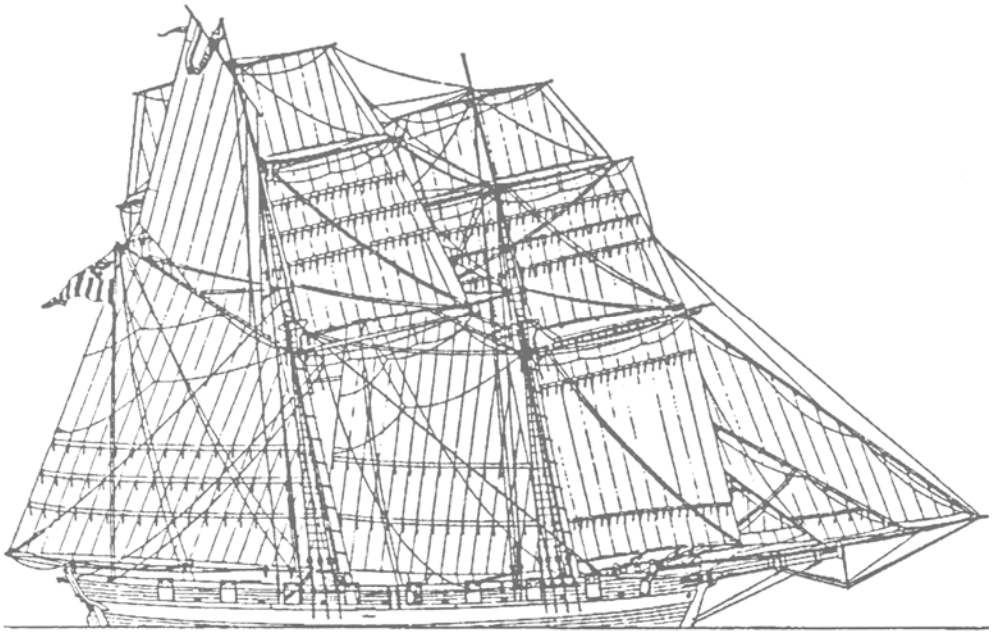
U.S. Department of Homeland Security
United States Coast Guard

AUXILIARY SPECIALTY COURSE
SEAMANSHIP
(AUXSEA)



STUDENT STUDY GUIDE

PUBLISHED FOR EDUCATIONAL PURPOSES ONLY

COMDTPUB P16794.42

U.S. Department of Transportation

United States Coast Guard

Commandant
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COMDTPUB P16794.42

15 APR 1992

COMMANDANT PUBLICATION P16794.42

Subj: Auxiliary Specialty Course Seamanship (AUXSEA); Student Study Guide

1. PURPOSE. This publication is intended for use as the student study guide for the Auxiliary Specialty Course in Seamanship. It is published for instructional purposes only and is not policy material.

2. DIRECTIVES AFFECTED. The Auxiliary Operational Specialty Course, Student Workbook, CG AUX 498-2(74), is canceled.

3. DISCUSSION. This publication contains instructional information regarding Coast Guard Auxiliary Seamanship. Major revisions in this new edition include:

   a. New chapter on anchoring techniques which reviews the proper safety procedures for anchoring and clearing a fouled anchor.

   b. New chapter on duties and manners which reviews the duties expected of the deck hand, radio watchstander, navigator, engineer, lookout, helmsman, and towing watch.

   c. Redesigned and expanded topics on terminology, boat construction materials, and steering gear types.

   d. Revised chapter on internal combustion engines, including information on inboard-outboards (I/O's).

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NON-STANDARD DISTRIBUTION: See page 2.

4. ACTION. District Commanders shall insure that this publication is used as a resource for Auxiliary training and that all Auxiliary instructors and teaching assistants are aware of this publication and become thoroughly familiar with its contents.

W. J. ECKER
Chief, Office of Navigation Safety
and Waterway Services

Nonstandard Distribution

Auxiliary National Board
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CHAPTER 1

TERMINOLOGY, BOAT CONSTRUCTION MATERIAL, AND STEERING GEAR TYPES

INTRODUCTION. This chapter provides overall information on construction materials used for boat building. It gives some of the advantages and disadvantages of each. Students are also introduced to some of the "Nautical Terms" associated with seamanship. Finally there is a review of common steering systems. The reading material for this lesson can be found in the following pages of this chapter and in designated portions of **CHAPMAN Piloting, Seamanship and Small Boat Handling**. In the earlier editions of CHAPMAN, the material is in the chapter on **Nautical Terms**. In the later editions, the material is in **Section 1, Chapter 1** and in **Abbreviations and Acronyms** of **Section 8, Appendices.** The study questions at the end of this lesson are based upon these readings.

Today's prospective boat owner has many boat building materials to choose from. It's a far cry from yesteryear, when practically all, boats were built from one material-wood. Now, there is wood, fiberglass, aluminum, steel, ferro-cement, plus many combinations of these. For instance, you can see fiberglass hulls with wooden decks, interiors, and deck houses. The same is true for all of the other materials.

You don't need the desire to be a boat builder to learn more about boat building. The more you know about how boats are built and what materials are used to build them, the better you will be able to select a boat and then to maintain her year after year. This lesson will introduce you to some of the boat building materials in use today and will explain the, steering systems you will find in nearly all powerboats.

FIBERGLASS BOATS. Let's begin with fiberglass. Today, fiberglass construction monopolizes the boat building industry. This was not always so. The use of fiberglass is a relatively new innovation and has only, within the last few decades, come to replace wood as the primary boat building material. The reason fiberglass has become so popular is due to the fact that it is so easily maintained. Thousands of boat owners have discovered to their delight that taking care of a fiberglass boat is far easier than maintaining its wooden counterpart. A look at fitting-out yards in the spring is proof enough. Owners of wooden boats spend hour upon hour getting them ready for launching. Owners of fiberglass boats find that much less maintenance-time is required.

But then again, fiberglass is not exactly a miracle material either. It requires proper care and, contrary to what many people think, needs painting periodically.

The word fiberglass doesn't really define the material. It is more exactly plastic reinforced with fiberglass. The British use a more accurate description - GRP, which stands for glass reinforced plastic. A fiberglass hull, then, is composed of strands and layers of fiberglass saturated with resin. This construction can be compared with that of reinforced concrete. The fiberglass strands compare to the steel rods and the resin compares to the cement.

Just as with any other kind of boat building material, there are good fiberglass boats and bad fiberglass boats. There are many ways to use fiberglass in building a boat; and, predictably, there are firm supporters of each of these.

Fiberglass itself, the reinforcing material, comes in four different forms-mat, cloth, woven roving, and chopped strands (figure 1-1). Mat is a mass of randomly chopped fiberglass fibers that are either bonded together with resin or mechanically stitched together. It is used as a primary reinforcement for the hull and the deck of a boat.

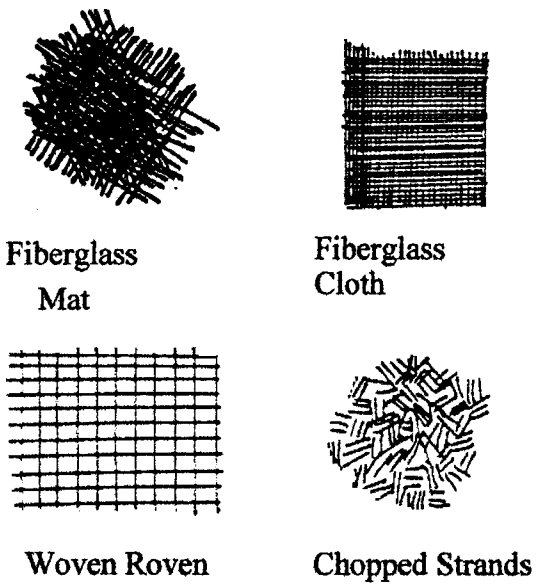


Figure 1-1.—The four primary types of fiberglass reinforcements.

It is also used to reinforce joints and to provide a waterproof barrier. Fiberglass cloth is just what the name implies. it is an open, square weave with strands going in two directions only. It is used as The four primary types of a primary reinforcement for hulls and decks, and commonly used as a reinforcement for the surface coat (called the gel coat). Woven roving is almost exactly like cloth but it has a heavier weave. It is used as a primary reinforcement for hulls and decks. Chopped strands are just that, fiberglass that has been chopped into very small pieces.

The two basic types of resin used in boat construction are polyester and epoxy. Polyester resins are most commonly found. They are versatile, easy to handle, and have a relatively low cost. Epoxy resins are stronger than polyesters, but then, they are more expensive. They are also very difficult to work with.

There are many substances commonly added to boat building resins. Some are used to harden the resin. Others are used to control the curing time of the resins. Still others are used to make the resin fire retardant since untreated fiberglass laminates are extremely flammable. Resins that have additives to make them fire retardant will discolor, smoke, and char in the presence of heat, but will not break into flame.

There are various steps which must be followed to build a fiberglass hull, or any fiberglass part for that matter. First a plug must be made. This is a male mold that looks exactly like the finished product. It can be made of wood, plaster, or almost any other material, and is often made very lightly and cheaply to cut down on costs. The plug is used to make a cavity mold, also known as a female mold. It too may be made of wood, plaster, or other materials. Many times it is made of fiberglass. The cavity mold is used to make the finished hull, much in the same way that a pan is used to bake a cake. There are two ways to use a cavity mold in building a fiberglass hull. One is the hand-layup process, and the other is the chopped-strand process. Sometimes a combination of the two is used. In the hand-layup process, first the gel coat is applied to the inside of the mold, which will give the boat its color and its finish surface. Next a layer of fiberglass cloth is laid down on the gel coat and bonded to it with resin. This layer of cloth acts as a reinforcement. After this, combinations of cloth, mat, woven roving, and sometimes chopped strands are added in successive layers until the desired thickness of the hull is obtained. How the fiberglass materials are combined has a lot to do with how strong and durable the hull will be.

In the chopped-strand process, gel coat is first applied to the inside of the cavity mold. Then a gun, which is fed with resin and fiberglass strands, in one operation chops the strands and mixes them with resins. The mixture is sprayed over the gel coat. Handling the gun requires a great amount of skill so as to get an even layer of fiberglass mixed with resin over the gel coat. Any miscalculations will result in a hull that is thick in some places and thin in others, something that will produce a terribly weak boat.

After the basic fiberglass hull has been built it is strengthened with stiffeners and other members. Then the rest of the boat is added such as the decks, the cabins, the superstructure, etc.

Another way to make a fiberglass hull is to use the matched die method. Matched dies are nothing more than male and female molds, usually made of metal, that are clamped together with a laminate between. By applying the correct amount of pressure and heat, the hull is made uniform throughout.

Still another construction method is called sandwich construction. It consists of a core material, usually wood, such as balsa, that is sandwiched on either side by layers of fiberglass impregnated with resin. Other core materials that are sometimes used are foamed plastics or plywood. Sandwich construction provides a boat that is very strong and buoyant. There is one drawback though. Should the laminate become cracked, moisture can enter and start dry rot in the wooden core. This can cause a major problem. (See figure 1-2.)

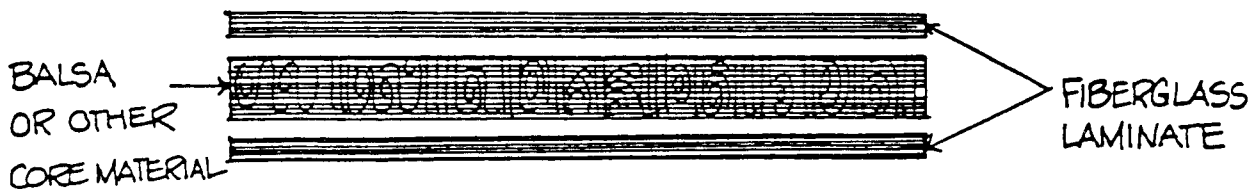


Figure 1-2.—Sandwich construction. The fiberglass laminate can be made up of any combination of mat, cloth, or roving. Usually only the outside of the boat formed in this manner is finished with gel coat.

The advantages of fiberglass boat construction are many. Fiberglass by its very nature is impervious to marine borers, shipworms, and rot. Since the fiberglass hull does not have any seams as such (after all it is a one-piece hull) there cannot be any leaks through seams or joints. The color can be molded into fiberglass, so for a few years, at least, the hull need not be painted.

Don't be fooled, however, the bottoms of fiberglass boats are still affected by marine growths and barnacles. It is wise, then, to coat the bottom with antifouling paint.

Fiberglass boats can be extremely strong. This is true even though they have very little framing. This is not to say there are no weak fiberglass boats, though. The quality of the engineering that goes into any kind of a boat directly affects how strong that boat will be.

Another advantage of fiberglass is that it can be molded into almost any shape, making it very easy for the boat designer. It should be noted, however, that flat surfaces are not exactly ideal for fiberglass boats. Flat surfaces, when used, are normally reinforced with some other type of material.

One of the disadvantages of fiberglass as a boat building material is that it is heavier than water. Fiberglass does not have inherent buoyancy. In other words, a fiberglass boat filled with water will sink, unless it has built-in flotation. Such flotation is usually provided by using air tanks, styrofoam, balsa wood, or other very light materials.

Another disadvantage of fiberglass boats is that they are usually very heavy. In fiberglass, strength and weight are related. Though it is hard to make a general rule, strong fiberglass boats are usually heavy fiberglass boats-light ones might or might not be strong ones. There is much research and development going on these days to cut down on the weight of fiberglass laminates while at the same time increasing their strength.

Another disadvantage of fiberglass boat construction is that it is all too easy to cover up shoddy workmanship. Air bubbles in fiberglass laminates can materially weaken the hull, and yet they are virtually unseen. There are so many layers in many of the fiberglass boats being built today that air bubbles in the innermost layers, for instance, are undetectable. Boats that are built by the chopped-strand method might have uneven thicknesses, yet it is very hard to determine that this is true.

Without cutting up a fiberglass hull, it is virtually impossible to tell what went into its make-up. Fiberglass boatbuilders who provide cross-sections and cutaways of their boats are doing the buying public a real service. Then you can, in truth, tell exactly what you are buying.

WOOD BOATS. The use of wood as a boat building material has declined rapidly in the last twenty years. In competition with fiberglass and other plastics, it has steadily lost ground. This is not to say that wood is not good for building boats. This is far from the truth. There are many people who would not trade a boat built of wood for any other one. Even to those who favor the modern synthetics, wood represents the ultimate. This can be seen in the large number of boat owners who insist that their boats, even though basically constructed in fiberglass, have as much wood as is economically possible.

All wood can be grouped in two general classes - hardwoods, which come from trees with broad leaves, and soft woods, which come from trees with needle-like or scale-like leaves. Actually, the words hardwood and softwood are not truly accurate, since some of the so-called softwoods, such as southern yellow pine and douglas fir are harder than some of the so-called hardwoods, such as basswood and cottonwood.

There are hundreds of different types of wood, but, surprisingly enough, very few are widely used in boat building. In many cases, the availability of certain wood in sufficient quantities and suitable dimensions has been the deciding factor. Many types of wood used in the past for boat building are no longer used because they are no longer readily available.

The following is a table of characteristics of some of the woods used in boat building today:

HARDWOOD

Type of Wood	Qualities	Use
Ash	Heavy, hard, and stiff	Mostly for oars
Greenheart	Decay resistant	General
Lignum Vitae	Very hard and very heavy	Propeller shaft bearings
African Mahogany	Hard and decay resistant	Furniture, fixtures and interiors
Mahogany	Heavy and hard, low shrinkage	Furniture, fixtures, interiors, and planking
Oak	Heavy, hard, stiff, and strong	Frames and other structural members
Philippine Mahogany	Moderately decay-resistant and moderately heavy	Interiors
Teak	Strong, fairly hard, easily worked, very decay resistant	Hull and deck planking, railings and other fittings
Black Walnut	Heavy, hard, strong, stiff, resistant to decay	Interiors

SOFTWOOD

Type of Wood	Qualities	Use
Cyprus	Moderately light and moderately strong	General
Alaska Cedar	Moderately light and moderately low in strength. Has excellent working and finishing properties	General
Cedar	Light, moderately strong, highly resistant to decay	Planking
Douglas Fir	Strong, moderately hard, heavy, and moderately decay resistant	General
Eastern Larch (Hack-matack)	Moderately strong	Knees
Southern Yellow Pine	Moderately hard and strong	Planking, keels, stems, deck beams
Eastern White Pine	Moderately light-weight, moderately low in strength	Decking and Planking

The principal considerations in selecting wood for boat building are strength, decay resistance, and availability. The secondary,but still important, properties of woods that affect their selection for building are workability and water absorption.

One of the biggest considerations of wood for boat building is how it will endure. The effect of decay, marine borers, weathering, heat, etc., makes the difference between good wood and bad wood. How wood stands up to decay is an important factor. Decay-causing fungus plants gradually reduce wood to a punky or crumbling mass.

Fungi that cause decay thrive in damp conditions caused by fresh water rather than salt water. Wood used in boats, that is not properly ventilated, allowing the dampness to evaporate, will almost surely be attacked by decay. More on this in lesson two.

Softwood of all wood species is low in decay resistance. Hardwood varies considerably in decay resistance according to the type of wood. Only a few types of wood are rated high in this property. Hardwood of such species as douglas fir, cedar, mahogany, southern yellow pine, western larch, and white oak, is usually classified as moderate in decay resistance and generally gives good service under mold conditions of decay.

STEEL. There are two metals that are most commonly used to build boats, steel and aluminum. Steel has been used in the past, and in the present, too, for that matter, for fairly large boats and yachts, while aluminum has been used for large and small craft. For instance, aluminum accounts for the majority of canoes and john boats built today.

There are several advantages to steel construction. The main advantage is that steel, on a strength-to-weight ratio is stronger than fiberglass, wood, or aluminum. It rates high in resistance to impact, stiffness, abrasion resistance, and fatigue resistance. A hull made of steel will be lighter than a hull of equal strength made of another boat building material.

Another advantage for steel construction deals with noise. Steel, aluminum, and fiberglass have been accused of being noisy materials; that is, they conduct noise more readily than wood. Though this is certainly true, steel, however, is less noisy than all material except wood.

The final advantage is resistance to fire. Steel and aluminum are more fire resistant than other materials. A steel hull will still be afloat after a fire that would have destroyed her fiberglass or wood counterparts. This does not mean, however, that the non-steel parts of a steel boat will be fire-shielded by the steel. To the contrary, a steel boat can be gutted just as quickly, leaving just the hull.

A potential disadvantage of steel for boats is its quick deterioration without proper maintenance. A steel hull that has not been protected correctly from corrosion can turn into a sorry mess within a short period of time. Boat owners who tend to neglect their boats would do better with a fiberglass boat.

ALUMINUM. Like steel, there are many advantages to aluminum construction. One of the primary advantages of aluminum as a boat building material is its light weight. This is why you see so many small boats made of aluminum. A canoe, which is required to be very light is ideally suited for aluminum construction.

Another advantage is aluminum, like steel and fiberglass, is impervious to marine borers. It must, however, like the others, be painted with a bottom paint to reduce the growth of marine plants on the bottom. It is important to remember that aluminum and the copper in bottom paint are dissimilar metals, and when in contact with each other will set up the process of electrolysis. Unless you put a layer or two of non-metallic paint between the hull and the bottom paint, your aluminum will be corroded in short order. Aluminum hulls and superstructures above the waterline need not be painted at all - aluminum does not oxidize to the extent of steel.

One disadvantage of aluminum is that it is a very good heat conductor. Aluminum hulls tend to sweat considerably because of this. Another disadvantage is that aluminum has a fairly low melting point. In the presence of a fire with intense heat, aluminum will melt more readily than will steel. Another disadvantage is that it is noisy. It is so noisy that if the hull of an aluminum boat is not specially treated against noise, it will conduct sounds unheard of in boats built of other materials. To sit in an outboard-motor-powered, non-sound-dampened aluminum boat being operated at high speed can be deafening.

FABRIC (Inflatables). A class of boats gaining increased popularity is the inflatables. They have been around for long time but only started to gain utility during and after WW II.

These boats have a wide range of uses from the light single ply for play to the many layered laminates used for running rapids and heavy ocean use.

Use of many of the synthetic materials, including one that is now used for bullet proof vests, enable the builders to fabricate for extreme toughness. As in other materials, a wide range of design is now being produced including large boats with inboard engines and rigid hulls with tremendous seakeeping abilities. These qualities make them valuable for such duties as boarding, rescue in heavy seas, and where the requirement is for maximum buoyancy and shallow draft.

There are several advantages of fabric boats over other boats. One is the ease of transport both in the deflated and inflated condition. Inflations may be accomplished by CO_2 bottles, but generally is done with an air pump. The materials are tough and with reasonable care these boats will last a long time. They do not rust, blister, or have dry-rot, and storage and haul out can be easier than boats made of other materials.

TYPES OF STEERING SYSTEMS. Basically, there are six different types of steering systems in use on pleasure boats today. Some of them are fairly simple, requiring few gears or pulleys, but others are extremely complex and employ scores of moving parts. Here are the six:

1. Tiller
2. Drum and cable
3. Sprocket and chain
4. Rack and pinion
5. Gear and shaft
6. Hydraulic

The tiller system is the earliest type of steering arrangement, and the simplest. It is still used widely on sailboats, but has found limited use for powerboats. Just about the only powerboats still using tillers are small launches. Tillers are easy to handle and have no complicated gears or pulleys. A tiller steering system is nothing more than a horizontal piece of wood or metal that is attached to the head of the rudder stock.

Tillers are predominantly used in sailboats. The main disadvantage of a tiller is that it takes up too much room in the cockpit of a boat. And, of course, a tiller in a large boat has very little mechanical advantage. (See fig. 1-3.)

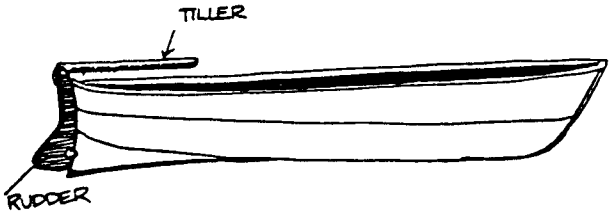


Figure 1-3.—A tiller steering system.

The drum and cable system is probably the next simplest steering system. It is made up of a drum connected to a steering wheel. A cable is bound around the drum. The two ends of the cable, after passing through pulleys, are attached to the tiller or rudder quadrant. When the wheel is tuned, one side of the cable is wound up on the drum while the other side is unwound. This is transmitted through the pulleys to rudder quadrant or-tiller; the boat will turn to the right or the left, depending on which way the wheel is turned. (See fig. 1-4.)

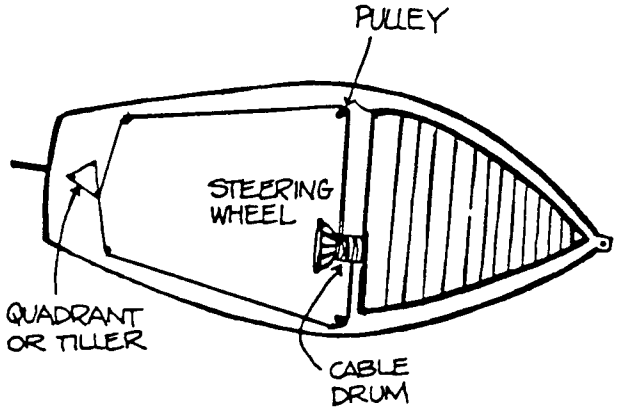


Figure 1-4.—The drum and flexible cable steering system. The cables can be attached to a tiller or rudder quadrant.

Actually, the sprocket and chain system is nothing more than a variation of the drum and cable system. Instead of a drum, a sprocket is used; and instead of a cable, a chain, compatible with the sprocket, is used. Operation of the steering system is identical to the drum and cable system

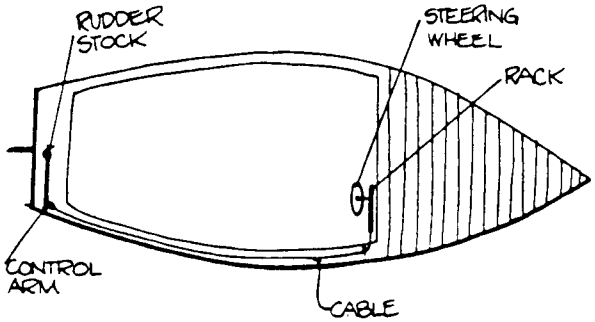


Figure 1-5.—The rack and pinion (push-pull) steering system.

