circuit breakers, replace fuses
	Dead battery	Replace battery
Alternator indicator light on	Loose/broken belt	Replace/tighten belt
	Loose terminal connections	Inspect and tighten as necessary
	Defective alternator or regulator	Replace defective item

REGARDLESS OF CAUSE, FOLLOW PROCEDURES BELOW

Problem	**Cause**	**Solution**
Shaft packing overheats	Packing too tight	Reduce speed, but do not secure engine or shaft
	Bent shaft	• Reduce speed, check hull for damage or leaks. • Loosen packing nuts by turning the two nuts securing spacer plate • In cases where nuts will not back, use raw water from a bucket, wet a rag, and place it on the shaft packing housing • When the housing is cool, tighten the two nuts on the space plate until a discharge of about 10 drops of water per minute is obtained • Maintain watch on water flow (step #3) and adjust discharge as needed • Check coolness by carefully placing the back of the hand near or on the packing gland housing. • Return to marina
Shaft Vibration	Damaged or fouled propeller	Place throttle neutral if possible
	Bent shaft	Reduce speed, check hull for

		damage or leaks
	Cutlass bearing worn	Check for lines fouled in the propeller or shaft
	Engine or shaft out of alignment	• Slowly increase speed on engine. On twin-prop boats, do one engine at a time to figure out which shaft is vibrating. • If vibration continues even at low speeds, secure the engine or engines involved. • If engines are secured, lock the shafts.

FOR ALL FIRES, FOLLOW PROCEDURES BELOW

Problem	Cause	Solution
ENGINE ROOM FIRES		
Petroleum based	Oil and grease in bilges	Secure engines, turn off fuel at the tank if possible
	Fuel or lube oil spill	Call for assistance immediately
	Improper containers of flammable liquids	Secure electrical power to and from engine room
	Improper venting of engine room before starting engine	• Use any available portable fire extinguisher • Seal compartment
Electrical Fires		• Secure electricity if possible • Select the proper extinguisher agent and employ
Engine stops suddenly and will not turn through a full revolution		• Check for obstructions within the cylinders • Engine may require overhaul
Engine stops firing hot and won't turn over when cool		Engine seized, overhaul is necessary
Engine stops with a loud clatter		Inspect for obvious damage. Damage may be to internal parts such as valves, valve springs, bearings, piston rings, etc. Engine overhaul is required
Engine oil level rises, oil looks and		• There may be coolant leaking into the engine

feels gummy		oil. Check for internal leakage. • Repair the engine before continuing operation
Engine oil rises or feels thin		• Fuel is leaking into the crankcase • Check fuel pump • After problem has been corrected, change oil and filters • Check internal fuel connections
Hot water in bilges		• Inspect the exhaust piping muffler, and/or cooling water level. It is probably leaking into the bilges. • Check all hoses
Engine runs with a thumping or knocking noise		• Inspect for obvious damage to internal parts of the engine. They may be damaged • Engine overhaul is required

Troubleshooting the Outboard

E.6. Problems and Corrections

Outboard motors are very common on recreational boats as well as Division vessels. The operator's manual provides the best guidance. Working over the transom of the vessel poses a hazard to the operator and creates the potential for loss of parts and tools. General advice is provided in **Table 8.5.**

Table 8-5
Outboard Motor Troubleshooting

Problem	Possible Cause/Correction
Engine won't start	• Fuel tank empty • Fuel tank vent closed • Fuel line improperly connected or damaged; check both ends • Engine not primed • Engine flooded, look for fuel overflow • Clogged fuel filter or line • Spark plug wires reversed • Loose battery connections • Cracked or fouled spark plug

	• Fuel pump not primed • Engine kill switch lanyard not connected
Starter motor won't work (electric starter)	• Gearshift not in neutral • Defective starter switch (sometimes gets wet and corrodes if motor is mounted too low).
Loss of power	• Too much oil in fuel mix • Fuel/air mix too lean (backfires). • Fuel hose kinked • Slight blockage in fuel line or fuel filter • Weeds or some other matter on propeller • Water has condensed in fuel • Spark plug fouled • Magneto or distributor points fouled • Clogged fuel filters
Engine misfires	• Spark plug damaged • Spark plug loose • Faulty coil or condenser • Spark plug type incorrect • Spark plug dirty • Choke needs adjustment • Improper oil and fuel mixture • Dirty carburetor filter • Partially clogged water intake • Distributor cap cracked
Overheating	• Mud or grease on cooling system • Too little oil • Water pump is worn or impeller (rubber) is broken • Defective water pump
Blue smoke	• Spark plugs are fouled, means too much oil
Engine surges	• Outboard not properly mounted/propeller rides out of the water • Carburetor needs adjustments
Poor performance on boat	• Wrong propeller • Engine improperly tilted compared with transom. Engine should be vertical when boat is underway • Bent propeller-usually accompanied by high level vibration • Improper load distribution in boat • Heavy marine growth on boat bottom • Cavitation