The rack and pinion steering system is becoming more and more popular, because it takes up less room than the three types described above and gives the boat operator more sensitive steering. (See fig. 1-5.) The steering wheel has a small pinion gear at the end of the steering wheel shaft. This pinion gear engages a rack, which is a flat, rather than round, gear. Attached to the rack is a cable, which is in a conduit. This cable is attached

at the other end to the rudder assembly. There is no need for pulleys in this system and the cable can go up, down, and around according to the layout of the boat. When the pinion gear turns and engages the rack, the cable is pushed or pulled, according to which way the steering wheel is turned. The cable transmits this push or pull to the rudder assembly, which in turn translates it into right or left rudder.

The gear and shaft steering system is seldom found on small boats. It is found more often on large craft, usually commercial boats. At the end of the steering wheel is a bevel driving gear, which engages another gear that is connected to a shaft. The shaft, sometimes utilizing universal joints, travels from the steering wheel to the rudder, where its motion is translated by a worm gear, a bevel gear, or cables and pulleys, to left or right rudder.

Hydraulic steering systems are similar to automotive power steering. This type of system is being found on an increasing number of recreational vessels. They use hydraulic fluid that is pumped through a system to actuate the rudder. The steering wheel is connected to a pump with valves. When the wheel is turned, the pump pushes fluid through the appropriate valves into hydraulic lines that carry the fluid to the actuating cylinder. In the cylinder, the motion of the fluid is translated into left or right rudder by a linkage to the rudder head.

STUDY QUESTIONS

1. A fiberglass hull is composed of _____ saturated with _____.

2. List the four types of fiberglass reinforcing materials:
   1. _____
   2. _____
   3. _____
   4. _____

3. The two types of resins used in fiberglass construction are _____ and _____.

4. There are many substances added to boat building resins. They are used to _____, _____ and to _____.

5. A male mold is known as a _____.

6. A female mold is known as a _____.

7. The hand-layup and chopped-strand processes are used in a _____.

8. In the hand-layup and chopped-strand processes, the _____ is applied to the inside of the mold first.

9. In the matched-die method the _____ are clamped together with _____.

10. What core materials are used in sandwich construction?
    _____ _____
    _____

11. List the advantages of fiberglass-built boats.
    _____ _____
    _____ _____
    _____

12. List the disadvantages of fiberglass-built boats.

_____ _____

13. What are the two general classes of wood?

14. What are the principal considerations in the selection of various types of wood for boat building?

_____ _____

_____

15. List the advantages of steel for boat building.

_____ _____

_____

16. The disadvantage of steel for boat building is _____

_____.

17. Why must you put a layer of nonmetallic paint between the hull of an aluminum boat and a layer of copper bottom paint?

18. List the advantages of aluminum for boat building.

_____ _____

19. List the disadvantages of aluminum for boat building.

_____ _____

20. The six types of steering systems are:

1. _____.
2. _____.
3. _____.
4. _____.
5. _____.
6. _____.

21. The simplest steering system is the _____.

22. The curve or sweep of the deck of a vessel when viewed from the side is the _____.

23. The outward curvature of the sides of the boat near the bow that is used to keep the deck drier is called the _____.

24. What are the three basic shapes of the bottom of a boat?

_____ _____

_____

25. What is the difference between a displacement and planing hull?

26. In wood boat construction, the plank attached starting at the gunwale is the _____.

27. What is the difference between a trunk cabin and a raised deck cabin?

28. What are limber holes and what purpose do they serve?

29. The use of two or more materials in the hull of a vessel is known as _____ construction.

30 The portion of the exterior hull at the waterline is called the _____ top.

31. The spoke of a steering wheel that is vertical when the rudder is exactly centered is the _____spoke.

32. The vertical distance between the waterline and gunwale is _____.

33. Describe the characteristics of the following sailboat types:

Catboat _____.

Sloop _____.

Ketch _____

Yawl _____.

Schooner _____

34. The gross tonnage of a vessel is _____

_____

CHAPTER 2

BOAT MAINTENANCE

INTRODUCTION. The study questions at the end of the lesson are based on the readings in this chapter and not on any outside readings.

HAULING OUT. Hauling out time is one of the most important times to ensure the proper maintenance of your boat. To most boaters, however, hauling out signals the end of the boating season, and maintenance is put aside until the fitting out period just before the boat is launched in the spring. That attitude is dangerous, since it can mean more work later. Many of the maintenance chores you might face in the spring can be handled when the boat is hauled out, or can even be prevented if the job is handled correctly at the beginning. What you do when you haul your boat, and how you go about doing it, can mean the difference between a well-maintained boat and a poorly maintained boat, regardless of your intentions.

When you haul your boat, whether the job is done by you or at a yard, the first thing to consider is the proper blocking of the hull. Boats should be stored upright, though dinghies, canoes, and other small craft can be stored upside down provided they are covered adequately. Upright boats must be blocked correctly. The weight of the boat should rest on the keel, which should itself rest on blocks to allow ventilation of the bottom of the keel. Blocks should be spaced about every five feet along the keel and should be high enough so that you can get to the bottom of the keel to perform your maintenance chores. When you block up your boat, try to get the waterline as level as possible; this will prevent the boat from being subjected to strains she was not designed to handle. Do not allow the weight of the boat to rest on the shoring that you will have to use to hold the boat upright; this shoring is intended only as lateral supports, since excessive strains on the sides and bottom of the hull could do severe damage to the structural strength of the boat.

The procedures to follow if you will be storing your boat on a trailer are the same. The boat should rest on her keel; the side supports of the trailer should only keep the boat upright. Be certain to block up the tongue of the trailer so that the boat will be level at her waterline.

After the boat is blocked up, the real laying-up procedure begins. It is here boats are neglected. Too many boat owners see their boats hauled up on shore at this stage and assume that all work on her has ceased until the following spring.

Immediately after the boat is hauled, clean the bottom of all growths and marine life. If you wait to do the job, all that growth on the bottom will dry up and harden like cement. In short order, it will seem as if that mess has become a permanent part of the hull. At the same time, wash the entire hull down with fresh water, including decks and superstructure. This is especially important if you are going to store the boat under cover, as the fall and winter rains will then have no chance to wash away all the saltwater that can become crusted on every surface.

LAYING UP. When laying up the boat, there are several important steps that must be taken.

Drain, and if necessary, winterize your water system with non-toxic RV antifreeze.

Fill the fuel tanks and use a fuel stabilizing compound. This will prevent the formation of varnish in the fuel system and aid in reducing water condensation in the tanks.

Drain the bilge. Leave the drain plug out, but stow it where you can find it before launching. If you don't have a drain in the bottom of your boat, pump out as much as you can and then sponge dry the rest.

Change the engine oil and filter and then lay up the engine according to the specifications of the particular engine that you are using; each manufacturer has instructions that apply to its machinery. This usually involves a "fogging" procedure which coats the cylinder walls with oil to prevent corrosion.

Remove the battery and store it in a location not subject to freezing. The battery should be checked periodically and maintained in a fully charged state during storage.

Go through the entire boat and remove all the perishables you can find. Don't be faced with returning to your boat in the spring and discovering a lingering odor that will not go away.

If you have a holding tank, flush it out with fresh water and add appropriate non-toxic RV antifreeze. Remove all liquids in the boat that might freeze.

Remove all clothes, bedding, mattresses, life jackets, etc., and clean them before storing in a clean ventilated, dry place.

Take out everything that is movable, including all those items that are likely aspects for theft, such as the compass, navigation tools, radiotelephone, oars, etc.

After all of this gear is out of the boat, wash down the interior, including the cockpit area, lockers, and forepeak. Remove the floor-boards and leave them off to allow the bilge to ventilate. If the boat is to be covered, leave the engine cover off.

Your boat is now ready to be covered. If you are going to keep the boat in a shed, so much the better. But if not, the best bet is to cover the boat with a tarp or plastic. Whatever you use, be sure that the boat is ventilated. Leave spaces around the covering to allow air to circulate. This will prevent condensation, which will result in dry rot and/or a foul smell. It might be a good idea to build a light framework over the boat, if it is large, to support the covering. PVC pipe makes an easily constructed framework.

Now check over the covering for security. Make certain that it is on tightly and that all tie-downs are knotted securely. Go over each stress point, and if there is any doubt in your mind about whether it will hold, then it will not. Check for places where chafe might occur, and put chafing gear in places where it is called for. Bungee cords are good for maintaining tension on the cover.

Check the boat periodically during her layup period, especially after storms (before, too, for that matter). If you leave the boat in a storage yard, make sure that somebody nearby has your telephone number so that you can be contacted in an emergency.

BOTTOM PAINTS. Moored boats suffer from a common problem-the fouling of their bottoms by marine growths over a period of time. The type of these growths and the severity of their presence depends on local conditions. Some areas of the country seem to promote more marine growths than others, but no matter the location, at least some organisms will become attached to a boat's bottom over the course of the boating season.

Marine growth takes two forms: vegetable and animal life. Though both types can be found over all parts of a boat's hull, the general tendency is for vegetable growths to congregate around the waterline and animal growths to spread over the lower parts of the hull. Vegetable growth includes weeds, algae, and fungi. Animal growths include barnacles, minute shellfish, and worms (in tropical climates).

Two things can happen to a wooden hull that is unprotected and attacked by marine growths. The build-up of plant life on the bottom can become so great that the performance of the boat is greatly reduced. The boat will become sluggish and her speed will be greatly reduced. The attack of animal growth can result in the weakening and perhaps even the destruction of the hull. This is especially true of marine borers that are found in tropical waters.

Boats of materials other than wood are not threatened by borers and worms; fiberglass, ferro-cement, aluminum, and steel boats are impervious to this type of growth. But contrary to some beliefs, they can still be attacked by vegetable growth and must be protected as carefully as wooden hulls.

In years past, the solution to the problem was to sheath hull bottoms with copper. Sailors discovered that, although copper does not corrode much in the presence of sea water, it constantly gives off soluble poisonous salts when immersed in salt water. These salts, as they wash off the surface of the copper, effectively prevent the adhesion of weeds, shellfish, and worms to the hull.

Today, boaters use modern bottom paints that perform the same function as copper sheathing. These paints kill marine growths in their early stages, preventing a build-up of vegetation and animal life on the bottom. The principle of these paints is the same as for the copper sheathing-a constant solution of poisonous matters (primarily copper and mercury) is given off by the paint. Marine growths are thus discouraged by what is in effect an antiseptic film on the bottom of the boat.

One difficulty of bottom paint is that it is far less permanent than ordinary marine paint. The paint is dissolving in the water, so that at the end of a boating season, there will be very little left. Most bottom paints sold today must be applied annually for this very reason. But when choosing between painting the bottom once a year, or scraping growths off the bottom periodically, most boaters wisely choose the former.

Another problem caused by bottom paint is galvanic action, which will be discussed later on in this lesson. Paints that contain mercury and/or copper react with certain other metals in such a way that the metals can be corroded. For instance, a wooden boat that has ferrous fastenings, such as iron, will soon have no fastenings at all if it is painted with a copper bottom paint. This is one reason why you don't hear much about iron boat nails these days. Even galvanized ferrous fastenings can deteriorate under copper paint if only a tiny nick is made in the zinc coating. Special sacrificial zinc anodes help prevent galvanic action (as discussed later) and should <u>not</u> be painted.

When buying and applying bottom paint, be extremely careful. Read the label and talk it over with your paint dealer. Match the bottom paint to your boat. Consider the other metals in your boat that will be influenced by the paint; for instance, the metal in the skeg, strut, propeller, shaft, rudder pintles and gudgeons, etc. Manufacturers have developed many different bottom paints for many different conditions. Odds are that you will find one that is ideally suited to your boat.

<u>DRY ROT</u>. Dry rot is one of the evils that face owners of wooden boats. It is always lurking about, ready to strike when and where you least expect it. If you have it and cure it, it often reappears just after you have convinced yourself that it is gone for good.

Dry rot is a misnomer, as this type of rot only can take hold in the presence of wetness or dampness. It is caused by a fungus that thrives on fresh water. Saltwater seems to discourage dry rot, though it will not necessarily cure it once it has taken hold.

Usually the first indication of dry rot is its smell. It has a musty, moldy odor. Once you have smelled dry rot you will probably never forget it. You are smelling the work of the fungus that attacks the fibers of the wood and reduces it to a soft, powdery, spongy, weak mess.

If you suspect dry rot, the first places to look are dark, damp places. Check out areas where fresh water, in the form of rain or condensation, can enter. Some of the more likely places are: in the bilge, especially the garboard strakes; in the floors; in the planking around and behind the frames; at the top and bottom of the frames; between the deck beams and the deck; under the deck; under the coaming and between the coaming and the deck; in the transom where it meets the bottom and the sides.

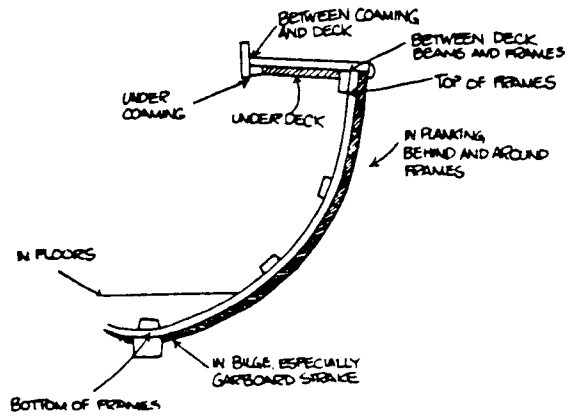


Figure 2-1.—Common areas where dry rot thrives. The transom at the bilge is also a great collector of dry rot.

Look in all of the above places, and any other likely locations as well. But don't confine your inspection to sight alone. Get out your knife, or a spike, and start probing. Dig around for soft spots that are easy to penetrate and disintegrate easily. You might have to remove various parts of your boat to get at suspicious areas, and even get your hands dirty, but the search must be done if you want your boat to last. (See fig. 2-1.)

After you have found dry rot, it must be removed. The fungus will spread like wildfire if it is not checked, and merely soaking it with a preservative, or something you think might kill it, is not enough. Cut out the affected wood immediately, and get as much on either side of the rot as you can. By cutting back into good wood, you are providing for a margin of error. There is no way to tell if the fungus has spread from the obviously rotten section or not.

There is a preparation on the market that is said to help you solve the dry rot problem without cutting out the affected wood. People who have used this material have had good results for the most part, and it is certainly worth investigating.

The most effective way to lick the dry rot problem is to prevent it from getting in your boat in the first place. The best way of doing this is to keep fresh water out and stop it from collecting. This means making sure that hatches are tight, decks are well caulked, fittings are bedded in compound, etc. If fresh water can't get into your boat, then you have nothing to worry about. But you must also be certain that fresh water can also get out of your boat. Condensation can form inside the boat and cause dry rot as easily as can rainwater from without. Make sure your boat is well ventilated at all times.

Another way to prevent dry rot is to apply wood preservative to all unpainted and unvarnished surfaces. There are many preservatives on the market today that are effective, though nothing will offer you total protection. Only by being constantly on your guard can you keep dry rot out of a wooden boat.

GALVANIC ACTION. The process of electrolysis is based on the principle that two dissimilar metals, when placed in salt water (or non-pure fresh-water), generate electricity by a chemical process. This is galvanic action. Galvanic action is the principle behind the functioning of a dry-cell battery. It is also the prime element in the destruction of metals in a boat.

The corrosion of metals by electrochemical action is something all boaters must be concerned with. Unless careful attention is paid to the types of metals that go into a boat, the fastenings, fittings, and even the hull of metal boats can quickly deteriorate and crumble away. Though galvanic action is a problem faced primarily by boats used in salt water, fresh-water boaters cannot be totally ignorant of the problem. Not all fresh water is chemically pure, and even water that is ever so slightly brackish can set galvanic action into motion.

Galvanic action as boaters know it, takes place when two dissimilar metals that are electrically connected are immersed in non-chemically-pure water. The metals actually don't even have to be in the water; corrosion can take place when the metals are connected only by damp wood. By galvanic action, one metal of the two is corroded at the expense of the other.

What exactly is a dissimilar metal? To make it easy on those boaters who are not chemical engineers, the following Electrolytic Table provides the answer. Metals are rated as being "most noble" or "least noble." Current will flow from the less noble to the more noble metal; in the process, the less noble metal will be destroyed.

In the table, the most noble metals are at the top, and the least noble metals are at the bottom. In other words, nickel together with aluminum in non-pure water will produce an electrical current that will eventually result in the destruction of the aluminum.

THE ELECTROLYTIC TABLE

Mercury
Monel
Nickel
Bronze (silicon)
Copper
Brass (red)
Bronze (aluminum)
Gun metal
Brass (yellow)
Bronze (phosphor)
Tin
Lead
Steel (stainless)
Iron
Steel (mild)
Aluminum
Cadmium
Galvanized iron and steel
Zinc
Magnesium

The metals close together in this table can be used together. Metals far apart cannot. For instance, bronze and copper can be used together; aluminum and copper cannot.

Galvanic action is insidious. It takes place when you least expect it. For instance, if you use copper bottom paint on the hull of an aluminum boat, the copper in the paint will corrode the aluminum in the hull. The only way you can prevent this, assuming that you must use a copper anti-fouling paint, is to put a layer of non-metallic paint between the two. But even then, you must be certain that the coverage of the nonmetallic paint is absolute. The slightest exposure of the aluminum below can result in galvanic action.

Ordinary yellow brass, composed of zinc and copper, carries the seeds of its own destruction in salt water. Over a period of time, the galvanic action in, say, a brass screw, will erode the zinc, leaving a spongy mass of copper. For that reason, brass screws, brass sea cocks, and valves are useless in salt water.

What can you do? Most boats require many types of metal for diverse purposes. For instance, a boat that has a bronze propeller and an iron rudder needs protection or the rudder will be quickly destroyed. The answer is to add a third metal to the process. This third metal is known as a sacrificial metal it is sacrificed to save the other two. To protect the iron rudder, a block of zinc or other metal less noble than iron can be attached to the rudder. What happens then is the zinc, not the iron, sets up a current with the bronze propeller, which is most noble, and is itself destroyed. Thus the iron rudder is protected. The bronze propeller, since it is most noble, takes care of itself.

Note: When using sacrificial metals on your boat, be certain to replace them periodically. If you do not, you will be fooled by your own craftiness the sacrificial metal will completely erode, leaving you with the original two metals, which will immediately go to work on each other. Remember, do not paint over the zincs, or else they will not work.

ELECTROLYTIC ACTION. Electrolytic action is an electrochemical process similar to galvanic action. When an electrical current from an independent source, such as a battery, passes through all electrolytic fluid, such as sea water, metal will be destroyed. If a stray current from some source on a boat (or adjacent boat) passes through a metal hull fitting, for instance, into the sea, metal will be transferred from the hull fitting. Eventually it will be eroded. Metal will not be transferred, however, where the current re-enters the boat.

The solution to the problem of electrolytic action is to eliminate stray electrical currents from the power sources in your boat. In most boats, the problem centers around the battery. Make sure that the negative pole of the battery rather than the positive pole is grounded to the engine. This should be done because current flows from positive to negative. Thus, current straying from the positive side of the battery will re-enter the boat through the propeller shaft, which is, of course, connected to the engine. As said previously, metal transfer will not take place at the point of entry of an electrical current.

In addition, to prevent other stray currents in your boat, check all other electrical equipment. Make sure that everything is properly grounded and secure.

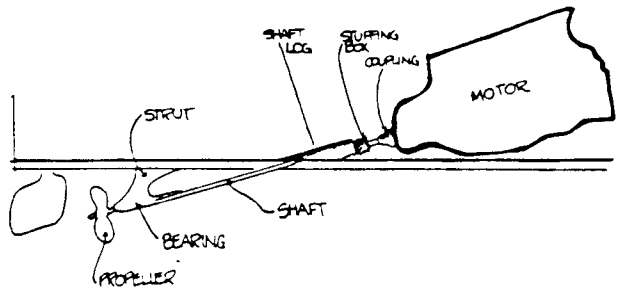


Figure 2-2.—The essential parts of the shaft train.

THE SHAFT TRAIN (figure 2-2). The shaft train of an inboard marine engine installation is the machinery that transmits the power of the engine inside the boat to the propeller outside the boat. It is made up, in most inboard boats, of the shaft log, the shaft, the strut, the strut bearing, and the propeller. The exception to this type of installation are V-drives and hydraulic drives.

The shaft is most usually a continuous piece that is attached to the engine by a coupling on one end and to the propeller at the other end. However, if for some reason the shaft cannot go in a straight line it might have a universal joint to allow for the change in direction. Most shafts today are made of bronze, monel, or stainless steel.

The shaft must eventually go through the bottom of the hull. To do this, it passes through a shaft log. At the inboard end of the shaft log there is a stuffing box. This is similar to the packing gland in a water faucet. This combination of the shaft log and stuffing box prevents water from entering the boat through the shaft hole. The stuffing box surrounds the shaft and holds rings of packing material. These rings are squeezed tightly around the shaft by a "gland" or "gland nut". Water can come up into the shaft log from the bottom, but is prevented from entering the boat by the packing material in the stuffing box. The shaft log and stuffing box are usually made of bronze. The packing material is made of a special flexible material.

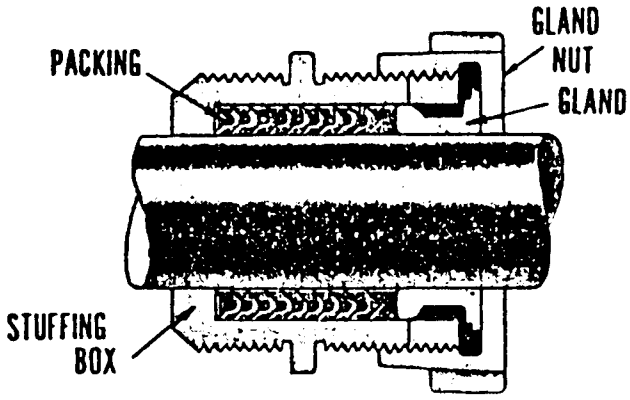


Figure 2-3. Typical stuffing box.

Check the stuffing box periodically, but don't be alarmed if there is a slight drip of water coming from it. Most stuffing boxes rely on a small amount of water getting through to work properly. Usually tightening down on the gland nut, which squeezes the packing material more, will control the amount of drip. If you have a leak, however, and no amount of tightening of the nut stops it, then you will probably have to replace the packing material. This is a simple process that amounts to nothing more than backing off the gland nut and wrapping new packing material around the shaft inside the stuffing box.

Once through the hull, the shaft goes through the strut. The strut is an appendage attached to the bottom of the boat that acts as a support and bearing for the shaft. There are many types of struts in use today, most with only one arm but some with two or three.

The strut must always be securely bolted to the bottom of the boat and must be rigid. If it is not, the shaft will be able to wobble, the bearing might be ruined, the shaft might bend, and you will at least get a considerable amount of vibration in your boat. As the strut, shaft, and strut bearing are underwater, the bearing relies on water for lubrication. Bearings in the old days were almost always made of lignum vitae wood, but now they are usually made of rubber or micarta. Many of them have grooves cut in them to allow for a continuous flow of water inside. The bearing must be checked

periodically to be certain that it is in good condition. If the bearing goes, the shaft can be damaged.

At the end of the shaft is the propeller, which comes in many sizes and shapes. Propellers differ in diameter, pitch, direction of rotation, shaft-hole size, and the number of blades. The diameter of a propeller is simply the diameter of the circle defined by the tips of the turning blades. The pitch of the propeller is the angle of the blades; to engineers, it is the distance the propeller would move ahead after one revolution. The number of blades for a propeller can go from two on up. Most powerboats use a three-bladed propeller.

The selection of a propeller is beyond the scope of this lesson. It is appropriately in the realm of naval architects, that many calculations and considerations must be applied to arrive at the right propeller for the right boat.

Your main concern about the propeller is whether it will stay on the shaft. Because most propellers must operate in forward and reverse, a lock nut must be used to keep it on the shaft. Most installations use a nut backed by a jamb nut combined with a key. Whatever your boat uses, check it out periodically to ensure that it is secure. The last thing you want to do is lose your propeller.

STUDY QUESTIONS

1. What is the proper way to block up a hull?

2. Why shouldn't you allow the weight of the boat to rest on the shoring?

3. List the lay-up chores that must be done after the boat is hauled out.

4. What is the purpose of allowing the boat to ventilate when it is layed up?

5. The two types of marine growth are _____ and _____.

6. What are the two things that can happen to a wooden boat that is not protected against marine growths?

7. How does copper protect a boat's hull?

8. What should you consider when selecting a bottom paint for your boat?

9. What causes dry rot?

10. A first indication of dry rot is _____.

11. List some of the places to look for dry rot in a wooden boat.

12. When dry rot is found, it must be _____.

13. How can you prevent dry rot?

14. What is the difference between galvanic action and electrolytic action?

15. Current will flow from the _____ metal to the _____ metal during galvanic action.

16. What is the principle of using a sacrificial metal to minimize the effect of galvanic action?

17. How can you prevent electrolytic action?

18. The shaft train is made up of _____, _____, _____, _____, and _____.

19. How does the stuffing box work?

20. The strut bearing relies on _____ for lubrication.

21. What is used to keep the propeller on the shaft?

CHAPTER 3

INTERNAL COMBUSTION ENGINES

INTRODUCTION. The study questions at the end of the chapter are based on the readings in this chapter and not on any outside reading.

RECIPROCATING ENGINES. The internal combustion engines (diesel and gasoline engines), with which most boaters work, are machines that change, or convert, heat energy into work by burning fuel in a combustion chamber. Since the pistons in diesel and gasoline engines use an up-and-down motion, they are classified as reciprocating engines.

IGNITION PRINCIPLES. The gasoline and diesel engines differ principally in the method of igniting the fuel.

Gasoline Engines. Gasoline engines uses a spark ignition system and are referred to as an **SPARK IGNITION ENGINE.** The fuel and air for the engine is mixed in the carburetor (or a injection chamber if fuel injectors are used). This mixture is drawn into the cylinders where it is compressed and ignited by an electric spark from the spark plugs.

Diesel Engines. The diesel engine takes in atmospheric air, compresses it, and then injects the fuel into the combustion space. The heat generated by compression of the air ignites the fuel. Hence it is referred to as a **COMPRESSION IGNITION ENGINE.** Diesel engines used in boats look very much like the gasoline engine. They have fuel injectors in place of a carburetor, and the lines leading to the cylinders carry fuel oil instead of an electric current.

OPERATING CYCLE. All reciprocating engines have a definite cycle of operation. It is necessary to atomize the fuel, get it into the cylinders, burn it, and dispose of the gases of combustion. All reciprocating internal combustion engines operate on either a 2-stroke or a 4-stroke cycle. A stroke is a single up or down movement of the piston, or the distance a piston moves between limits of travel. Each piston executes two strokes for each revolution of the crankshaft. The number of piston strokes occurring during any one series of operations (cycle) is limited to either two or four, depending upon the design of the engine.

FOUR STROKE CYCLE engines are used in most automobiles. Each piston goes through four strokes and the crankshaft makes two revolutions to complete one cycle. In this case, each piston is delivering power during one stroke in four, or there is one power stroke for each two revolutions of the crankshaft.

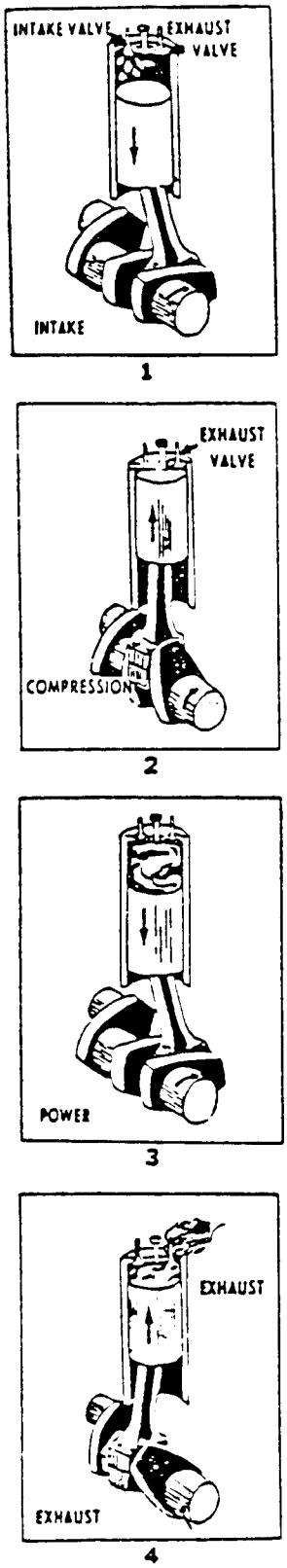


Figure 3-1. The Four Stroke Gasoline Engine.

Let us use one cycle of a gasoline engine to trace its operation through the four strokes that make up a cycle. (See Figure 3-1.) First there is the **INTAKE STROKE.** The intake valve is open and the exhaust valve is closed. The piston moves down, drawing a mixture of air and gasoline into the cylinder through the open valve. This is shown in 1.

Next is the **COMPRESSION STROKE.** Both the intake and exhaust valves are closed and during this stroke and the piston starts moving upward (illustration 2). The air/gas mixture which entered the cylinder during the intake stroke is compressed into the small space above the piston. The volume of this air may be reduced to less than 1/8 of what it was at the beginning of the stroke.

The high pressure which is a result of this great reduction in volume creates a highly explosive mixture. When the piston reaches the top of the compression stroke, the spark plug in the cylinder receives high voltage from the distributor. This creates a spark which ignites the air/gas mixture.

During the **POWER STROKE**, which follows the ignition, the inlet and exhaust valves are both closed. The increase in temperature resulting from the burning fuel greatly increases the pressure on top of the piston. This increased pressure forces the piston downward and rotates the crankshaft. This is the only stroke in which power is furnished to the crankshaft by the piston. (Illustration 3)

The last stroke of the cycle is the **EXHAUST STROKE** (illustration 4). The exhaust valve is open and the intake valve remains closed. The piston moves upward, forcing the burned gases out of the combustion chamber through the exhaust valve. This stroke is followed immediately by the intake stroke of the next cycle, and the sequence of events continues.

The 4-stroke cycle diesel engine operates on the same mechanical, or operational, cycle as the gasoline engine. In the diesel engine, the compression ratio is much higher than in the gasoline engine. This is necessary to increase the heat generated by the compression of the air in the compression stroke. The fuel is injected into the cylinder at the top of the compression stroke where it is ignited by the heat.

TWO-STROKE-CYCLE diesel engines are widely used. Although some gasoline engines operate on the 2-stroke cycle, their use is limited principally to outboard motors. Every second stroke of a 2-stroke-cycle engine is a **POWER STROKE**. The strokes between are **COMPRESSION STROKES**. The intake and exhaust functions take place rapidly at the bottom of each power stroke. With this arrangement there is one power stroke for each revolution of the crankshaft, or twice as many as in a 4-stroke cycle engine. (See Figure 3-2.)

The cylinder of a 2-stroke-cycle diesel engine has an exhaust valve but no intake valve. The air enters the combustion chamber through ports (openings) in the cylinder wall. These ports are uncovered by the piston as it nears the bottom of each stroke. (Illustration 1)

When the piston moves upward on the compression stroke, the exhaust valve is closed and the intake ports are covered. (Illustration 2) The piston compresses the air trapped in the combustion chamber. At the top of the stroke, fuel is first sprayed into the cylinder and then ignited by the hot compressed air.

Illustration 3 shows the downward motion of the piston on the power stroke. The exhaust valve is still closed and the increased pressure, resulting from the burning fuel, forces the piston downward, and rotates the crankshaft.

As the piston nears the bottom of the power stroke, it uncovers the intake ports and the exhaust valves open. (Illustration 4) Air delivered under pressure by a blower (air pump) forces air in through the intake ports, and the burned gases are carried out through the exhaust valve.

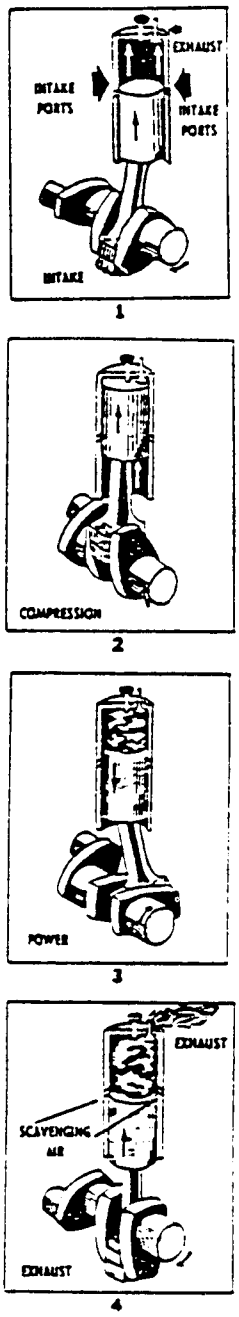


Figure 3-2. The Two Stroke Diesel Engine.

This scavenging operation takes place almost instantly and corresponds to the intake and exhaust strokes of the 4-stroke cycle.

On the compression stroke, the exhaust valves are closed, the intake ports are covered, and the air is trapped in the cylinder. The rising piston compresses the air and heats it adiabatically, or without a loss or gain of heat. By the time the piston reaches the top of the stroke, the volume of the combustion chamber has been greatly reduced. The relation between the volume of the combustion chamber with the piston at the bottom of the stoke, and the volume of the combustion chamber with the piston at the top of the stoke is called the compression ratio. Compressing the air to approximately one-sixteenth of its original volume representing a compression ratio of 16 to 1. Gasoline engines operate at compression ratios between 4 to 1 and 8 to 1, but the compression ratios of diesels range between 12 to 1 and 16 to 1.

As the compression ratio is increased, the rise in the temperature of the air in the cylinder increases. For example, with a compression ratio of 14 to 1, the temperature will be slightly over 1000° F. This means that on the compression stroke of a diesel engine the air is heated to about 1000° F. At this temperature, the fuel begins to burn when it is injected into the cylinder.

You might expect a 2-stroke-cycle diesel engine to develop twice as much power as a 4-stroke cycle engine; however, such is not the case because approximately 10 to 14 percent of the engine's power is required to drive the blower. Nevertheless, 2-stroke-cycle diesel engines give excellent service.

POWER SYSTEM. The Power System of the engine transmits power from the cylinders to the drive shaft. The power system includes the cylinders and pistons, the connecting rods, and the crankshaft.

The cylinders of most marine engines are cast in a single block. Each cylinder is lined with a special hardened alloy iron sleeve to reduce wear.

The pistons are attached to the crankshaft by connecting rods, which transmit power from the pistons to the crankshaft. The rods are joined to the pistons by piston pins (wrist pins) and are connected to the crankshaft by bearings (see figure 3-3). A seal is provided between each piston and the piston wall. This seal is accomplished by piston rings in grooves in the piston wall. As the piston moves up and down, the rings press against the cylinder wall, thus preventing the air or gases (during the exhaust stroke) from passing down into the crankcase and the oil from working up past the piston.

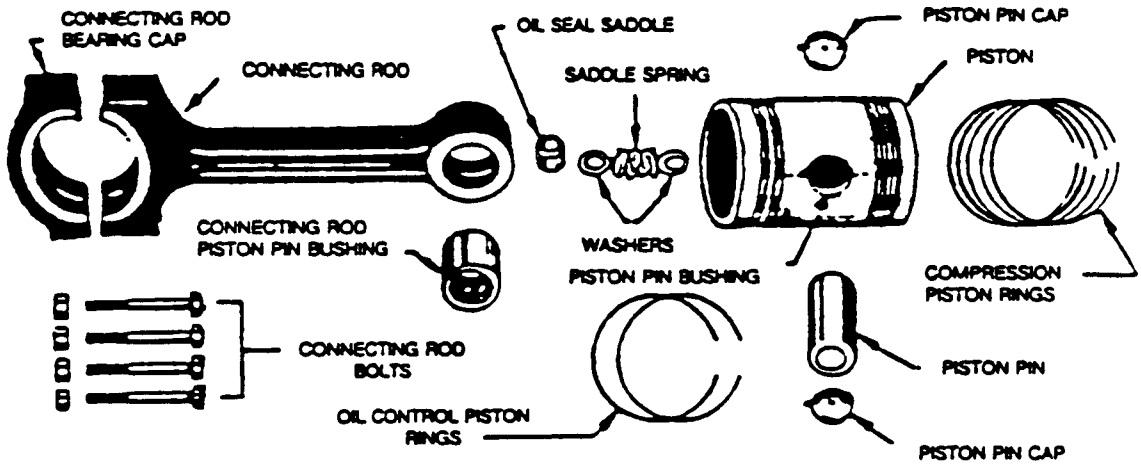


Figure 3-3. Piston and connecting rod parts.

The crankshaft is a device used to change the reciprocating motion of the piston and the connecting rods into rotary motion needed to drive such items as reduction gears, propeller shafts, generator- alternator, and pumps. There are many common applications of this principle; the treadle of an old-fashioned sewing machine and the up-and-down motion of your legs on the pedals of a bicycle. Figure 3-4 shows the crankshaft action of a sewing machine treadle and band wheel. This arrangement can also be used to change rotary to reciprocating motion. During three of the strokes of a 4-stroke-cycle engine, the rotary motion of the crankshaft is moving the piston up and down.

Valve Mechanisms. The valves are opened by the action of a camshaft, driven by the crankshaft through a train of gears.

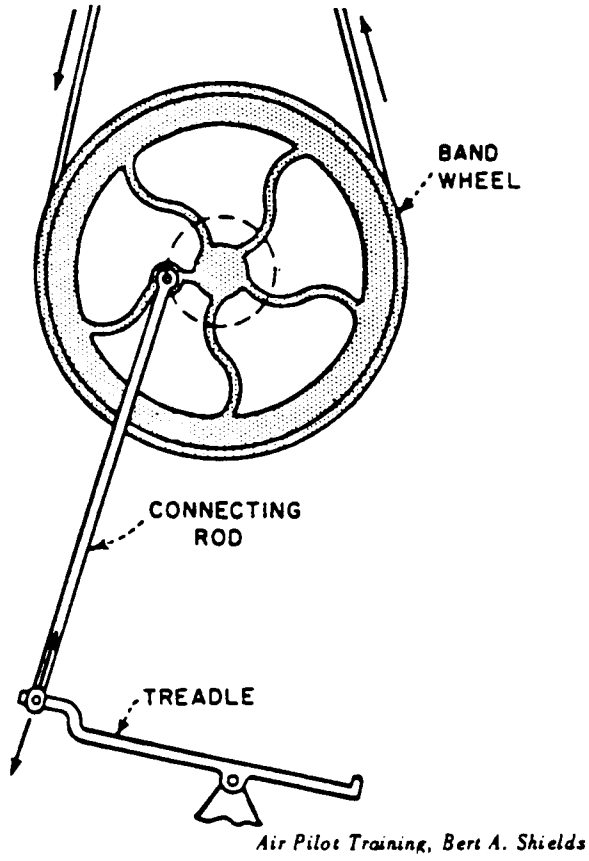


Figure 3-4.—The crankshaft action of a treadle and bandwheel.

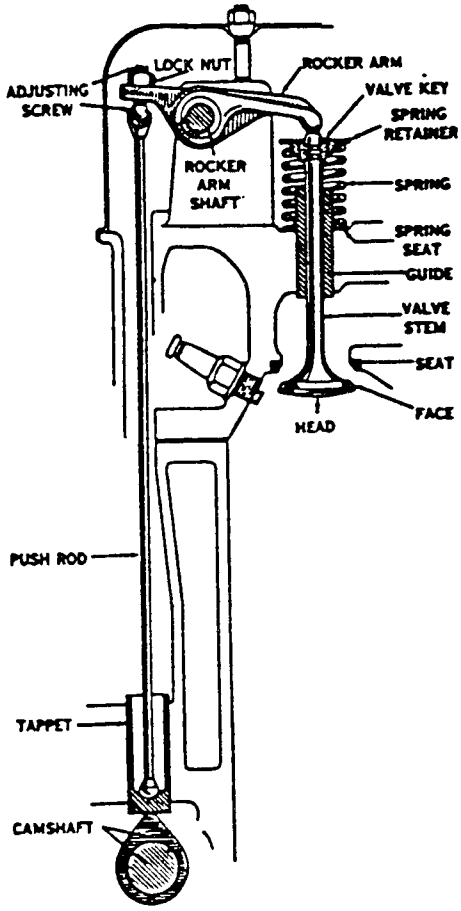


Figure 3-5 Simple Camshaft and Valve Mechanism

The <u>camshaft</u> is a long steel shaft that extends the length of the engine and carries one or more cams for each cylinder. The shaft is cylindrical, but the cams are irregular in shape (see figure 3-5). Each cam is partly circular in outline but carries a LOBE (HUMP) which gives it an egg-shaped appearance. The circular part of the cam is called the CAM FLAT. The camshaft is designed to change rotary to intermittent reciprocating motion. A tappet riding on the rotating cam is lifted each time the lobe comes around.

On some types of engines, the camshaft is located near the crankshaft. In these designs the action of the cam roller is transmitted to the rocker arm by a push rod. In other engines, the valves are inverted and are located in recesses at the side of the cylinders. With this arrangement, the valve stems may ride directly on the cams or they may be separated by a short steel shaft called a TAPPET. This arrangement is shown in above.

The camshaft must be timed with the crankshaft so that the lobes will open the valves in each cylinder at the correct instant in the operating cycle. In the 2-stroke cycle the exhaust valves are opened for only a short time, at the bottom of the power stroke, to permit the burned gases to escape. Since the cycle is completed in one revolution, the camshaft rotates at the same speed as the crankshaft.

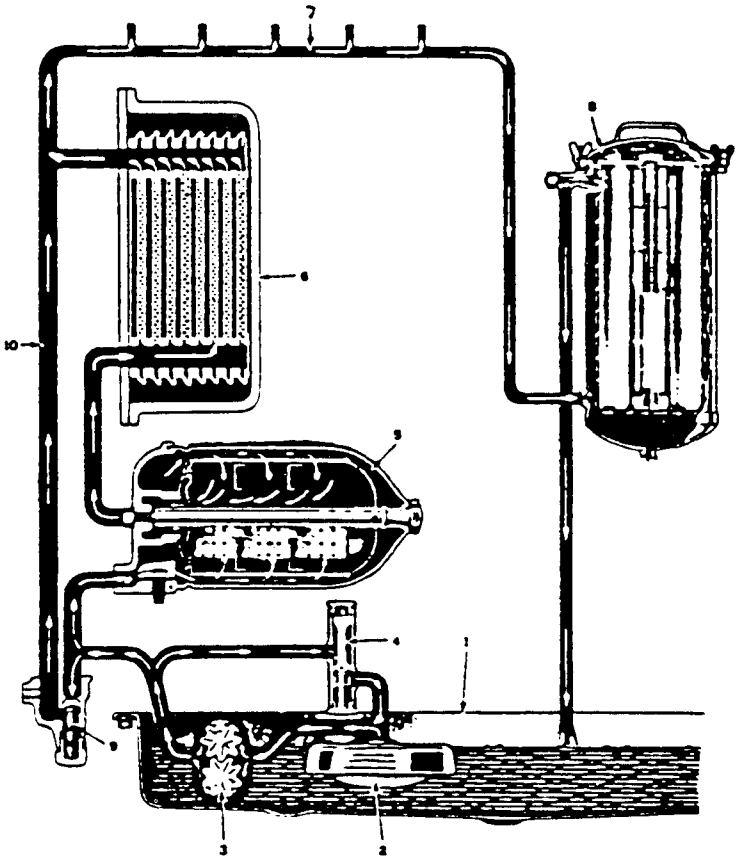
The 4-stroke-cycle engine has an intake and an exhaust valve in every cylinder, each of them operated by a separate cam. The intake valve is held open during the intake stroke, and the exhaust valve opened during the exhaust stroke. Both are opened and closed several degrees of crankshaft travel before and after the top and bottom of the piston travel. Since two revolutions of the crankshaft are necessary to complete a 4-stroke cycle, the camshaft of these engines turns one half the speed of the crankshaft.

Air System. In the 4-stroke cycle engine, the air enters the cylinders through the intake valve. As each piston goes down on the intake stroke, the volume of the combustion chamber increases and the pressure decreases. The normal atmospheric pressure then forces the air into the cylinder through the intake valve.

The 2-stroke cycle engine does not go through an intake stroke. The air enters through intake ports, uncovered when the piston approaches the bottom of the power stroke. Since the exhaust valves open as the intake ports are being uncovered, the incoming air forces the burned gas out through the exhaust valves and fills the cylinder with a supply of fresh air. On large 2-stroke cycle diesel engines, blowers must be provided to force air into the cylinders.

Lubricating System. The lubrication system is a vital part of an internal combustion engine. If the lubricating system should fail not only will the engine stop, but all of the parts are likely to be damaged beyond repair.

The lubricating system delivers oil to the moving parts of the engine to reduce friction and assist in keeping them cool. Most diesel and gasoline engines are equipped with a pressure lubricating system that delivers the oil under pressure to the bearings and bushings, and also lubricates the gears and cylinder walls. The oil usually reaches the bearings through passages drilled in the framework and the crankshaft of the engine. The lubricating system of a typical 4-stroke cycle inboard engine is shown in figure 3-6.



1. OIL PAN
2. SCREEN–OIL PUMP INTAKE
3. PRESSURE OIL PUMP
4. VALVE–PRESSURE RELIEF
5. OIL STRAINER
6. OIL COOLER
7. OIL MANIFOLD IN CYLINDER BLOCK
8. OIL FILTER
9. BY-PASS VALVE
10. BY-PASS AROUND STRAINER AND COOLER

Figure 3-6. The Lubrication system of an inboard engine.

Many methods of lubricating the individual parts of each type of engine are in use in the different engine models.

The oil is delivered by the gear-type oil pump. This pump takes suction through a screen from an oil pan or sump. From the pump, the oil is forced through the oil strainer and the oil cooler into the oil manifold in the cylinder block. This manifold extends the length of the engine and serves as a passage and reservoir from which the oil is fed to the main crank-shaft bearings and one end of the hollow camshaft. Most moving parts and bearings are lubricated by oil drawn from these two sources. The cylinder walls and the teeth of many of the gears are lubricated by oil spray thrown off the rotating crankshaft. After the oil has served its purpose, it drains back to the sump to be used over again.

Constant oil pressure, throughout a wide range of engine speeds, is maintained by the pressure relief valve that allows the excess oil to flow back into the sump. All of the oil from the pump passes through the strainer and cooler, unless they are clogged or the oil is cold and heavy. In such cases, the bypass valve is forced open and the oil flows directly to the engine. Part of the oil fed to the engine is returned through the filter, which removes flakes of metal, carbon particles, and other impurities.

The oil pressure in the line leading from the pump to the engine is indicated on a pressure gage. A temperature gage in the return line provides an indirect method for indicating variations in the temperature of the engine parts. Any abnormal drop in pressure or rise in temperature should be investigated at once. It is advisable to stop the engine until the trouble has been located and corrected.

The oil should be changed according to the manufacturer's specifications. This is particularly true for diesel engines.