Steering Casualty

E.7. Problems and Corrections

A steering casualty may have a simple solution or require outside assistance. It may also test your boat handling skills if the boat has two propellers. General advice is provided in **Table 8-6**

Table 8-6
Steering Casualties

Problem	Possible Cause/Correction
Broken or jammed cable	• Rig emergency steering as applicable. Advise Park Manager or Harbor Master
Broken hydraulic line, or hydraulic system malfunction	• Inspect hoses for leaks, check fluid level, add if necessary • Replace hose if spare is onboard • Rig emergency steering as applicable • Steer with engines if twin screw • Try to center rudder amidships • Anchor, if necessary • Notify Park Manager or Harbor Master
"Frozen", damaged or blocked rudder, outdrive or outboard	• Attempt to free, if possible • Center rudder, if possible, and block in place

Section F. Care and Operation of Division Equipment

Introduction
The Division has invested a great deal of money into vessels and trailers. Some Division vessels cost a little more than a couple thousand dollars while *Rescue One*, located at the Great Salt Lake Marina was a three hundred and fifty thousand dollar investment. The Division's goal is to maintain this equipment in such a manner that it will last more than ten years. This is only possible if the equipment is maintained in a professional and timely manner.

F.1. Administrative Guideline
Administrative Guideline PR-96-10 pertains to equipment maintenance and can be found in the Division Guidelines Manual. It outlines what is expected of everyone who uses, or is in charge of the use of Division vessels and trailers. It is imperative that you are familiar with these guidelines.

F.2. Maintenance Logs
A very important maintenance procedure is to maintain a hull and engine maintenance log. Ideally, the log should be in two parts. One part would include a series of alphabetically arranged entries: battery, filters, oil, zincs, etc. This makes it easy, for example, to look up "S" for spark plugs or "P" for points. The other should contain several pages available for chronologically entering haul-outs and major maintenance work. To structure the log properly, the engines manufacturer's maintenance manual is needed. Also, a good practice is to buy a large ring binder or folder case and put in it every instruction or technical manual for electronics, instruments, heads, stoves, etc. that comes with the boat.

F.3. Basic Maintenance Actions
There is not enough space in this chapter to write a maintenance manual for every Division vessel. The primary source for a vessel's maintenance requirements should be in the boat and engine maintenance manual that came with the boat. Many maintenance items should be able to be performed by a boat crewmember. Others must be performed by the Division Boat Shop.

F.4. Hull Maintenance
Every Division vessel should be removed from the water on a periodic basis for hull maintenance and cleaning. The hull should be thoroughly washed to removed dirt, grease and algae. If algae is not removed periodically it will start penetrating the gel coat causing blisters or crazing. A pressure washer can be used for this cleaning.

If using an acid to clean the hulls of vessels care must be taken to protect the trailer and the environment. Some acids can damage the galvanized finish of trailers. A good cleaner is jet white.

Vessels should be waxed periodically to protect their gel coat finish.

Visually inspect the entire hull to determine any problems that may develop or need to be addressed by the shop.

F.5. Batteries
Check battery condition and charge. You should check for a full charge before leaving on any mission. If you show a low charge the vessel should not leave the dock. Many Division vessels have extensive electronics packages that can put a significant drain on the batteries. It may be necessary to charge the batteries on occasion. If a low charge is detected it may well be because of low battery fluid. If your vessel is equipped with a solar charger you will want to check the fluids regularly. Also check to make sure batteries are covered and are securely strapped down so they cannot shift while underway.

F.6. Fuel System
Visually check the fuel system for deterioration or leaks. Check hose clamps for integrity and tightness. Check primer bulbs for condition and proper function. Ethanol has been creating problems with water buildup in the fuel system. Only premium fuel should be used in Division vessels. DO NOT USE fuel with ethanol as this may damage the motors and void the manufacturer's warrantee. Several motor failures have been attributed to the use of ethanol.

F.7. Oil
On four stroke motors the oil level should be checked periodically and topped off when necessary. The Boat Shop will change the oil each year during the vessels annual maintenance schedule. But check the oil for color or condition. If you suspect oil deterioration the oil should be changed. If you see milky oil or detect shavings in the oil contact a mechanic at the Division Boat Shop before using the vessel.

F.8. Steering
Most Division vessel use hydraulic steering. The fluid levels must be checked periodically and topped off when necessary. Check all hydraulic lines for leaks and deterioration (cracks). Check the steering system for binding or loose components. Visually check the steering link rod fasteners for proper tightness.