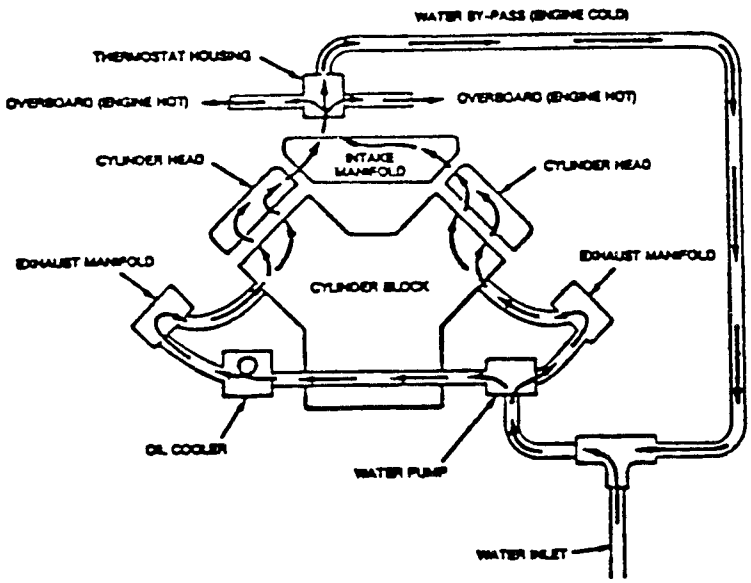


Figure 3-7. The inboard cooling system

<u>Cooling System</u>. Marine engines are equipped with a water-cooling system to carry away the excess heat produced in the engine cylinders. The water is circulated through water jackets in the cylinder walls and passages that surround the valves in the cylinder head. The lubricating oil acts in cooling the pistons and cylinder walls.

Either fresh water or sea water may be used for cooling. In some engines the sea water is circulated through the engine and then discharged overboard.

In other types of engines, fresh water is circulated through the engine and then through a heat exchanger. Sea water is pumped through this exchanger and cools the fresh water. An advantage of the fresh-water system is that it keeps the water passages cleaner, avoids the corrosive effects of sea water, and thus provides better cooling.

Electrical System. The electrical system of most inboard engines consists of the familiar generator/alternator, and electric motor that serves as a starter, a suitable battery, and the necessary wiring. The generator/alternator keeps the battery charged and provides current for lights and other equipment. The charging rate of the generator/alternator is controlled by a voltage regulator, and a cut-out is provided to keep the battery from discharging through the alternator/generator at low speed. When the starter button is pressed the starter bendix gear engages with the teeth on the flywheel and turns the engine over. Diesel engines generally require double the battery capacity of gasoline engines. Some large diesel engines are started with compressed air or a small auxiliary gasoline engine.

Diesel Engines. Figure 3-8 shows the components found in the typical diesel engine. The power, air, lubricating, cooling and electrical systems are generally as described above. As stated earlier, the diesel engine is a Compression Ignition engine. The fuel system of the diesel engine is different from that found with gasoline engines.

The fuel pump draws the fuel oil from the tank through a primary filter and delivers it to the injector through the secondary filter. The outlet line carries the excess fuel oil from the injector back to the fuel tank. In some installations a transfer pump is installed between the tank and the primary filter.

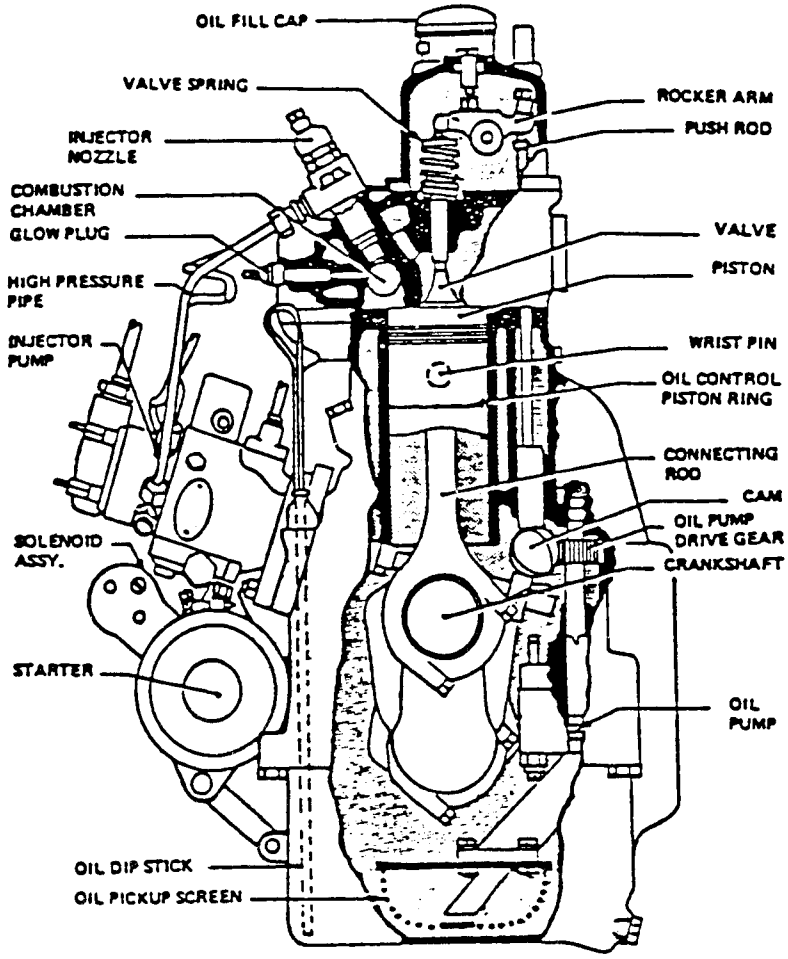


Figure 3-8. Components of the diesel engine.

A diesel engine will not operate efficiently unless clean fuel is delivered to the injector. As the fuel oil is pumped into the fuel tanks, it should be strained through a fine mesh screen. The larger particles of the solids suspended in the fuel are trapped in the primary screen. The secondary filter separates the finer particles of foreign matter that pass through the primary filter screen. The final filtering takes place within the injector. Most filters have a drain plug for removing the water, sludge, and other foreign matter. The filter should be drained once a day, or as specified in the manufacturer's technical manual.

There are many methods of fuel injection and just as many types of injectors. One is the "unit injector" system. The injector consists basically of a small cylinder and a plunger, and extends through the cylinder head to the combustion chamber. A cam, located on the camshaft adjacent to the cam that operates the exhaust valves, acts through a rocker arm and lowers the plunger at the correct instant in the operating cycle. When the injector plunger is depressed, it squirts, or injects, a fine spray of fuel into the cylinder, through small holes in the nozzle. The smooth operation of the engine depends to a large extent on the accuracy with which the plungers inject the same amount of fuel into each combustion chamber. The amount of fuel injected into the cylinders on each stroke is controlled by rotating the plungers of a unit injector. The throttle, which regulates the speed of the engine, is connected to the injectors through a portable linkage. Changing the throttle setting rotates the plungers and varies the amount of fuel injected into the cylinders on each stroke.

Another system is call the "common rail" system. This is most commonly used in engines other then General Motors. Instead of a pump being located at each cylinder in a separate unit, there is one pump for all injectors. This system has one drawback. If air gets into the system it must be purged. This usually is done by loosening the small delivery tube at the cylinder and rolling the engine over with the starter until the air is purged and only fuel comes out. Performance of the "common rail" system is generally as good as with the "unit injector" system. Caution should be used before making any adjustments to either system. Serious and expensive damage can occur from improper adjustments.

<u>GASOLINE ENGINES</u>. Most inboard engines are a 4-stroke cycle engine. Two-stroke cycle gasoline engines are used principally to drive outboard motorboats, motorcycles, and model airplanes. The power, air, lubricating, cooling and electrical systems are generally as described above. The principal difference between the gasoline and the diesel engines is that the gasoline engine has a carburetor and an ignition system. In addition, the gasoline engine has a lower compression ratio than the diesel engine. A typical marine gasoline engine has a compression ratio of about 7 to 1, compared to an approximate ratio of 16 to 1, even 20 to 1, in some diesel engines.

Induction System. This system draws gasoline from the fuel tank and air from the atmosphere, mixes them, and delivers the mixture to the cylinders. It consists of the fuel tank, the fuel pump, the carburetor, and the necessary fuel lines and air passages. Flexible tubing carries the fuel from the tank to the carburetor, while the intake manifold carries the fuel-air mixture from the carburetor to the individual cylinders.

The FUEL PUMP commonly used on gasoline engines is slightly different from any of the pumps discussed later on in this training course. In some respects this is like the old-fashioned water pump, with the piston replaced by a flexible diaphragm. This diaphragm, which forms the bottom of the pump chamber, is composed of several layers of treated cloth held between two metal disks. (See figure 3-9)

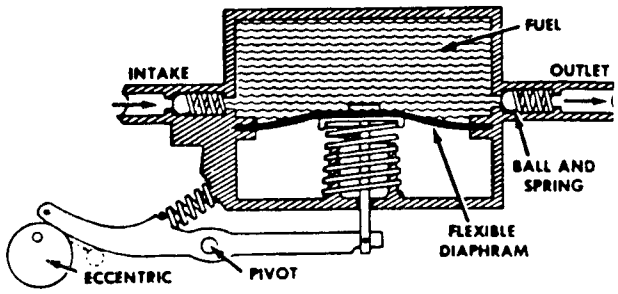


Figure 3-9. A schematic drawing of a gasoline engine fuel pump.

The diaphragm is actuated by the rocker arm, which rides on the eccentric. However, the parts are connected in such a way that the diaphragm can be pulled downward only. An eccentric is merely a circular-shaped cam that is mounted off-center on its shaft and wobbles up and down as it rotates. The diaphragm is raised by the action of the spring that pushes against its under surface. An inlet and an outlet-check valve permits the fuel to flow through the pump chamber in one direction only.

When the engine is running, the eccentric acts through the rocker arm to lower the diaphragm against the spring pressure. This draws a charge of fuel into the pump chamber through the inlet check valve. During the next half-revolution of the eccentric, the spring pushes the diaphragm upward and forces the fuel out of the pump chamber, through the outlet check valve, into the line leading to the carburetor. The pump will continue to deliver fuel as long as the force of the spring is able to overcome the pressure in the carburetor fuel line.

From this description, it can be seen that the cam action of the eccentric merely moves the diaphragm downward and compresses the spring, while the actual pumping is done by the spring as the pressure on it is released. The pressure which the pump maintains in the fuel line depends on the strength of the diaphragm spring. As the pressure builds up, a point is reached where the spring will be strong enough to lift the diaphragm only part of the way. When no fuel is being taken into the carburetor, the diaphragm will remain in the lowest position and the pump will not deliver any fuel.

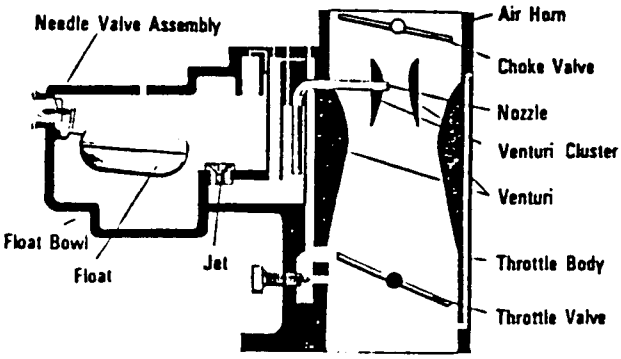


Figure 3-10. A schematic drawing of a float-type carburetor.

The CARBURETOR is a device used for sending a fine spray of fuel into a moving stream of air on its way to the intake valves of the cylinders. The spray is swept along, vaporized, and mixed (as a gas), with the moving air. The carburetor is designed to maintain the same mixture ratio over a wide range of engine speeds. The MIXTURE RATIO is the number of pounds of air mixed with each pound of gasoline vapor. A RICH MIXTURE is one in which the percentage of gasoline vapor is high, while a LEAN MIXTURE contains a low percentage of gasoline vapor. Gasoline engines normally operate best on a mixture ratio of about 12 to 1. A carburetor consists of several principal parts, each of them performing some particular function (see figure 3-10). These units are the float chamber, the main jet and idling systems, and the throttle and choke valves. A throttle connected to the throttle valve controls the engine speed, and adjustments are provided for regulating the idling speed and mixture.

The FLOAT maintains a constant fuel level in the float chamber by regulating the flow of gasoline through a needle valve. As more fuel enters the chamber, the float rises and closes the valve. While the engine is running, the float allows gasoline to enter the float chamber at the same rate as it is being used by the engine. A constant fuel pressure is maintained on the needle valve by the fuel pump.

The MAIN JET SYSTEM consists of the discharge nozzle located in the venturi-shaped air passage or throat of the carburetor. A restriction, called a metering jet, is located in the passage that carries the fuel from the float chamber to the nozzle. The main air-bleed permits air to pass into the discharge nozzle and mix with the fuel. This air-bleed arrangement, when properly designed, will maintain a fairly constant fuel-air mixture ratio at all engine speeds above idling.

The term VENTURI is applied to the constricted section of the air passage around the main jet.

The incoming air must speed up to get through this small passage. According to a law of physics, the speeding up of a fluid in a closed passage is accompanied by a corresponding decrease in pressure. The reduction in pressure in the venturi section of the carburetor causes a fine stream of fuel to spray from the main jet. The fuel level in the float chamber is maintained slightly below the tip of the discharge nozzle, so that fuel will not run out of the nozzle when the engine is stopped.

The IDLING SYSTEM provides a rich mixture for slow engine speeds and for starting. It is made up of the idling jet, the idling air-bleed, and the idling passage. The idling passage opens into the air passage through the idling jet, which is just above the throttle valve. When the engine is idling with the throttle almost closed, the action of the intake stroke in each cylinder creates a high vacuum in the air passage above the throttle valve. Fuel flows up through the idling passage and discharges into the air stream. The idling air-bleed is adjusted to regulate the idling mixture ratio.

The operation of the idling jet depends on the position of the throttle valve, but the main jet depends on the velocity, or speed, of the air passing through the venturi. This means that the engine starts and runs up to a certain speed on the idling jet; but as the speed increases, the main jet begins to function and the idling jet cuts out. Carburetors are designed and adjusted so that the main jet will cut in before the idling jet cuts out. Over a range of a few hundred rpm, both jets are functioning. If the throttle is opened too suddenly, the engine may stall, because opening the throttle valve has caused the idling jet to cut out, but the engine speed is not yet high enough to start the main jet functioning.

Most carburetors have only two or three operating adjustments. The idling air-bleed should be set when the engine is turning over slowly. It should be turned to the right or left to find the position in which the engine will run smoothly. Turning this adjustment to the left leans the mixture, while turning to the right makes it richer. The idling speed is adjusted by means of a set screw in an arm mounted on the throttle shaft. Some carburetors have a third adjustment for regulating the mixture delivered to the engine by the main jet.

Ignition System. In a gasoline engine, the fuel-air mixture is ignited by an electric spark. The compression ratio is not high enough to heat the air to the kindling (igniting) temperature of the fuel. The relationship between the gasoline and diesel principles can be seen when you try to stop an overheated gasoline engine. It often continues to "run on" for some time after you have turned off the ignition. The engine is operating on the diesel principle. The overheated cylinders and pistons increase the normal compression temperature to a point high enough to ignite the fuel mixture.

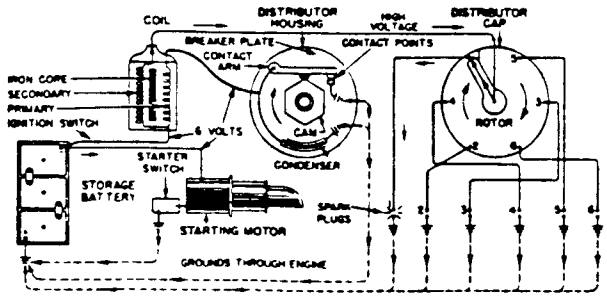


Figure 3-11. Schematic diagram of the ignition system of a gasoline engine.

The ignition system is designed to deliver a spark in the combustion chamber of each cylinder at a specific point in that cylinder's cycle of operation. A typical ignition system consists of an ignition coil, a mechanical breaker, a condenser, a distributor, a sparkplug in each cylinder, a switch, and the necessary wiring.

Like the diesel engine, the gasoline engine also has a storage battery, a generator or alternator to keep the battery charged, and an electric starter.

There are two distinct circuits in the ignition system, called the primary and secondary. The primary, or low voltage circuit, contains the battery, the ignition switch, the ignition coil, and the breaker points and condenser. The secondary, or high-voltage circuit, is also connected to the ignition coil, and includes the distributor and spark plugs.

THE STORAGE BATTERY is usually the 6 or 12 volt type. It is similar to the heavy-duty automobile type. One terminal is grounded to the engine frame while the other is connected to the ignition system.

The IGNITION COIL is in many respects similar to an electromagnet. It consists of an iron core surrounded by the primary and secondary coils. The primary coil is made up of a few turns of heavy wire and is connected in the primary circuit. The secondary coil has a great many turns of fine wire and is connected in the secondary circuit. In both coils, the wire is insulated, and the coils are entirely separate from each other. The only thing they have in common is the iron core.

THE BREAKER POINTS constitute a mechanical switch connected in the primary circuit. They are located in the bottom of the distributor and are opened by a cam that is timed to break the circuit at the exact instant at which each cylinder is due to fire. This abrupt stopping of the current flowing through the primary coil induces a voltage in the secondary coil. Because the number of turns in the secondary coil is much greater than those in the primary coil, the voltage induced is also much greater. Some newer engines have an electronic ignition module which replaces the breaker points.

A CONDENSER is connected across the breaker points to prevent arcing when the points are opened.

THE DISTRIBUTOR, contains a rotor, located secondary or high voltage circuit, serves as a selector switch to "distribute" the high voltage current to the individual spark plugs. The same drive shaft operates both the breaker points and the rotor.

The SPARK PLUGS, which extend into the combustion chambers of the cylinders, are connected by heavy insulated wires to the distributor. A spark plug consists essentially of a metal shell that screws into the spark plug hole in the cylinder. (See figure 3-12.) There is a center electrode embedded in a porcelain cylinder, and a ground electrode connected to the shell. The ground electrode is adjusted so that the space between it and the center electrode is about 0.025 inch. When the high voltage is sent to the plug, it "fires". That is, an electric spark jumps across this gap between the electrodes.

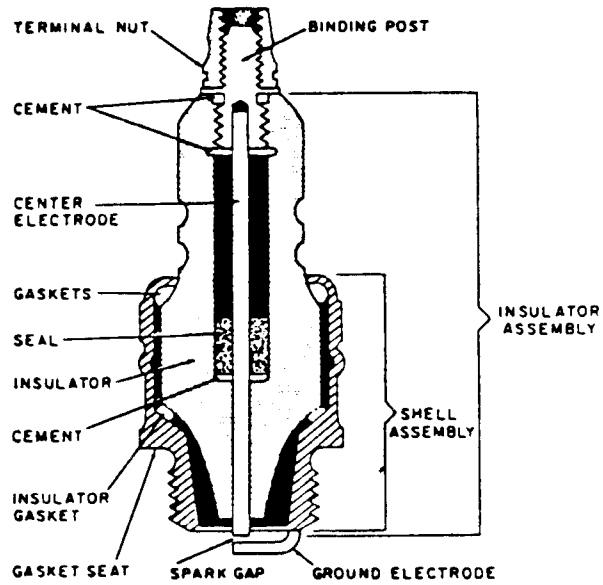


Figure 3-12. Sectional View of a typical spark plug.

When the engine is running, the electric current in the primary circuit flows from the battery through the switch, the primary winding in the ignition coil, the breaker points, and then back to the battery. The high voltage is produced in the secondary winding of the ignition coil and flows through the distributor rotor to the individual spark plugs and back to the ignition coil through the engine frame. It is interesting to note that the high voltage, which jumps the gap in the spark plugs, does not come from the battery, but is produced in the ignition coil.

The electrical system should require little care other than routine maintenance as specified in the owners manual. You should keep the connections tightened and the battery terminals covered with a light coating of petrolatum or Vaseline. The condenser, breaker points,and spark plugs, should be changed at the interval specified in the owners manual.

A good rule to follow in locating engine trouble is to never make more than one adjustment at a time. Stop and think how the engine operates, and figure out the probable cause of any irregular operation, locating the trouble by elimination. Remember that the cause usually is a simple one, rather than a mysterious and complicated one.

INBOARD - OUTBOARDS (I/O's). I/O's have gained popularity as the engine is installed in the stern section of the boat leaving more unobstructed space in the boat. An outdrive goes through the transom and down the lower unit to the propeller assembly similar to the outboard drive. However this does call for one more angle to transmit the power to the propeller and hence one more possible source of maintenance problems. The outdrive usually goes through the hull at or near the waterline and since the leg cannot be lifted clear of the water, in most instances, it leaves the drive mechanism in the water when not in use. In salt water, I/O's have trouble with the part which is made of an alloy of aluminum which is subject to electrolysis. Engine operation and maintenance is the same as for any other inboard engine.

OUTBOARDS. Outboard engines have a wide choice of horsepower and size, ranging from 25 pounds to six hundred pounds in weight, and from 3 h.p. to 300 h.p. in power. One engine block at present can be increased to 400 h.p. capacity. This great range in horsepower and weight gives a utility range for most any application you may need.

The advantages of the outboard are ease of access for maintenance, lighter weight, the ability to change the tilt of the engine to adjust trim of the boat, the fact that it can be tilted up out of the water when not in use saving the ravages of constantly being immersed, and the capacity to operate in water shallower than conventional inboard boats.

A wide selection of propellers are available for outboards enabling a close efficient tailoring to the needs of getting the most thrust out of the engine for the hull type on which it is used. Several types of corrosion fighting materials involving chromate bonding, epoxy coating, and acrylic enamel finishes are being used to slow down corrosion thus making them more adaptable to salt water use.

STUDY QUESTIONS.

1. In the spark ignition engine, fuel and air is mixed in the _____.

2. The fuel in a diesel engine is _____ into the cylinder.

3. What ignites the fuel in a diesel engine?

4. List the operations performed by each of the four strokes of a four stroke cycle engine:

   1. _____
   2. _____
   3. _____
   4. _____

5. List the operations performed by each of the two strokes of a two stroke cycle engine:

   1. _____
   2. _____

6. The exhaust valve is open at the bottom of the _____ stroke on a 2-stroke engine.

7. List the main working parts of the power system that transmit power from the cylinders to the drive shaft.

   _____ _____

   _____ _____

8. The valves are opened by _____.

9. The _____ is designed to change rotary to intermittent reciprocating motion to open the valves.

10. The lubricating system in an internal combustion engine delivers oil to the moving parts to _____ and to _____.

11. Marine engines are cooled by _____.

12. What are the parts of the induction (fuel) system of a gasoline engine? _____

_____ _____

_____ _____

13. In the gasoline engine, the ratio of the fuel to air mixture is controlled by the _____.

14. What is a rich mixture in a gasoline engine?

15. What is a lean mixture?

16. The _____ provides a rich mixture for slow engine speeds and for starting.

17. A typical ignition system of a gasoline engine consists of _____, _____, _____, _____, _____, and _____.

18. List the components in the primary ignition circuit of a gasoline engine.

_____ _____

_____ _____

19. List the components in the secondary ignition circuit of a gasoline engine. _____ _____ _____

20. The high voltage that produces the spark in the spark plug is produced in the _____.

CHAPTER 4

MARLINSPIKE SEAMANSHIP

INTRODUCTION. The reading material for this lesson can be found in the following pages as well as the chapter on **Marlinespike Seamanship** in the earlier editions of **CHAPMAN *Piloting, Seamanship, and Small Boat Handling*** and in **Section 3, Chapter 13** of the later editions. The study questions at the end of this lesson are based on these readings.

TYPES OF ROPE. Today there are three basic types of rope available to boaters. They are natural rope, synthetic rope, and wire rope, However, there has been a great shift away from the natural lines to the synthetic lines in the past few years. Once rope is placed aboard a vessel and/or put to use, it is termed line.

Natural Line. Until the 1950's, there were six types of natural fiber line readily available for use. These were manila, sisal cotton, hemp, linen, and jute. Of these six, manila and cotton lines are just about the only ones which can be found in most marine supply stores today. Because of this, only manila and cotton will be discussed here.

Manila line is made from plant fibers and is fairly strong and durable. It is the most popular of natural fiber lines. Its main advantages are: it is readily available, relative inexpensive and is very durable. With proper care, manila line can last for years. It has virtually been replaced, however, by synthetic line for running rigging and other light use. Compared to synthetic fiber line, manila is fairly stiff. Its chief disadvantage is that it will deteriorate if stowed wet, or allowed to lie out in the sun or foul weather. It dries easily, though, and is not very hard to maintain.

Cotton line has only about half the strength of manila line. It is mostly used by small boats. Unlike manila, it is pliable and soft to the touch, and will run smoothly in blocks. Its main disadvantage is that it is susceptible to rot. It also stretches quite a bit like some of the synthetics.

Synthetic Line. Synthetic line may look like natural fiber line but there is a world of difference between them. Synthetics usually cost much more than natural fiber line, but the difference in price is generally well worth it. The use of synthetics is very advantageous.

Synthetics can be stowed wet, and they are almost impervious to salt, air, water, and anything else that could destroy natural line. They last an incredibly long time. They are tougher and stronger size for size than just about any other line material. Synthetics can do anything that fiber line can do and do the better just about every time.

Synthetic line needs hardly any maintenance. To be sure, it will deteriorate when left out in the weather, but this rate of deterioration is fairly slow. It can also mildew if stored wet. If synthetics are given the care that is usually given to fiber line, then their longevity is almost limitless.

All synthetics tend to unlay when they are cut, so care should be taken when cutting them. After cutting, you should immediately whip them. Heat can help you a lot when whipping synthetic line. For instance, a soldering iron held against the end of a nylon line will melt the fibers. When the iron is taken away, the molten mass will harden, giving you a self-contained whipping.

There are four types of synthetic lines in common use today. They are nylon, dacron, polypropylene and polyethylene.

Nylon line has many characteristics that make it better than any other type of line. Nylon has the highest elasticity and can absorb seven times the shock load of manila. For this reason, nylon is used extensively for mooring and towing lines. Nylon has high abrasion resistance and will not rot even after being left wet for long periods of time.

When comparing line of like size, nylon is twice as strong as manila. In other words, nylon line of smaller diameter can be used when replacing natural fiber line. As in most synthetic materials, nylon line is more expensive than natural fiber line, but in the long run it is much cheaper. It is soft to the touch and extremely flexible. It requires no breaking in to work out any stiffness, as required with manila and other natural fiber lines.

Elasticity, an advantage of nylon, is also the main disadvantage of nylon line. When it reaches the end of its elongation, it will snap like a rubber band and become extremely dangerous to anybody or anything within its reach.

High Tenacity Polyester Fiber (Dacron) like nylon, is soft to the touch, is extremely flexible and requires no breaking in. Dacron (polyester), on the other hand, is not elastic like nylon yet it has all of the other desirable qualities of nylon. Dacron line does not stretch much more than manila line. It has greater strength, flexibility, and higher wear resistance than manila. It, too, can be stored wet and is impervious to rot, or salt water. Dacron is used a lot for all running rigging. In fact, it has just about replaced cotton line for this purpose. This goes hand in hand with the fact that Dacron, like cotton, is fairly light in weight.

Aramed Fiber (Kevlar). This is a new fiber that combines strength and strong dimensional abilities. It is expensive and used mainly by those in sailing competition.

Polyethylene and Polypropylene are two other types of synthetic line in use today. They have similar properties and, quite understandably, similar names. Compared to the other synthetics, however, polyethylene and polypropylene line have several disadvantages. One is low abrasion resistance. Another disadvantage is that they are not as supple as the other synthetics. They have the same flexibility as manila.

Both types of line are very popular because they float. They have just about replaced all other types of line as water-ski tow lines.

Polypropylene differs from polyethylene line in that it is actually stronger when it is wet than when it is dry. Also, it is not as slippery as polyethylene.

Wire Rope. Wire rope is not used very much by small boaters. Its use is generally confined to rigging on sailboats and anchor lines for small boats. Its manufacture is similar to fiber and synthetic line. It is made up of wound strands of wire, generally over a core, which is sometimes made of wire, but usually of fiber. Using fiber for the core of wire rope gives it flexibility and forms a cushion for the wire strands. This provides the wire rope with a certain amount of elasticity or give. Wire ropes are made in five grades, which are relative to strength. These grades are, in declining order: improved plow steel, plow steel, mild plow steel, traction steel, and iron.

CARE OF LINES. Line, no matter what it is made of, needs care at all times. Even the strongest synthetic line, if abused, can deteriorate. Given the high price of any type of line these days, it is a good idea to take care of what you have, rather than let it get run down and require new line. Here are a few basic maintenance rules that will keep your line in good shape if you follow them diligently.

Do not overload your line. For lines of all types, assume that the safe working strength is one-fifth its breaking strength. In other words, if the breaking strength of a line is one thousand pounds, then never subject it to a strain of more than two hundred pounds. What you are doing, in effect, is saving those other four-fifths or 800 pounds for an emergency. If your line is old or worn, make an allowance to this one-fifth rule. In other words, make it one-tenth.

Protect your lines against abrasion. Both the outer and inner fibers of your line contribute equally to its strength. It stands to reason that worn line is weakened line. Where line is subject to local abrasion for instance, when it will rub against a chock protect it with chafing gear, such as canvas wrapped tight around the line.

Avoid sudden strains on your line. Lines of all types that are strong enough to hold up to a steady strain can be broken with a sudden jerk. Care when working with lines is extremely important.

Store your lines properly. Natural fiber lines will deteriorate quickly if not stored properly. They should only be stored when dry, should be well ventilated, should be protected against direct sunlight, and should be coiled properly. The same rules apply to synthetic lines if you want to get the best use out of them. Synthetics, however, need not be given special storing care other than keeping them out of sunlight and out of extremely hot compartments.

Always keep your lines clean. Dirt acts like sandpaper on both natural and synthetic line. It is an abrasive and is dangerous to lines if it is allowed to work into the fibers. Wash your lines thoroughly with clean water when it becomes dirty. And, of course, allow it to dry before you put it back into use. Even though synthetic line will not rot if stored wet, you do not want to induce any more moisture into your storage lockers than necessary.

Always match your line to its use. For instance, use the right size line for the sheaves in a block or pulley. Don't force thick line into a small chock. Misusing your line in this way can put excess wear on it.

Keep chemicals of all kinds away from your lines. Natural fiber lines can be severely damaged by exposure to chemicals. Though the rule books say that synthetic fiber line is immune to damage from oil, gasoline, paint, turpentine,, alcohol, and most other chemicals, be on the safe side. Make it a general rule to keep chemicals away from all kinds of line.

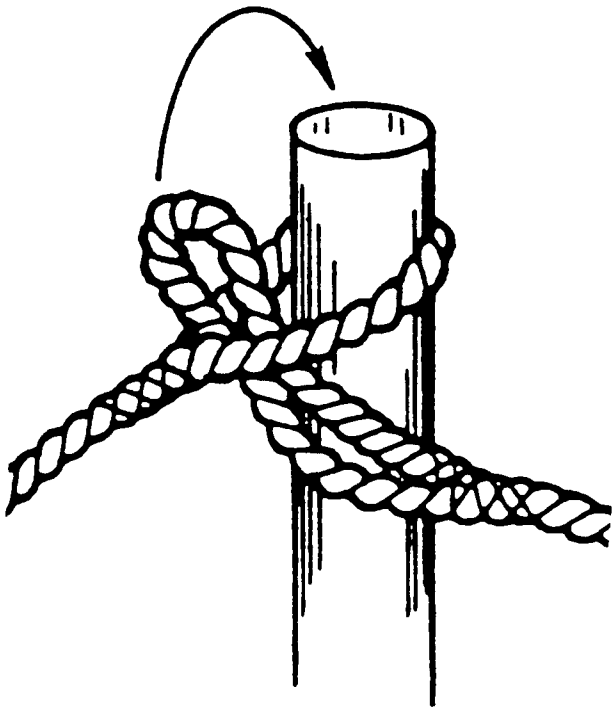
Avoid excess wear. To avoid wear, reverse your line end for end periodically. This will distribute the wear more evenly on your line and give a longer life. For instance, end-for-end your anchor line at regular intervals, the part that is regularly immersed in water should be substituted for the part that remains dry on deck.

Avoid kinks in your line. A kink is the result of a line that is repeatedly turned or twisted in one direction. If you have a kink in your line, get it out immediately and, for certain, don't put a strain on it. A kink in a line is like the weakest link in a chain.

Do not run your lines over sharp angles. Sharp bends in a line decrease its strength in that spot. If you have to run your line over a sharp angle, pad it for safety.

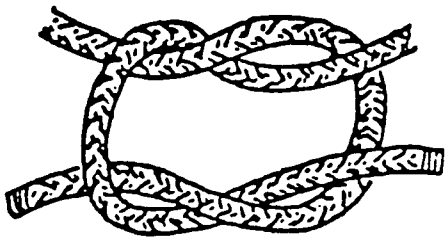
LINE USAGE, KNOTS, HITCHES, BENDS, AND SPLICES.

"Dipping the Eye" on a bollard. Most mooring lines used dockside have an eye splice in one end, which makes it convenient to put the loop over a bollard and snub the line to a cleat on your deck. This will work fine until another boat comes along and uses the same bollard for a mooring line. For instance, when you use a bollard for your bow line and the boat ahead of you uses it for his stern line. If your line was the first one on, then it would appear that it would have to be the last one off. In other words, the eye of your line is under the eye of the boat ahead of you. You would have to lift off the other line before you could lift off yours. This could prove difficult to do, but not so if you "dipped the eye".



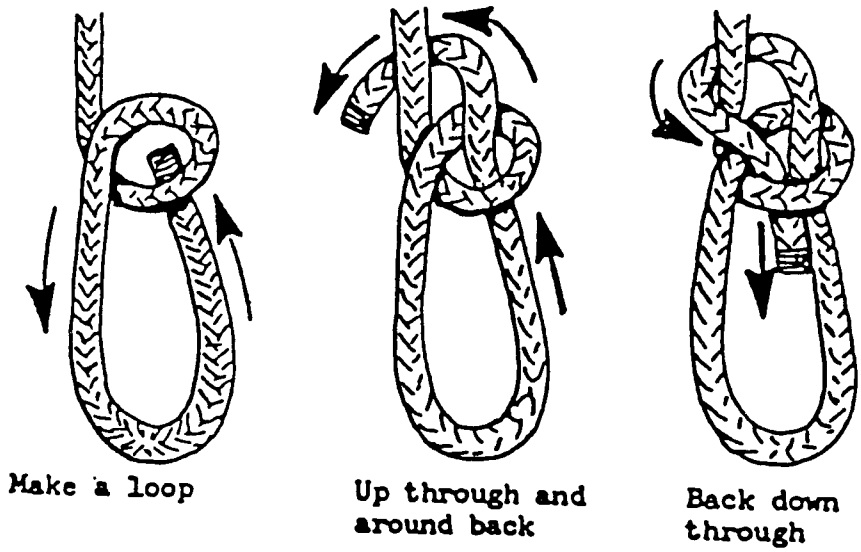
The procedure is simple. Merely take the eye of your line, move it up through the eye of the other line (you might have to slacken your line to do this), slide it up over the top of the bollard, and then pull it back through the eye of the other line. You have accomplished the job without disturbing the line of the other boat (figure 4-1).

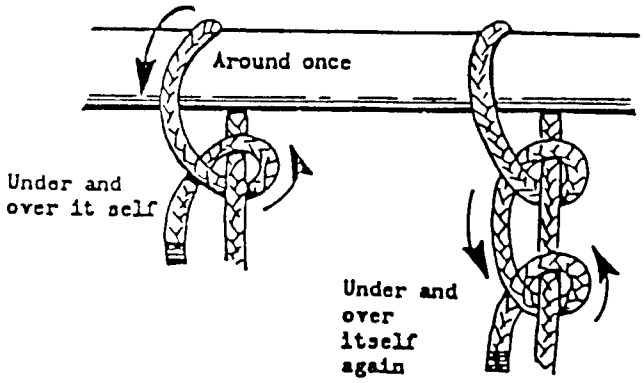
The SQUARE KNOT, (figure 4-2) or Reef Knot, is one of the most common knots for joining two lines of equal size together where no great load is placed. It jams up tight and is hard to undo when given great strain and, if one side is pulled unevenly, might cause the knot to fall into two half hitches.



Square knot. Also called reef knot.

The BOWLINE (figure 4-3), often referred to as the "King of Knots", is the most used knot for making a temporary loop. It is made with a single line, is easy to tie, wont slip under load and is easily untied. It may also be used to join two lines together by tying the of one bowline inside the loop of the other.

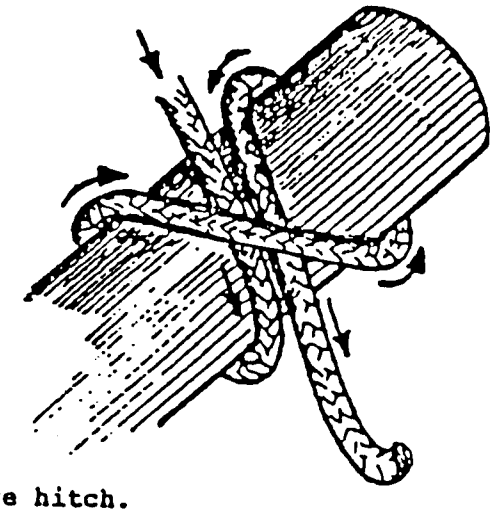




TWO HALF HITCHES

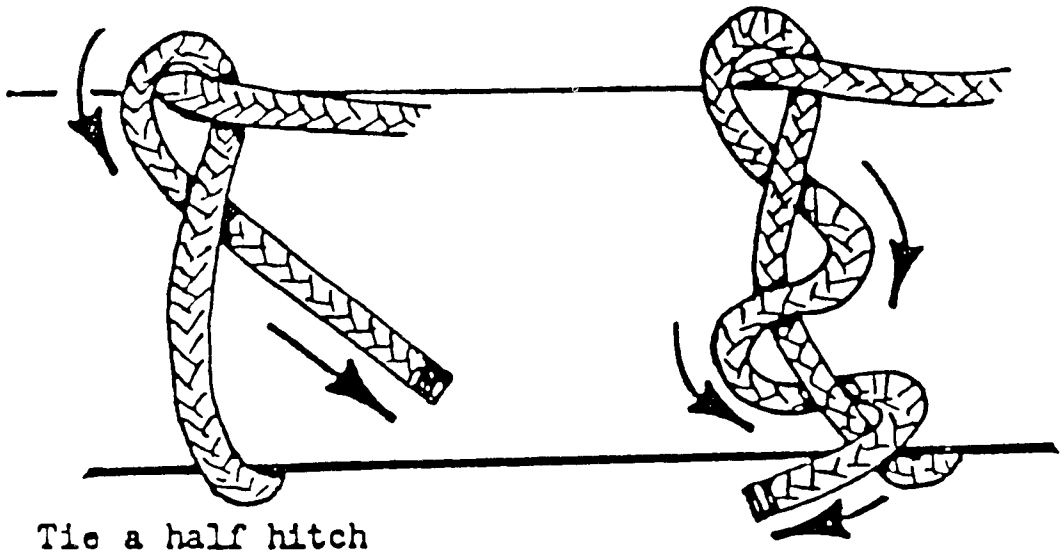
The HALF HITCH (figure 4-4) is simple and is used in connection with many other knots. When two half hitches are used together it makes a sliding knot that will set up under load in tightness in direct relation to the load. A round turn with two half hitches is shown below. It is fast and easy to tie. It can be used as a long term fastening to secure a line to a piling.

The CLOVE HITCH (figure 4-5) is a basic knot used to temporarily tie a line to pilings, etc. When a strain is maintained, the line will not slip. It will setup tight and can be hard to untie. When left slack after tying, it can work loose, so watch it.



Clove hitch.

The TIMBER HITCH is a very simple, fast and easy way to secure a line to logs and other round objects for towing. To tie, pass the bitter end of the line around the object, over the standing part of the line, and then wrap the bitter end back around itself 3 or 4 turns. It may be followed by a half hitch or two around the object to give it alignment with the standing part of the line during the tow. When half hitches are used, they should be made first.

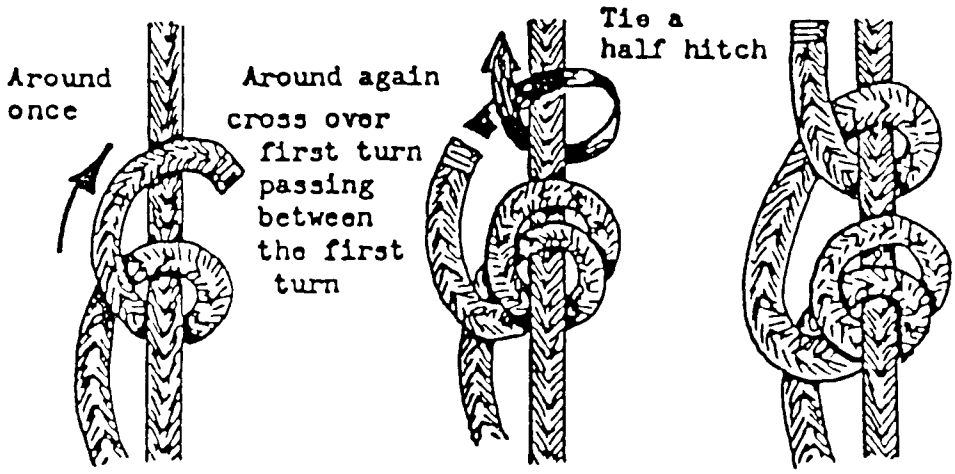


Tie a half hitch

Continue over and under for an additional 3 or 4 turns

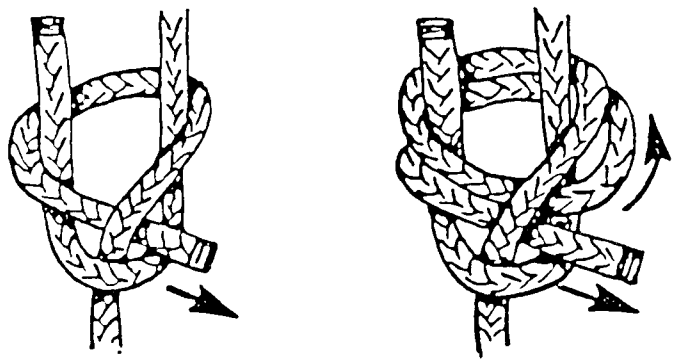
TIMBER HITCH

The ROLLING HITCH, or stopper knot, can be attached around a line under strain and used to maintain the strain while the other line is being moved or fastened. It can also be slid along the line under strain by hand, but will hold when load is on it. You can bend a line on to a spar or another line at a mid-point of the spar or line. Sometimes used when converting a single towline into a bridle.



ROLLING HITCH

The SHEET BEND/BECKET BEND uses either name and is used to tied two lines of unequal size together. Unlike the square knot it is easily untied after strain. The double becket is simply an extra turn again back under and through.



Back under itself once - single becket bend

Around again back under - double becket bend

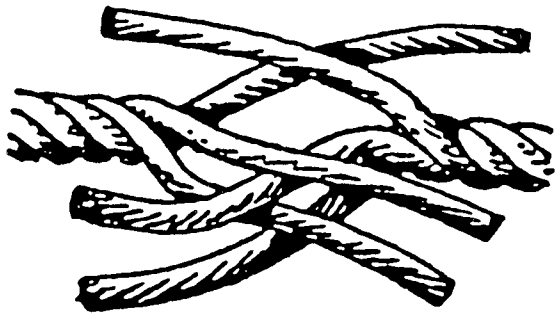
DOUBLE BECKET / SHEET BEND

SPLICING is the preferred method of permanently joining two lines together and to make a permanent eye in a line. A splice is stronger than a knot, hitch, or bend.

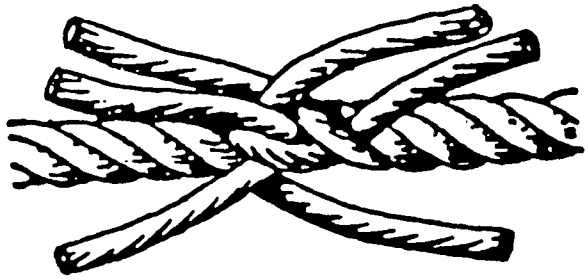
A Long Splice or Short Splice can be used to join to lines together. A long splice does not increase the diameter of a line and is used when the spliced line must run over the sheaves of a block. While this splice is much neater looking, it is not described here since it is harder to make, requires considerable practice, and large amounts of line.

To start a SHORT SPLICE, unlay the end of each rope about six inches. Secure the ends of the three strands with tape to keep them from further unlaying. With synthetic line the ends of each strand can be fused with a soldering iron. Also tape the point on the line where the unlaying is to cease.

Marry the three strands from one rope to the three of the other, much like interlocking two tripods. Tape or seize the union together.



Bring one strand from the right side over a strand from the left rope and tuck it (the right strand) under the next left strand. Using a fid or your fingers, separate a strand on the main body of the line. Now run the middle of the three taped strands under this opening. Select the one to the left of the middle and go over one strand, separate the next strand with the fid. Now push the second taped strand into and out of this opening. The rule to follow is, the next strand "goes in" where the previous strand "came out". Note the two strands inserted so far are inserted against the lay of the line not with it. Also, at no time is more than one inserted strand coming out of the same opening.

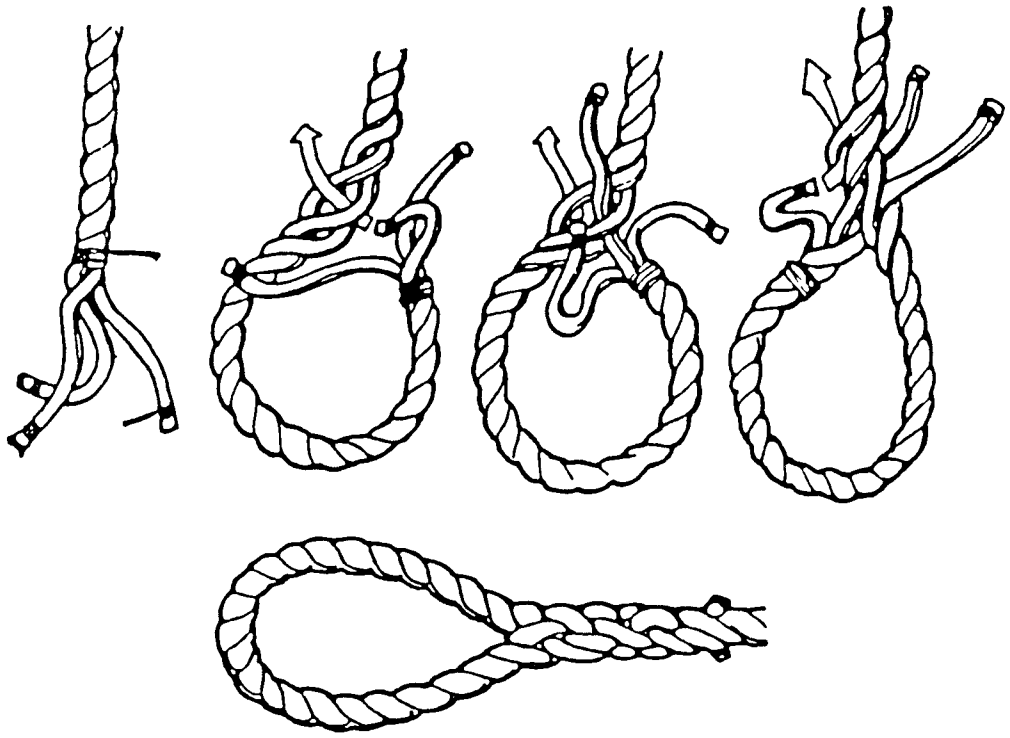


When the splice is properly started, each of the three strands from each end is secured under a strand on the opposite side.