F.9. Outboards
Check outboard motors for tightness on the transom. Inspect cowling fasteners. Check zincs. Replace if necessary. At Great Salt Lake zincs should be checked at least monthly. Also the cowlings should be removed monthly during the summer so that spider egg sacs and spiders may be removed from the engine. Salt can also build up and crystalize in the cooling lines for the outboards. Usually these obstructions will be at the nipple where the cooling water exits the upper unit. Keeping a paper clip onboard will serve well if a nipple clogs with salt preventing cooling water form exiting. The paper clip can be inserted in the nipple clearing the obstruction. On occasion the obstruction will be further down in the cooling system. It may be necessary to take a hose to the cooling intakes or the exhaust nipple and flush fresh water through the system until the obstruction blows itself out.

F.10. Prop Blades
Prop blades and props need to be inspected occasionally. Check for damaged blades. If a blade is damaged the prop must be removed and replaced. Running with a damaged prop can cause serious damage to the outboard. The dense water of Great Salt Lake can be especially harsh on prop blades. The water tends to scour the blade causing hairline cracks. If a hairline crack develops the prop must be immediately removed and replaced. This prop can be welded and repaired. If the prop is allowed to be used to the point that the blade brakes (which it will eventually do) the prop is lost and a new one must be purchased. Running with a broken blade can cause engine damage.

Props should be removed periodically and the shafts greased. When changing props on twin screw boats make sure you have a right-hand prop for the starboard motor and a left-hand prop for the port motor. The left had props will have an "L' stamped on them next to the pitch stamp.

F.11. Zincs
Zincs should be checked periodically (Once a month at Great Salt Lake). This includes outboard zincs, motor mount zincs, hull zincs (on metal boats) and cooling system zincs if equipped. Replace any zincs that have been heavily deteriorated.

F.12. Bilges
Keep boat bilges clean and free of oil, dirt and other debris. Dirty bilges are a major cause of bilge pump failures. Check bilge pumps for proper operation. During the winter keep bilges free of ice as this can damage the pump and switch.

F.13. Engine Alarms
An engine buzzer means either the engine is experiencing an oil problem, overheating, or as with the HPDI series of outboards there may be water in the fuel filter. The Yamaha outboard motors will automatically reduce RPMs to 2000. Stop the engine at once and investigate the problem.

F.13.a. Oil Problems
If an engine buzzer has sounded assume low oil first. After shutting down the outboard check oil reserves. If low add oil and then start the outboard again. If the buzzer has stopped this was likely the cause of the alarm.

F.13.b. Overheating Problems
If there is no water exiting the cooling nipple on the upper housing expect an overheating issue. This may be as simple as a plastic bag or other obstruction blocking the water intake. At Great Salt Lake this can be caused by salt crystal buildup in the cooling system or even brine fly carcass buildup or even mud or sand in the cooling system. Of nothing obvious can be found and you have flushed the motors then the impellor in the water pump has likely failed. DO NOT RUN MOTOR as serious damage will occur.

F.14. Boat Trailer Lights
Before trailering any Division vessel on a Division trailer make sure the trailer lights function properly. Do not use the trailer without properly functioning lights. Use a 12 volt test light to check for power at your trailer plug.

F.15. Bearing Buddies
There are two types of bearing buddy caps used on Division vessels. These bearing caps have grease zerks on them. The old style is usually silver and has a spring-loaded piston in the center. This type needs grease when the piston is not compressing the spring a small amount. Do not put too much grease in this type as it might blow the cap off or blow the seal.

The other type is on newer trailers. The bearing caps are black or silver and when this type is greased the excess is pushed out a hole in the axle behind the backing plate. This type will need to be greased every time the trailer comes out of the water or else water will be sucked into the bearing.

F.16. Trailer Jacks

For trailers operating in Great Salt Lake you will also need to grease the trailer jack on a regular basis or it will "Freeze" seize up from corrosion. Many jacks have a zerk fitting on them and can be greased by squirting grease in the zerk. Otherwise the jack will have to be fully extended and then greased manually.

F.17. Major Servicing or Repair

Division vessels are required to be fully serviced annually. This is done by specially trained Division mechanics located at the Boat Shop. In most cases the vessel must be delivered to the shop annually. The vessels must be delivered clean and free of algae, dirt and other debris. The shop may refuse a vessel if it is not cleaned first. All personal or Park specific equipment should be removed before bringing the vessel to the shop.

F.17.a. Work Requests

Be prepared to fill out a Work Order / Job Request when you deliver your vessel to the Boat Shop. You need to list everything that is wrong with the boat. Listing annual service only will not guarantee the mechanics will see everything that is wrong.