Snug up on what you have done and continue the process until the three strands from each side have been tucked a minimum of three times for manila and five times for synthetic lines. Leave about 1/4 to 3/8 inch of strand projecting. The somewhat lumpy splice can be reduced in diameter by rolling the completed splice on the ground under foot or putting it under tension.

The EYE SPLICE is used when a permanent eye is desired and may be made around any object such as eye splice thimble, stanchion, or simply made without anything in the eye. To start, tape each of the three strands to keep them from unlaying and unlay six inches or more of the line and prevent further unlaying of the line at that point by taping there.

Determine the size of the eye, keep the turn of the eye towards you and the standing part of the line away from you, with a fid or fingers separate a strand on the standing part of the line and run the middle of the three taped strands under this opening. Separate a strand on the standing part to the left of your first tuck and repeat step number one. Remember the rule, the next strand "goes in: where the previous strand "came out". Tuck the third strand through the remaining lay on the standing part that has no strand under it. Repeat this process three or more times making sure that no lay on the standing part has two strands under it.



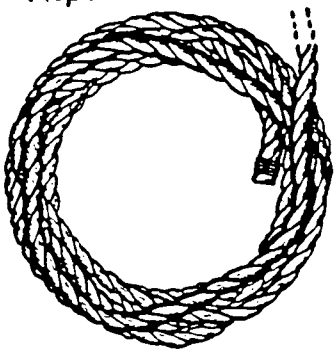
STOWING LINE. Stowing your line so it is ready for use can be done in several ways.

Coiled. Coiling is described in detail in Chapmans.

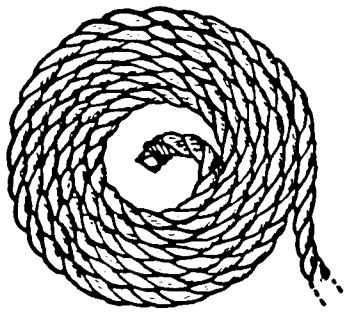
Flemished. Flemishing is a decorative method to store a short length of line. It is usually done on the deck near a cleat or other fastening where the line was secured. It can stain or cause a discoloration of the deck if left too long in the weather.

Faked. When you want to lay a line on the deck, in its full length, so that it is ready to run out rapidly without tangling, it should be faked down.

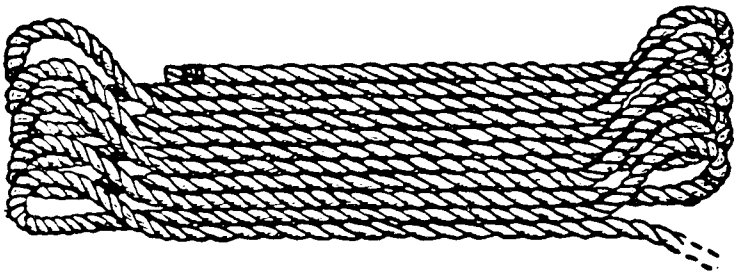
Rope Coiled Down



Rope Flemished Down.



Rope Faked Down



STUDY QUESTIONS.

1. The two types of natural fiber rope generally available in marine supply stores are _____ and _____.

2. The advantages of manila line are; it is _____, _____, and _____.

3. Manila line will _____ if stowed wet.

4. Cotton line has _____ the strength of manila line.

5. The four types of synthetic line in common use today are:

_____ _____

_____ _____

6. Because nylon line is so elastic, it is used for _____ and _____lines.

7. Why is nylon dangerous at times?

8. What are the characteristics of Dacron (polyester) line?

_____ _____

_____

9. Dacron differs from Nylon line in that it is not _____.

10. What is the difference between polyethylene and polypropylene line?

11. Why is fiber used in the core of some wire ropes?

12. What are the five grades of wire lines?

_____ _____
_____ _____
_____

13. List the ten rules for the proper care of line.

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

14. A Clove Hitch can be used to make a _____ fastening to a piling.

15. To temporarily join two lines of different diameters, you would use a _____.

16. A _____ is preferred when permanently joining two lines together.

17. A _____ is used when a temporary loop is desired.

18. To secure a line to a log for towing, you would use a _____.

19. To secure a line to a piling, on a long term basis, the safest fastening to use would be a _____.

20. Explain uses of stopper/rolling hitch.

21. When laying a long line down on deck, where the full length must be run out fairly rapidly, the line should be _____.

22. When might it become necessary to dip an eye on a bollard?

23. A _____ will cause less reduction in line strength than any _____.

24. Tie the following knots: square knot, bowline, round turn and two half hitches, clove hitch, double becket/sheet bends, and timber hitch.

25. Make an eye splice.

CHAPTER 5

BOAT HANDLING

INTRODUCTION. The reading material for this lesson may be found in the chapter covering **Power Cruiser Seamanship** in the earlier editions and in **Section 3, Chapter 9** of the later editions of **CHAPMAN Piloting, Seamanship, and Small Boat Handling.** The student should read this entire chapter paying particular attention to the topics and sub-topics in the following study outline.

STUDY OUTLINE

Basic Principles of Boat Handling

- Effect of wind and Current
- Right and Left-Hand Propellers
- How the Propeller Acts
  - Suction and Discharge Screw Currents
  - Unequal Blade Thrust
- How a Ruder Acts
  - Propeller Current's Action on Rudder

Response of Boat to Rudder and Propeller

- No Way On, Propeller Not Turning
- No Way On, Propeller Turning Ahead
- With Headway, Propeller Turning Ahead
- With Headway, Propeller Reversing
  - With Rudder to Port
- No Way On, Propeller Reversing
- With Sternway, Propeller Reversing
  - Backing With Left Rudder
  - Backing With Rudder Amidships
  - Backing with Right Rudder
  - Steering While Backing
- With Sternway, Propeller Turning Ahead

Turning in close Quarters

- Backing Around a Turn
- Backing to Port From a Slip

Leaving a Mooring

- When There Is Wind or Current

Picking Up a Mooring Under Power

Dock Lines and Their Use

Terminology

Mooring a Boat
Two Lines on One Pile
Heaving Lines and Monkey's Fists

Using Spring Lines
Going Ahead on a Spring
Ahead on an After Spring
Reversing on a Spring

Landing at a Pier

Wind or Current Parallel to Berth
Landings Downwind or With Current
When Boats Lie Ahead and Astern
Using Wind or Current
Balancing Current Against Propeller Action

Landing on the Leeward Side
Bow Line First
Holding with One Spring
Doubling the Spring

Landing Starboard Side to Pier

Getting Clear of a Berth

With Wind or Current Ahead
From a Windward Berth
With Wind or Current Astern
Backing Around
Turning in a Berth
Turning With Power
Make Use of Fenders

Maneuvering at slips in Tight Quarters

A Berth Between Piles
Using Springs to the *Piles*
Approaching Upwind
Getting Clear of a Pile

Making a Tight Turn

Handling Twin-Screw Boats

Basic Turning Maneuvers
One Propeller Going Ahead or Backing
Response to Rudder While Backing

Steering With The Throttles
Turning in a Boat's Length

Docking a Twin-Screw Boat
Using Springs With Twin-Screws

Other Twin-Screw Manuevers

STUDY QUESTIONS

1. The part of the current that flows into the propeller is called _____ _____ _____.

2. When a right handed propeller is turning clockwise, the boat will go _____.

3. On a motorboat, turning the steering wheel to starboard gives the boat_____ rudder and throws the stern to _____ and turns the boat to _____.

4. The stern of a single screw boat with a left handed propeller tends to go to the _____ when the propeller is reversing.

5. When a boats rudder is put over, the stern is kicked _____ _____.

6. When backing an inboard, with a single right hand propeller and rudder amidship, the stern will tend to move to_____.

7. FOUR mooring lines that may be attached to the bow of a boat for dock mooring are:

8. The four lines that may be used as springs are:
   _____ _____
   _____ _____

9. The mooring line that keeps the boat from going ahead is the _____.

10. To spring into a dock, use a _____ spring, and go ahead slowly with the rudder turned _____.

11. Getting away from a dock, when the boat is being set into it by the wind generally requires using an _____ _____ _____.

12. Backing on a forward quarter spring on the port side, the bow will _____.

13. A forward quarter spring line leads forward from the _____to the _____.

14. A 4 to 6 foot long plank hung horizontally on the side of the boat and backed with _____is called a _____.

15. By going ahead on one engine while the other reverses, a twin screw boat can be _____.

16. A twin-screw boat is stopped by reversing its propellers, but unlike a single-screw vessel, this will usually not _____ _____ _____ _____ _____ _____.

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CHAPTER 6

HEAVY WEATHER

INTRODUCTION. The reading material for this lesson can be found in the following pages as well as the section **Boat Handling Under Adverse Conditions** in the chapter on **Special Seamanship Techniques** in the early edition of **CHAPMAN Piloting, Seamanship and Small Boat Handling** and in **Section 3, Chapter 11** of the later editions. The study questions at the end of the lesson are based on these readings.

The best advise for someone considering going out in a boat in rough weather is don't. If you have a choice, stay in a sheltered harbor until the weather clears. You will never regret it. Many boatman, however, through no fault of their own, do not have a choice. Along the coast and even in inland waterways, squalls can develop suddenly with little or no warning. Cruising men making long passages often find themselves faced with prolonged stormy weather and not enough time to make it to a safe refuge before a storm strikes. Even today, when weather forecasting is fairly accurate, a sudden change in expected weather patterns can catch boaters offshore at the mercy of wind and wave.

Your best bet is to prepare yourself for heavy weather operations in advance. Knowing what to expect and the capabilities of your boat can go a long way in an emergency. Self-confidence is the name of the game in bad weather, and this quality can only be obtained through knowledge and experience.

There are many facts about the wind, water, and your boat that you can learn. But in practice many things can happen that are impossible to prepare for such things as sudden shifts in the wind, freak waves, etc. Because of this, you must try to keep a clear head at all times; panic can only compound difficult situations, common sense can often solve the most complicated problems. Knowing something about the challenges you must face can give you confidence. That is the purpose of this lesson.

In this lesson, some of the principles of waves and wind will be covered. Because boating conditions are so variable, however, depending as they do on location, time of year, the type of boat being used, and scores of other factors, you should study other sources as well to really get a feel for what you might be up against.

WIND WAVES. Nearly all waves are caused by the wind blowing over the surface of the sea. Wind blowing over the surface of the water will cause waves. The longer and stronger the wind blows, the higher the waves. If the wind blows in the same direction for a long period of time, the waves will tend to run in the same direction.

If the wind direction should change for a period of time, the water will be turbulent. Then the direction of the waves will begin to conform to the new direction of the wind.

There are two other basic types of waves that are not created by wind. They are TIDAL waves and SEISMIC waves. More about these later.

There are many different characteristics of waves. To facilitate study, oceanographers have come up with what they call an "ideal wave." The anatomy of an ideal wave can be seen in figure 6-1.

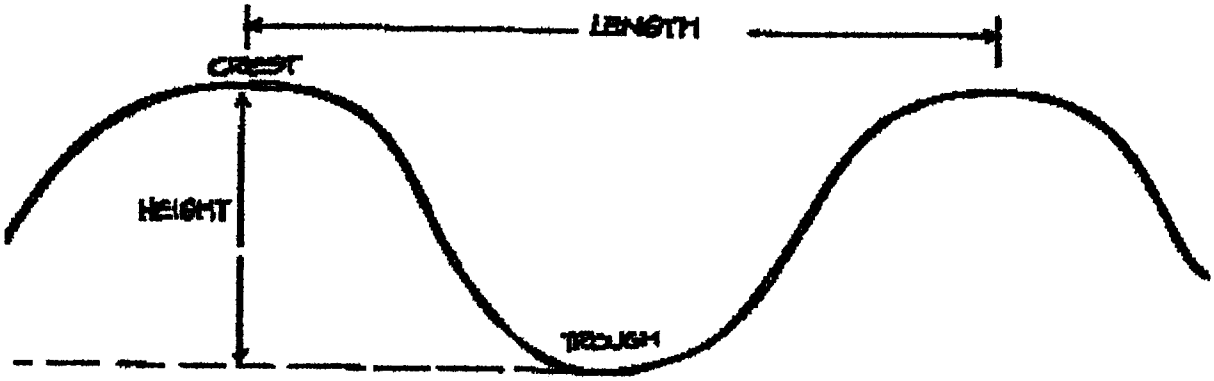

Figure 6-1.—Measuring this ideal wave. The length is measured from crest to crest and the height is measured from trough to crest. The period is the amount of time it takes two crests to pass a given point.

As you can see, there are several ways waves are described. There is height, length, period and slope.

The **HEIGHT** is the distance from the trough to the crest measured vertically. The maximum height of a wave is hard to pin down. It really depends upon whom you talk to. Waves in excess of a hundred feet have been reported, but most experts concede that about fifty feet is more likely. It is possible that waves in a cross see, when two or more wave systems converge from different directions, probably have even greater height. But the question of height is academic for the most part; the highest wave, unless it is breaking, is no more dangerous than the third or fourth highest wave as far as a small boatman is concerned. A sailor used to inland waterways would probably find any wave over five feet in height frightening.

The **LENGTH** of a wave is the distance between two consecutive crests. The greatest length that has been measured is over 2,700 feet.

The PERIOD of a wave is the time it takes two crests to pass the same point. It stands to reason that the longer the length, the longer the period; but of course, faster moving wave systems do not always obey this rule. Wave speeds for the most part average about 30 m.p.h.

FETCH is another important consideration for wind generated waves. The amount of "fetch" will have a direct impact on the size and characteristic of the waves. Fetch is the uninterrupted expanse of water over which the wind operates. The longer the fetch, the more effect the wind can have over the water. Illustrated in figure 6-2 is a body of water with a passage formed by an island to the east and one to the west, 20 miles apart. If the wind were blowing from the east or the west, there would only be a fetch of 20 miles. The water would only be affected by the wind over a short distance. But if the wind were blowing from the south or north, the fetch would be much greater. The water would be affected by the wind over a long distance and the waves could really build up. If you added an opposing tide to a long fetch, you would have a tough condition indeed.

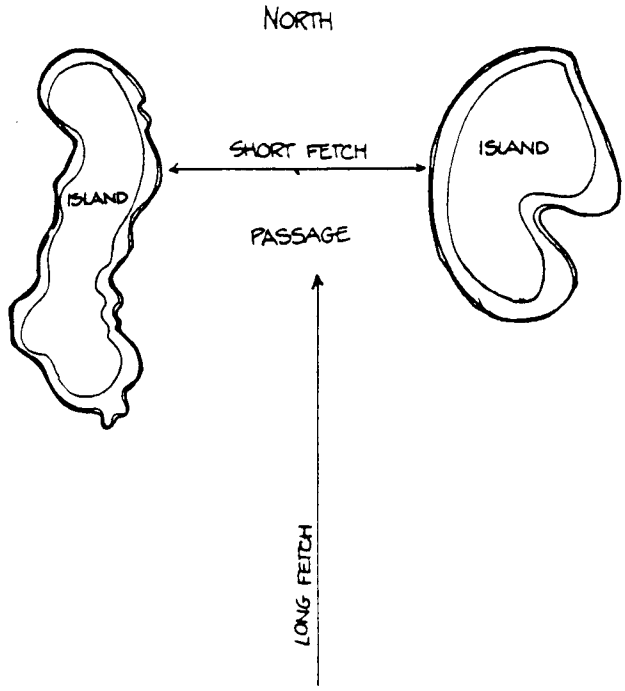

Figure 6-2.—The fetch of a wave.

The SLOPE of the wave is the angular measure from the trough to the crest. (See figure 6-3.)

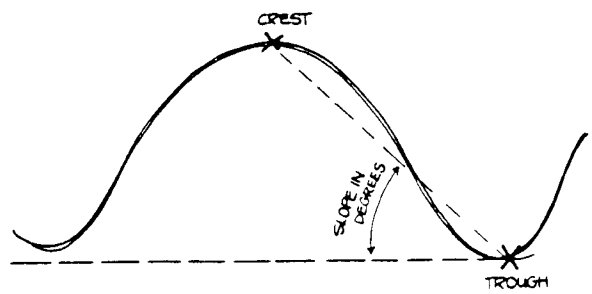

Figure 6-3.—The slope of a wave. Slope is measured in degrees.

STORM TIDE WAVES, as they are generally called, are associated with tropical hurricanes. They are, in reality, caused by the tropical storm wind rather than the tide. The wind from the storm, driving the water before it, can build up a great wall of water. When the tide shifts, this wall of water is released and a huge wave is formed. Every few years a storm tidal wave will destroy many million dollars of beachfront property in the time span of a couple of minutes.

SEISMIC WAVES are sometimes incorrectly referred to as tidal waves. They are commonly called "Tsunamis". These waves are caused by earthquakes, volcano eruptions, and dislocations under the ocean floor. Their wave lengths are usually very long, for instance, several hundred miles, and surprisingly enough their heights are also very low. A seismic sea wave will do very little damage to anybody out in the open ocean. When it gets close to shore, trouble begins. When it reaches shallow water, the wave becomes short and much steeper. The closer it gets to shore, the higher it becomes until its crest breaks and it crashes to the beach.

TIDAL WAVES are generated by the gravitational pull of the sun and moon. These waves occur in places with where there is a huge difference in height between high and low tides. When there is a rapid rise of the tide, an incoming wave is generated. An outgoing wave is formed with the rapid fall of the tide.

SWELLS are waves that were originally generated by the wind but continue to exist long after the wind has died down. In effect, swells are dying waves. You will generally find swells in areas where there are long fetches. They originally begin in a storm area when fierce winds kick up the waves. After the wind dies down, the waves will continue on, provided, of course, that they meet no obstructions. The passage of time and distance reduces what once might have been huge waves into smoothly undulating swells. But don't be fooled they can be dangerous again. When swells reach shoal water, they will be tripped up by the bottom and if conditions are right they can easily become dangerous SURF.

SURF. Waves turn into surf as it nears the shore. Contrary to popular opinion, the particles in a wave do not really move in a horizontal direction. Oceanographers have discovered that the particles of a wave actually travel in a circular path orbiting around the axis of the wave. As the wave nears shore the bottom of the wave begins to touch the ocean bottom. When the water depth falls below approximately one half of the wave length, the bottom of the wave will be slowed by the ocean bottom. At the same time, the top of the wave continues on at the same speed the wave was originally traveling. The angle of the forward slope of the wave will become greater and greater until it finally reaches 90 degrees. The wave crest will fall forward into the trough in front of it and you will have surf. Breaking waves and surf are much stronger than non-breaking waves.

Breaking waves and surf can be broken down into two categories; plungers and spillers.

A **PLUNGER** is the product of a long ground swell called a trochoidal wave. Trochoids are generally very long and very low. They are waves that are a long distance from the point where they were originally generated. On the beach, plungers rise up and crash forward, creating a thunderous noise.

SPILLERS, on the other hand, are the result of cyclical waves. Sick-outs are short choppy waves that have been fairly recently formed by the wind. Spillers are just the opposite from plungers. They break quietly and gently.

WAKES. One wave that is very dangerous for small boats is the wake caused by a motorboat. If more people were more careful about wakes, there would be far fewer accidents on the water. Power boats produce two kinds of waves: the bow wave and the stern wave (see figure 6-4). The bow wave spreads diagonally away from the bow. The stern waves follow the boat transversely. The extent of a boat's wake is a function of her waterline length, displacement, and speed. The stern wave is the one that is most dangerous to other craft, but it is also dangerous to the boat that is causing it if that boat is in shallow water. The water that is between the shoal bottom and the bottom of the boat will build up on either side of the stem. The stern will then sink deeper into the trough and get even closer to the bottom. In a situation like this, speed should be reduced immediately.

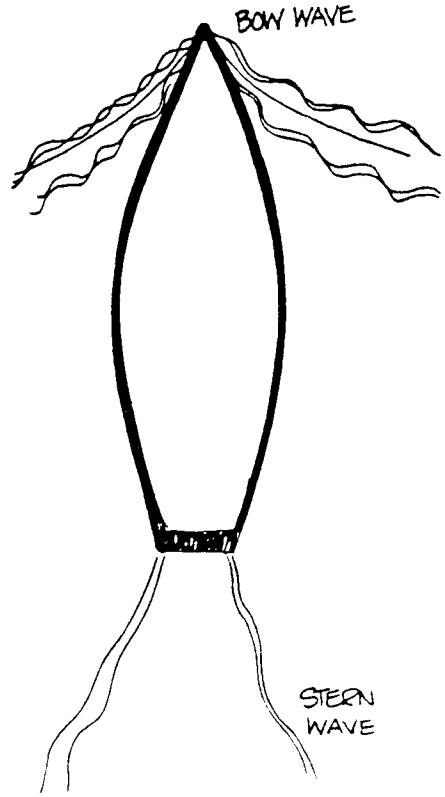

Figure 6-4.—Bow and stern waves. The stern wave is the most dangerous of the two.

CROSS SEAS. Other types of waves that can be dangerous to small boats are cross seas caused by a variety of forces. A tidal current, meeting an opposing wave system head on, or at an angle, can create an evil chop. Two wave systems from different sources that meet at an angle can have the same effect. Sudden shifts in the wind can create a situation where the wind will be blowing against oncoming waves, tossing the sea in all directions.

THE EFFECT OF WIND AND CURRENT ON MANEUVERING. Both wind and current affect the movement of a boat. How much is a function of the amount of superstructure of a boat, the amount of underbody of a boat, the strength and direction of the wind, and the strength and direction of the current.

The amount of effect will be greater if the boat has a shallow, flat bottom and less if the boat has a deep draft. (Figure 6-5.)

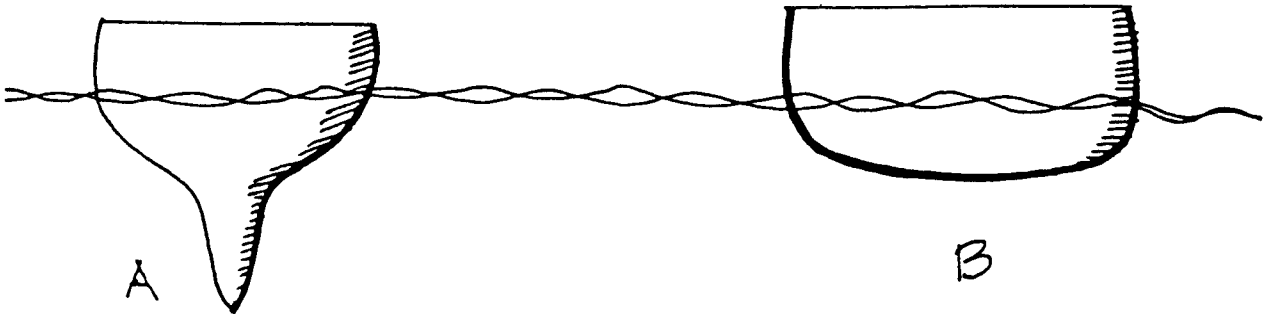

Figure 6-5.—Draft makes a big difference in regard to leeway. Boat A, because of her deep hull, will not make as much leeway when the wind is abeam as Boat B.

A strong wind blowing broadside to a boat that has low freeboard and very little superstructure (a low-profile boat) will not have very much effect on the maneuvering of that boat. On the other hand, there will be a considerable effect on a boat that has a high freeboard and high superstructure. With the strong wind blowing broadside to, this type of boat will have considerable difficult in maneuvering.

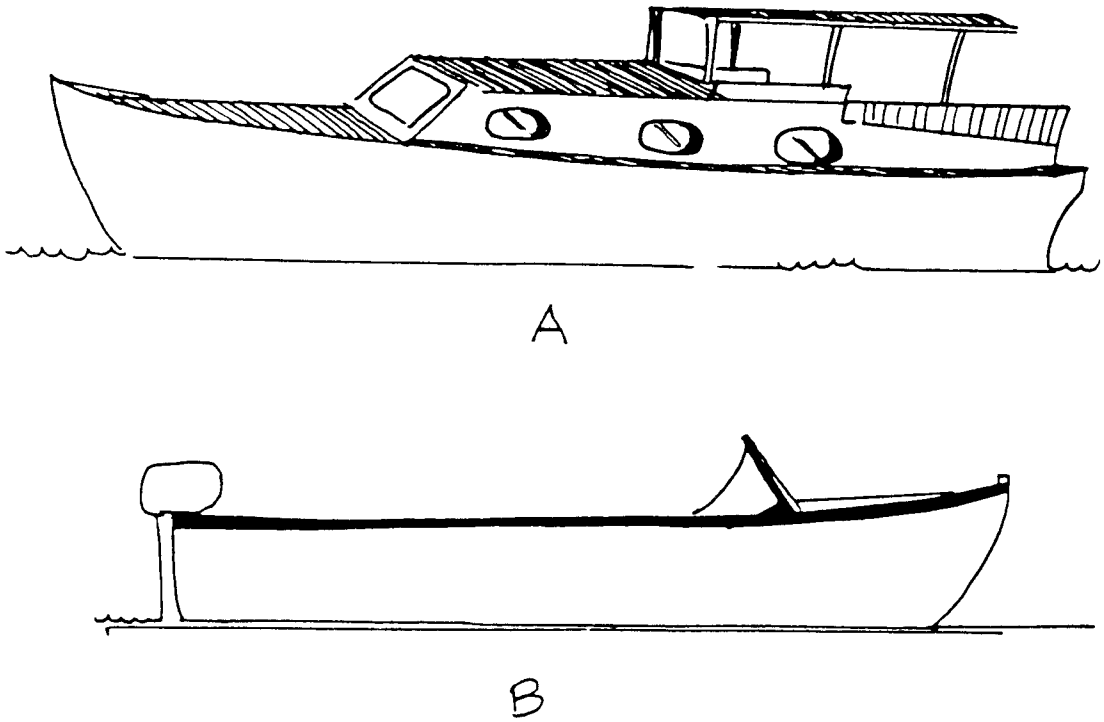

Figure 6-6.—The wind has more surface to act on with Boat A than Boat B. Boat A will be more difficult to handle in windy weather.

Current has the same effect. A current moving broadside to a shallow boat will give that boat less drift than another boat of equal length but a deep draft. It goes without saying that the stronger the wind or current, the greater its effect, regardless of the shape of the boat.

The direction from which the wind or current meets a boat also governs its effect: from dead ahead, the effect is less than from the quarter, which is less than from broadside. The reason? A boat heading into the wind shows less profile than one running at cross angles to the wind. (See figure 6-7.)

It is virtually impossible to look at any boat and determine exactly how much it will be affected by the wind and current. Only by experimenting with your boat in all conditions will you be able to come up with accurate estimates.

The effect of wind and current are related to each other as well. A strong wind acting on a boat from one direction and a strong current acting on a boat from the opposite direction can cancel each other out. A boat with a high superstructure and shallow draft can drift quite a lot in a short period of time if it is confronted with a strong wind and a strong current from the same direction.

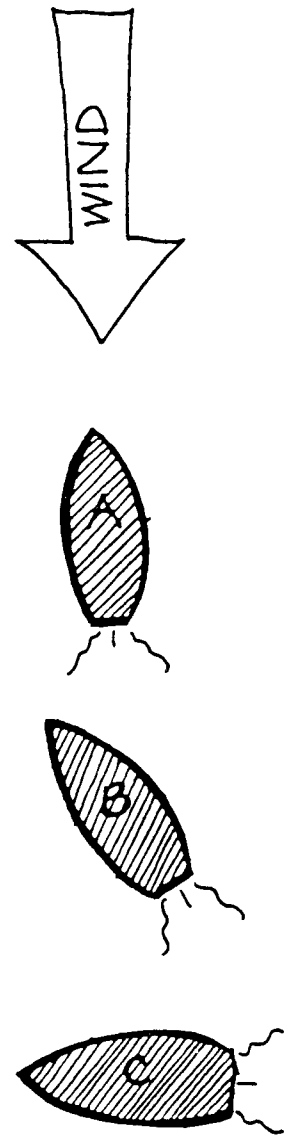

Figure 6-7.—The wind will have most effect on Boat C and least on Boat A because of the amount of surface the boats present to the wind. The assumption is that Boats A, B, and C are equal in hull and superstructure.

From the foregoing, it can be seen that the effect of wind and current on a boat depends upon:

(1) The strength of the wind
(2) The strength of the current
(3) The length of the boat
(4) The superstructure of the boat
(5) The freeboard the boat
(6) The draft of the boat
(7) The direction of the wind in relation to the heading of the boat
(8) The direction of the current in relation to the heading of the boat
(9) The direction and strength of the current in relation to the direction and strength of the wind.

SURF OPERATION. As the surfers have found, all incoming waves are not the same but run in a series called "sets". This means that the big ones have several smaller ones in between. Understanding this, is very useful when trying to operate in the surf and particularly when there is a wave build up to surf conditions in a harbor channel.

Before running into this condition, stand off and count the waves between sets, then time your operation to take place after the big one and before the next big one. This requires experience and a limber neck, or astern lookout, as well as eyes in the back of your head to watch what is coming up astern.

When going down the front of a wave the water at your stern is going towards your bow while the water at your bow is going toward your stern. This makes it very easy to swing sideways to the wave and broach. That is, the boat rolled over on its side. Observation and experience will show what can and what cannot be done with a particular boat and given conditions. Do not trust to luck and better yet stay out of surf - it can be deadly!

HEAVY WEATHER OPERATION. When you are caught out in high wind and/or seas, there are extra dangers you must prepare for. If left to its own devices, a boat will normally fall into a trough. When the winds are strong enough and/or the seas high enough, this action can cause a **BROACH**. As long as you can maneuver, you need to keep the bow pointing into the wind/seas. Instead of running "head-on", try running at an angle, of up to 45 degrees, to the waves.

The danger comes when you can no longer maintain headway. This is when a BROACH becomes possible. To prevent this, you can utilize a Sea Anchor as described below.

Another scenario is when you are running before the sea. As the wind/waves hit your stern, the boat has a tendency to **YAW**. That is, the stern going from side to side. Steering becomes extremely difficult. You find yourself turning the wheel from side-to-side trying to offset the stern's motion. If the yawing is not kept under control, the boat can again broach.

There are several techniques for keeping the yawing under control. All require continual change of throttle setting. When running before the sea, the best position for the boat is on the "back side" of the wave. The speed of the boat should be adjusted to keep the boat in that position on the wave if possible. There are time when you will find your self on the front of the wave. It is like racing down a hill and a broach becomes a distinct possibility. The relative motion of the water past the rudder decreases under these conditions and therefore has less effect. Less rudder effect, the more difficulty in keeping yawing under control. Speeding up the engine, to increase your "down hill run" and increase rudder control, is a possibility. There is also another danger with this action. As you reach the bottom of the wave, if the speed is too great, the bow can dig in and the stern be lifted up and over by the following wave. This end-over-end flip is called **PITCHPOLING**.

To assist you in keeping yawing under control while running before a sea, you can use a DROGUE as described below.

<u>THE SEA ANCHOR (DROGUE)</u>. The sea anchor, or drogue, is used to slow the drift of a boat and to help control the boat in relation to the direction of the waves. Although they are really the same, the term "sea anchor" is used when it is connected to the bow of the boat. When connected to the stern, the term "drogue" is used. In heavy weather, they are useful to sailboats and powerboats alike. Depending upon who you talk to, these devices are highly effective or worth nothing. An entire book could be written about their limitations. But when you are out in the ocean in a terrible storm and all else has failed, you will probably be willing to try one. Regardless of their many detractors, sea anchors and drogues have helped countless sailors over the years. (See figure 6-8).

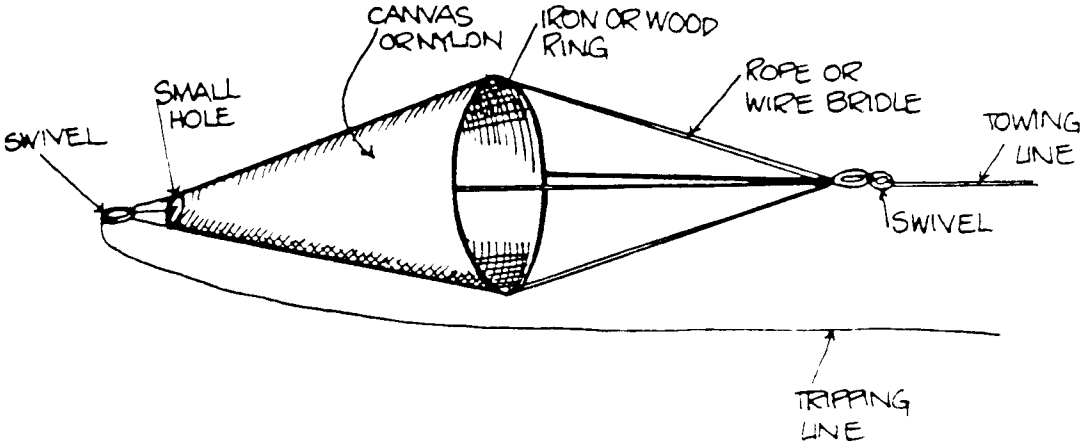

Figure 6-8.—A conic sea anchor (drogue). This is the most commonly seen type.

The classic sea anchor is constructed like a cone. The anchor itself is made of canvas or other cloth shaped like a bucket open at both ends. The ends are held open in circles by hoops. The wide end faces toward the boat and the narrow end faces away from the boat. A cable is attached to the anchor by a bridle to the wide end and a tripping line is attached to the narrow end. The purpose of a sea anchor so constructed is to keep the bow of the boat heading into the seas. This prevents the boat from falling into the trough and possibly broaching. A boat lying to a sea anchor is making leeway, but not as much as she would if she were drifting free.

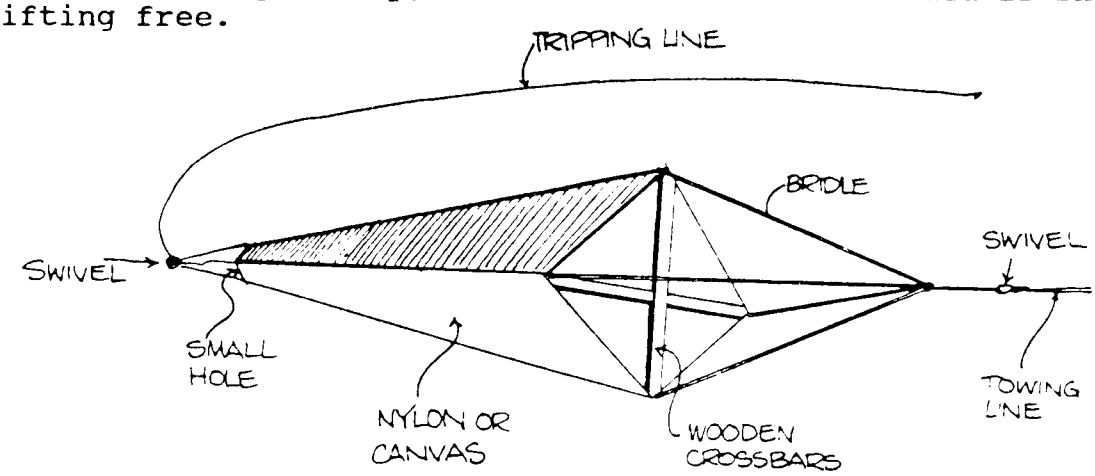

Figure 6-9.—Crossbar-type sea anchor.

As with a regular anchor, a long line should be used with the sea anchor. This will minimize any snapping as the boat surges. When the sea anchor is rigged, it should be invisible but not more than, say, 15 feet below the surface of the sea. Chain or wire rope should never be used for the sea anchor as they would sink the anchor too low to have any effect at all.

The theory of a sea anchor makes it seem very easy to stream and very easy to handle. In practice, however, it is very difficult to handle and is hard to control. As you can see, a tripping line is attached to the narrow end of the cone. The purpose of this line is to enable you to collapse the sea anchor by pulling on it. You should then be able to pull in the entire assembly. The problem is that the tripping line can become tangled with the towing line and eventually collapse the sea anchor all by itself. You could have a mess hanging from your bow that will lose its effectiveness.

Sometimes an oil bag will be attached to the cable just aft of the sea anchor. The effect of the oil seeping from the bag is to create a slick on the waves since oil is lighter than water and will rise to the surface. The oil slick will cut down on the amount of breaking water in front of the boat.

If you do not have a regular sea anchor, you can construct one in an emergency. An old bucket will do in a pinch, as will a large basket, deck chairs, an ice chest, a wooden crate, or even a wide board fastened to a line with a bridle attached to the four corners. Even a swamped dinghy, fastened securely, can be used for a makeshift sea anchor. Just remember the purpose of the sea anchor when you are building it -- that is to create drag which will keep the bow pointed into the seas, cut drift and provide directional stability for your boat.

When running before the seas, this same device is called a DROGUE. Again,its purpose is to provide directional stability, this time to keep the yawing under control. With it streamed from the stern, the possibility of BROACHING or PITCHPOLING is minimized.

An alternative to a drogue when running before a sea is to tow a WARP. A warp is a long length of heavy line with nothing attached to the end. It will act as a brake, will help keep the boat running straight, and will help quiet the sea astern of the boat. It creates friction or drag. The longer the warp, the more drag it will create. Towing more than one warp will also increase the drag. If the line is long enough, you could attach both ends, one to each side of the boat. When you use a warp, experiment with it; let more or less line out until you achieve the results you seek. Be sure to make the warp fast to something strong.

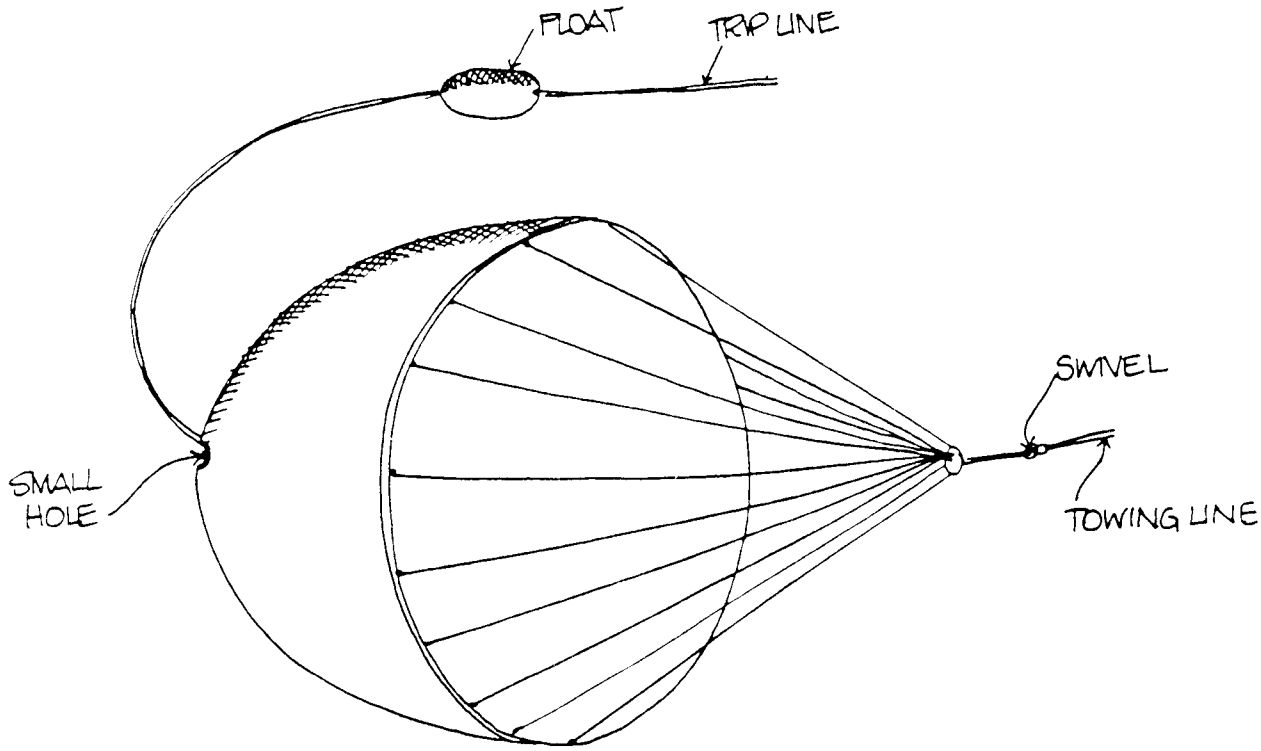

Figure 6-10.—The parachute-type sea anchor.

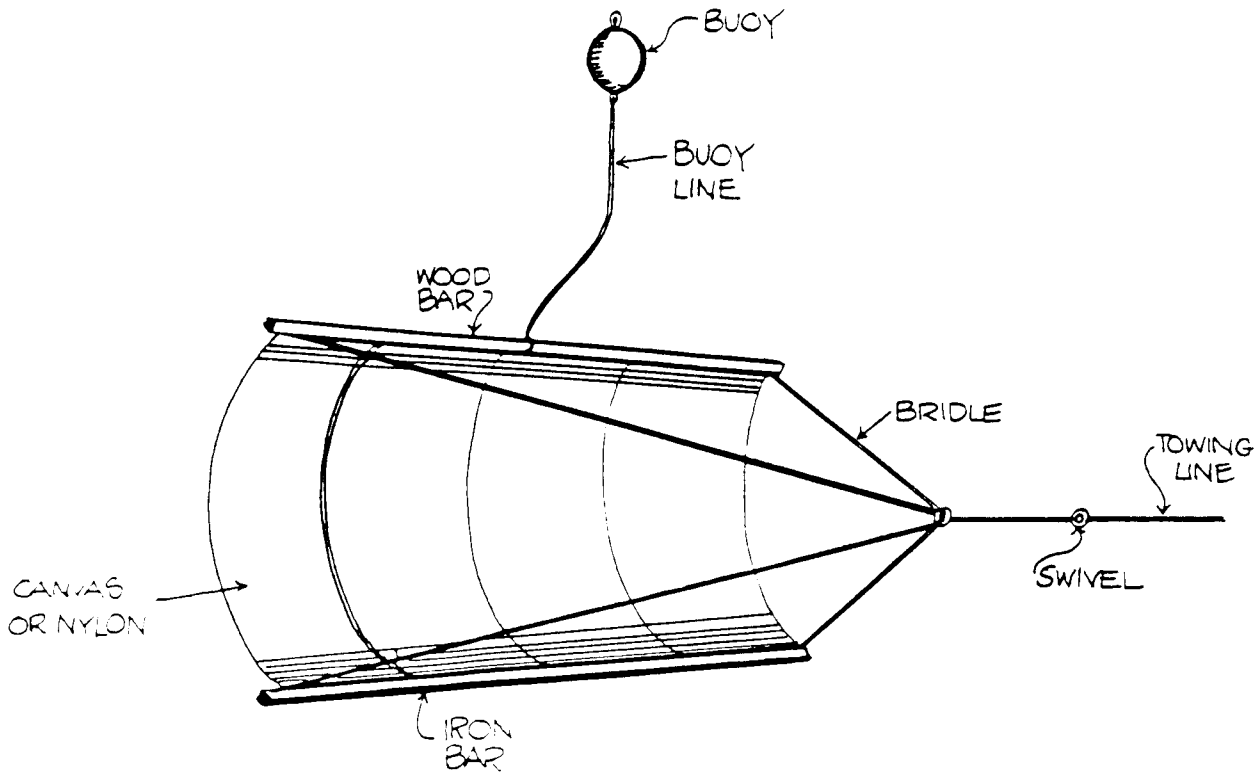

Figure 6-11.—A sail-type sea anchor. This type is hard to trip when you wish to haul it in, hence the buoy rather than a trip line. The buoy also holds the anchor at the desired depth, as the sail-type drogue has a tendency to sink.

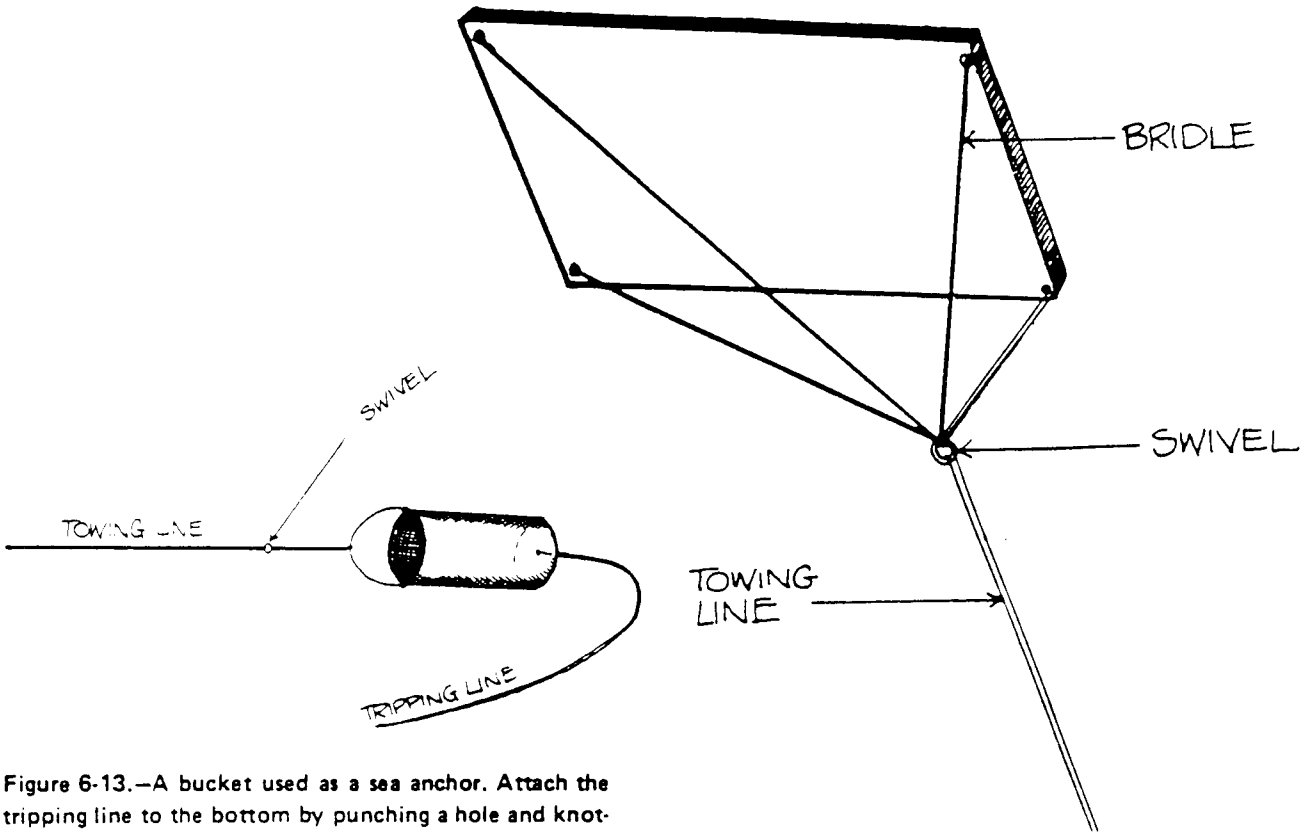

Figure 6-13.—A bucket used as a sea anchor. Attach the tripping line to the bottom by punching a hole and knotting the end of the line on the inside of the bucket.

Figure 6-12.—A board used as a sea anchor.

STUDY QUESTIONS.

1. The height of a wave is the distance measured vertically from the _____ to the _____.

2. The length of a wave is the distance between _____.

3. The time it takes two wave crests to pass the same point is known as the _____.

4. What is fetch?

5. The angular measure from the trough to the crest of a wave is the _____.

6. Name two types of non-wind waves.

7. What is a swell?

8. Waves turn into surf as they _____.

9. The two types of breaking waves and surf are _____ and _____.

10. _____ and _____ are the two types of waves that are caused by the passing of a motorboat. The _____ wave is the most dangerous.

11. List three ways that a dangerous cross sea can develop.

_____

_____

_____

12. A boat with a _____ will be greatly affected by strong winds.

13. A boat with a _____will be greatly affected by a strong current.

14. List some of the elements that the effect of wind and current upon a boat depends.

15. When running before the seas, if possible, the boat should be maintained on the _____ _____ of the wave.

16. What is the purpose of a sea anchor?

17. List the steps to prepare for rough weather.

_____ _____

_____ _____

_____ _____

_____ _____

18. What is the pitfall in using a tripping line with a sea anchor?

19. List some items you can use to make an emergency sea anchor in the absence of a ready-made one.

20. What is the purpose of towing a warp?

21. If conditions get really bad, slow down and hold your bow at an angle of about _____ degrees to the seas.

22. In a head sea, a vessel with too much weight forward will _____ rather than rise.

23. In a head sea, a vessel with too much weight aft will tend to _____ .

24. Thrown broadside to the swells, or "in the trough," can cause the vessel to _____.

25. When a vessel runs down a steep wave, buries her bow, and the next crest throws her stern over, she has_____.

26. What happens to a vessel that is pooped?

27. The primary needs of safety in fog or other conditions of reduced visibility are to see and be seen, and to _____ and be _____.

28. One way to be "seen" in reduced visibility by vessels that have radar sets is to hoist a _____.

CHAPTER 7

ASSISTANCE TO BOATS IN DISTRESS AND DAMAGE CONTROL

INTRODUCTION. The reading material for this lesson can be found in the following pages and in the sections on **Stranding, Assisting and Towing** and, on **Emergency Procedures** in the chapter on **Special Seamanship Techniques** in the earlier editions of ***CHAPMAN Piloting, Seamanship, and Small Boat Handling*** and **Section 3, Chapter 4** of the later editions. Study questions at the end of the lesson are based on these readings.

At some time or another, you will have to render assistance to another vessel, as a member of the Auxiliary or as a private citizen. You may even have to take steps to help yourself. How you handle yourself and your craft is of utmost importance. In an emergency, life and property is at stake. Even the simplest assistance effort -- such as righting a capsized sailboat in a protected cove -- can turn out to be dangerous. The smallest leak far out at sea can equal in importance the largest leak close to shore. This lesson will touch on some of the techniques you should know to help others and yourself in an emergency.

RIGHTING A CAPSIZED SAILBOAT. Before approaching a capsized sailboat in another boat to assist her, there are a few things that must be done first. Get your anchor and anchor line out on deck and make them ready f or use. In a pinch, you might need them later. Collect all your personal flotation devices and ready them for use. Have some ready for the sailboat crew and be sure to don one yourself. Then break out your heaving line and towing line, and coil them for use. Try to keep all of this gear separate and out of your way.

Unless there is something in your way, such as shoal water, you must decide to approach the capsized sailboat either from upwind or downwind. There are two schools of thought on this procedure and each school has equally strong points.

If you approach from upwind, you may blow down on the boat trapping crewman and gear between the two vessels.

If you approach from downwind, you stand a chance of fouling your prop on the sailboat gear-mast, boom, rigging and sails.

You must make your decision based on the conditions on hand. Some factors which may aid you are the drift rate of both vessels (are you drifting downwind faster that the sailboat), the amount of gear that you see in the water, and the ability of the sailboats crew to clear some of this gear away.

After you reach the sailboat, check on the condition of the crew. If they are in poor condition, get right in there and render assistance. Your first responsibility is to save lives; property comes second. If the crew is in good condition, have them stay in the water. They can help you right their boat.

The next step is to have the crew of the sailboat haul in the sails and running rigging. It is generally wasted effort to try to right a sailboat with her sails up. Odds are that she will immediately capsize again from the weight of the water aloft. Now to assist in righting the boat, have the crew stand on the keel or centerboard and hold on to the gunwales. Their weight will help right the boat, perhaps even doing the job without your assistance. If the boat still will not right, maneuver carefully downwind until you can grasp the end of the mast. Carefully lift the mast from the water (sailboats are delicate and cannot stand great amounts of abuse). Your lifting of the masthead, and the weight of the crew on the centerboard or keel, should now right the sailboat.

All you have left to do is get a line aboard the sailboat, help dewater the hull, and tow in the boat, if required. Dewatering and towing are covered later on in this lesson.

REFLOATING A STRANDED VESSEL. In general, Coast Guard policy precludes providing assistance to refloat a grounded vessel. This is considered "Salvage", a task that Coast Guard (and Auxiliary) units are precluded from doing. You may, however, have occasion to provide this help as a private citizen. Helping a stranded vessel get off, or getting yourself off, can be easy or hard, depending on the circumstances. Whatever happens, always keep a clear head and think out each maneuver before you make it. Take your time. Unless the boat is in danger of going further aground without immediate action, you cannot go wrong by being deliberate and careful. Before attempting to refloat a grounded vessel, check for hull damage. If there is severe damage, it may be better to leave it aground until temporary repairs can be made.

One of the obvious things to consider first is the state of the tide. If the boat ran aground at low tide or halfway between high and low tide, with the tide rising, your best action just might be no action. The rising tide will refloat the boat without your lifting a hand. In such a situation, though you must take care. If the tide comes in with a strong current, or the wind is unfavorable and strong, you could easily be driven further aground with the rising tide before you can get underway.

If it is your boat that is aground, rather than a boat you are trying to assist, be careful about throwing the engine immediately into reverse and trying to back off. You might suck sand up from astern and deposit it under your boat, adding more shoal beneath you. In addition, sand and other debris from that bottom could be sucked up into your engine.

As soon as a boat has stranded, get an anchor out to prevent it from going further aground. With luck, you might be able to keep the stern afloat and only the bow aground. Consider the wind and/or the current when setting the anchor. By setting the anchor upwind or up-current, you will prevent the stern from swinging and thus putting your boat broadside to the shoal. You can then use the anchor as a kedge; that is, when you are ready to make your attempt to get off, put the engine in reverse and haul in on the anchor line. If you have a winch to help you haul, so much the better. The thrust of the propeller and pulling on the anchor should pull you free. (See figure 7-1).

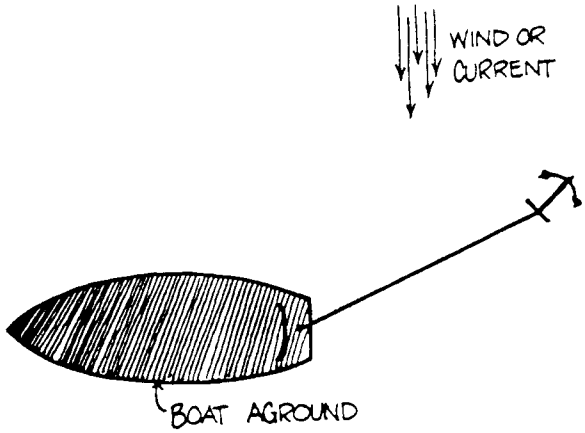

Figure 7-1.—Using a kedge to haul off a grounded boat With the engine in reverse, haul in on the anchor line The location of the anchor here will give the boat minimum swing from the current or wind when it break loose.

If you are going to assist a stranded boat, prepare all the gear you need before you make an approach. Get personal flotation devices on deck and don yours. Make ready a heaving line and towing line. Prepare a float if you will be floating in a line. Make up a bridle (and one for the other boat as well) if required. Get out an anchor and anchor line.

Consideration must also be given to the type of bottom that the distressed vessel has grounded on. If the bottom is rocky, you may do considerably more damage trying to pull her off. If the bottom is sandy or muddy, there is little likelihood of damaging the hull of the distressed vessel; however you may experience difficulty due to bottom suction or sand build-up.

How you make your approach will depend on the wind and current. Be careful of the shoal; you could run aground yourself trying to make an assist. Your judgment on the scene will tell you whether conditions are favorable for going in bow first to get a line aboard the stranded vessel, or whether you should go in stern first. If an approach is impossible, an alternative might be to float in a line, or use a dinghy to haul it in. In the event that one or the other of the latter alternatives is selected, anchor your boat in position before making the attempt. You will have better control over the situation.

Always attach your line to something substantial. Use the trailering stem eye or ski towing transom eyes or other secure fastenings such as sampson posts. Towing puts tremendous strains on both boats, especially when one of the boats is aground. (See figure 7-2.)

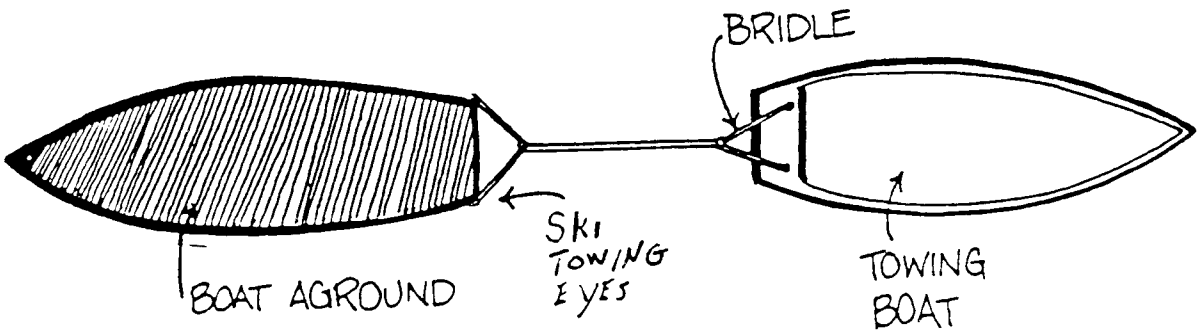

Figure 7-2.—Towing off a grounded boat when wind or current is not a factor. The direct tow, with the strain carried in the direction you want the grounded boat to move, is most effective.

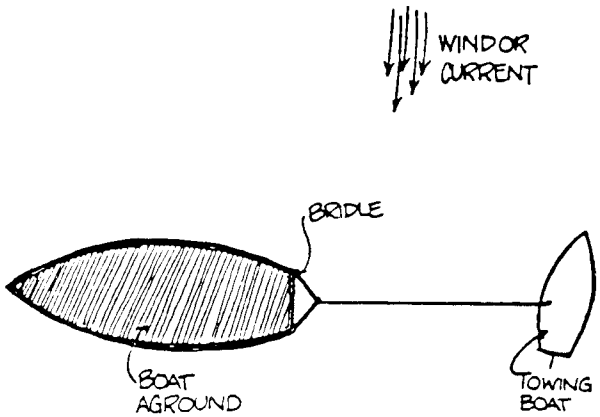

Figure 7-3.—Towing off a grounded boat when wind or current is a factor. The towing boat is not presenting her broadside to the wind or current, so leeway is kept to a minimum.

When you begin towing the stranded boat off, tow in a direction that will compensate for the wind or current, whichever is strongest. If you don't, you might find yourself being swept downwind or down-current, with the ultimate possibility of going aground yourself. Start towing slowly and gradually build up speed as the stranded boat begins to come free. (See fig. 7-3)

If the stranded boat is still stuck fast after all this, she might be stuck in the bottom by suction. Have the crew of the stranded boat move from one side to the other, or from the bow to the stern, thus rocking the boat. This might be enough to break the suction. If the boat is still stuck fast, and you think more power might do the job, have the boat set out an anchor as described previously. With you towing, and the stranded boat going in reverse and hauling in on her anchor line at the same time, odds are she will come free.

CAUTION: Have all crew members of both vessels don PFD's and stand clear of tow line.

APPROACHING A BURNING VESSEL. Approaching a burning vessel to take off the crew can be a tricky and a dangerous operation. Since speed is essential, the chances of your being able to prepare well enough in advance are slim.

As you make your approach, get your gear ready. Break out personal flotation devices, fire extinguishers, buckets, heaving lines, and whatever else you will need. If you have the time, wet down thoroughly the bow or the stern, depending on whether you will be making a bow-to or stern-to approach. This wetting down will help protect your boat from the intense heat of the flames.

Always approach a burning boat from upwind. If you come from downwind, you will have to face the flames and smoke, which will be blowing down on you. You will not be able to see clearly and you will stand the risk of catching fire yourself.

Approach slowly and carefully from upwind, ready to do what you came to do - take off people. The fire, no matter how small, can soon reach an advanced stage, and there is always the danger of it reaching the fuel tanks. Don't try to fight it, take off the crew and depart the scene immediately. Keep curious boaters out of area of danger.

FIRE FIGHTING. Fires are classified into three basic types, according to the nature of the materials fueling the fire and the extinguishing agents used to put them out. The three classes are A, B, and C.

Class A fires are those that take place in ordinary combustibles such as bedding, clothing, wood, canvas, rope, and paper. These fires can be put out with water, though other extinguishing agents will work as well. Class A fires leave ashes and embers that still might be present after the flame is gone, which is why they must be cooled (with water) before they can be considered extinguished.

Class B fires are those that take place in inflammable liquids, such as gasoline, kerosene, oil, grease, paint, and turpentine. Materials in a Class B fire burn at the surface, where vapors are given off. The best way to extinguish them is to smother or blanket the burning liquid with such agents as foam, CO_2, Halon, and dry chemical.

Class C fires take place in electrical equipment. Before these types of fires can be put out, the electrical circuit must be de-energized. A nonconducting extinguishing agent is of the first importance. Carbon dioxide, Halon, and dry chemical are used to put out an electrical fire.

For many years the three sided fire triangle was used to describe the combustion and extinguishing theory. Recently, a new theory has developed. This new theory adds "chemical reaction", as a base to the three sides of fuel, heat, and oxygen. The fire triangle has become a fire tetrahedron which represents a pyramid. Take away one or more of the four sides, and the fire will go out. For instance, by shutting off the oxygen by smothering a fire, it will no longer burn. Cool the fire and there will no longer be any heat for combustion. Take away the fuel, and the flame will be gone. In like manner, for those fires supported by a chemical reaction, stop it and the fire will go out (See figure 7-4)

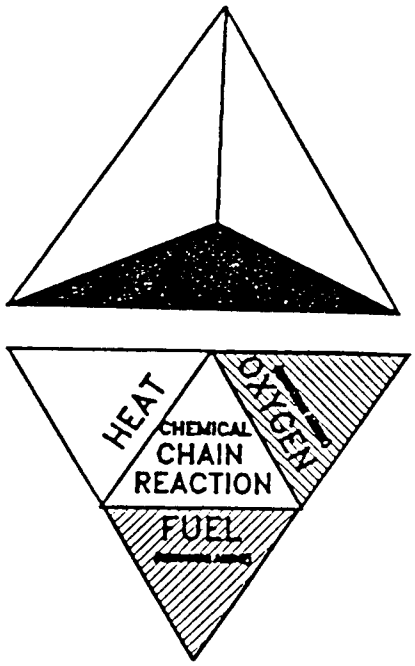

Figure 7-4. The four elements of the fire tetrahedron necessary to support combustion. Take away one of these and the fire will go out.

Fuel	Class	Extinguishing Agent
Wood, clothing, rope, paper	A	Water, CO_2, foam, dry chemical, anything that will smother
Gasoline, oil, grease, paint, turpentine	B	CO_2, dry chemical, foam, anything that will smother
Electrical and electronic equipment	C	CO_2, dry chemical

This table shows the fuels that form three classes of fire, and extinguishing agents that can be used against the various types of fires. HALON is also effective on Class B and C fires, and may be used on small Class A fires.

PLUGGING AND PATCHING. In an emergency situation, there are two ways that you can repair a hole in the hull below the waterline. You can use a patch or a plug. Which one you use, will depend upon the circumstances. It will be governed by the character of the hole and the tools and materials that you have on hand to make the repair.

A plug can be used in situations where the hole is fairly small and has a rounded shape. Such a hole might be caused by an object piercing the hull or it could be caused by a through-hull fitting breaking. If your small, rounded hole is jagged on the edges and you can easily get to it, try to smooth off the edges so that your plug will fill the entire hole. Make your plug out of a piece of soft wood, preferably white pine. Taper it so that you can drive it into the hole and it will fit snugly before you reach the end. (See figure 7-5.)

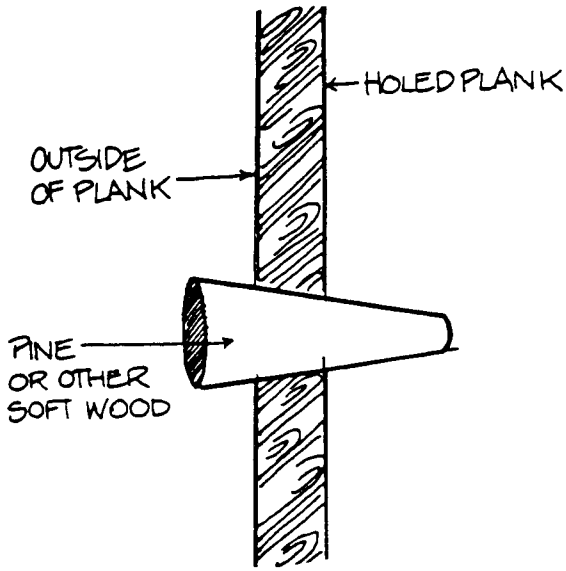

Figure 7-5. A temporary plug for a hole that can be reached from the outside. Before it is driven home, this plug can be wrapped with canvass or cloth which will make an effective gasket.

A plug is most effective when it is driven in from the outside of a hull, rather than from the inside. This is not always possible, of course, since the hole may be well below the waterline and out of reach. In an emergency, you're not going to have time to careen your boat for such a job. But assuming that you can reach the hole from the outside, drive the plug in from that side. The reason why this is done is that the water pressure will help hold the plug in place, whereas if it were driven in from the inside, the water pressure on the outside of the hull could eventually pop the plug through, especially if it is a weak plug to begin with. To be doubly sure that you will get a tight fit, wrap some canvas or other cloth around the plug before you drive it home. Be certain however, not to use glue when setting the plug, if this is to be a temporary repair.

In the event that you can't get to the hole from the outside of the hull, you will have to begin on the inside. Go through the same procedure as in the above repair, but one more step will have to be added. Once you have your plug in place, cut it off flush on the inside of the planking. Then take a piece of wood that will cover the head of the plug and then some, and put it over the plug against the planking. When this is done, nail or screw this wooden patch into place. What you have done is made a brace that will keep the water pressure from pushing the plug back through the planking into your boat. (See figure 7-6)

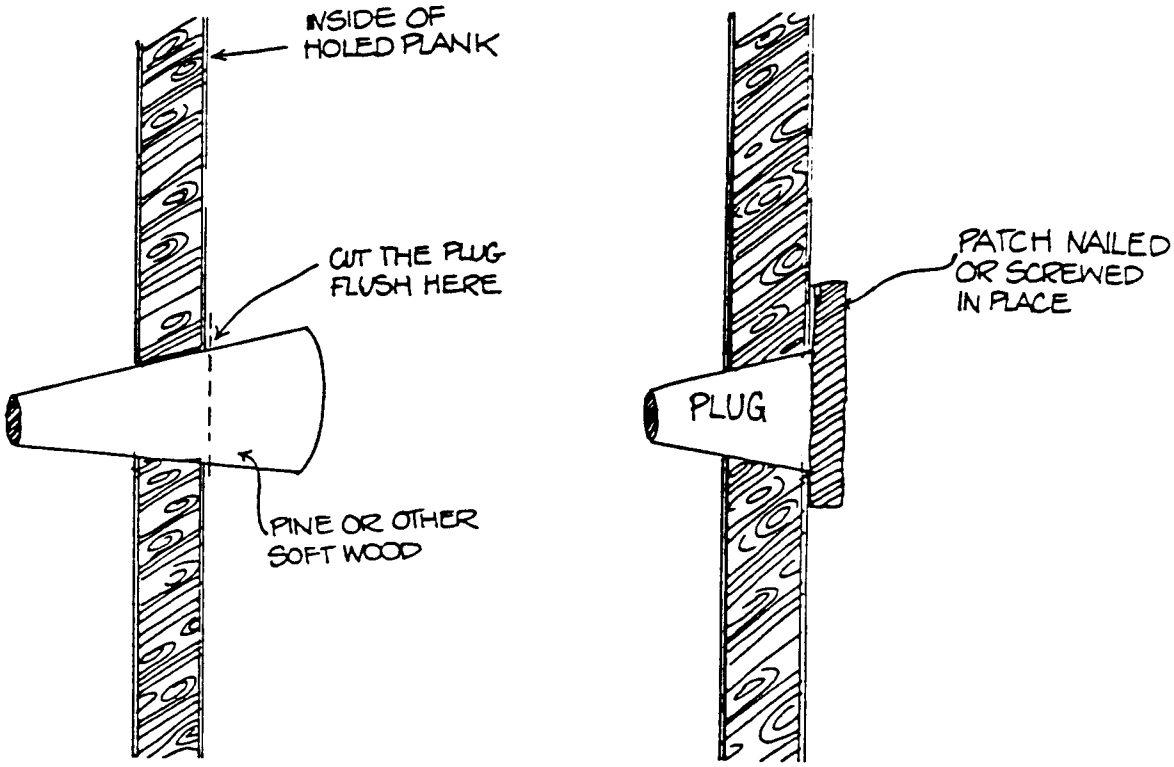

Figure 7-6 - A temporary plug/patch applied from inside the hull. The patch will keep the plug from being forced out of position by water pressure. Cloth can also be used as a gasket.

These procedures described for wooden boats are also effective with boats of other material, such as fiberglass, steel, aluminum, or ferro-cement. However, you should exercise caution in using a plug on fiberglass boats. It may cause more damage by splitting the hull. You will also have to use some other means of securing the patch over the plug on the inside job. What you do will depend on the location of the hole and the materials you have on hand. For instance, if the hole is in the very bottom of the boat, you might try putting something heavy on top of the protruding head of the plug, or have a crew member hold it in place. In a situation like this, improvisation is your only salvation.

Most of the holes that you will have to deal with in an emergency probably will not be effectively repaired with a plug. Unfortunately, the hole you most likely will have to deal with will not be small, perfectly shaped, and easy to get to. The hole probably will be nearly impossible to reach, large with an irregular shape, or a long, open seam. For these a patch is most effective.

A patch can be made out of just about anything that may be handy at the time. As a matter of fact, it will probably take some ingenuity on your part to come up with anything that will meet your needs. Even those who carry around in their boat pieces of wood and cloth and other materials for just such an emergency usually find that what they have, when the time comes, is too small or too large or too thick or too thin, or for some other reason ineffectual. Some of the things that have been used in the past to make a temporary patch have included bundles of rags or clothes, sails, floorboards, pieces of boxes, mattresses, blankets, foul weather gear, PFDs, engine covers, and many other items. The idea is to get something that will fit over the hole and stop the incoming water. (See figure 7-7.)

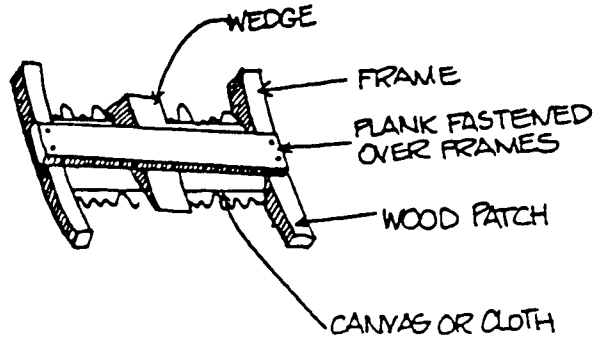

Figure 7-7. A quick and effective temporary patch. The cloth acts as a gasket.

Once again, the most effective way to use a patch, as when using a plug, is to apply it from the outside of the hull. This is especially true when you are talking about repairing a large hole below the waterline. Anything that you cover a hole with from the inside, below the waterline, will more than likely be immediately dislodged by the pressure of the water. If the outside part of the patch is going to be made of wood or some other rigid item, it is better to put between this outer patch and the hull a piece of cloth to act as a gasket. Any patch, whether applied from the inside or the outside, should be considerably larger than the hole that it will cover. Patches applied from the outside can be either nailed, screwed, or lashed in place.

If your patch cannot be applied from the outside, then you will have to work from the inside. Cut a piece of wood or some other material that is rigid, so that it is bigger than the hole and will fit between frames or whatever hull members might be in the way. Put a piece of cloth to act as a gasket between the patch and the plank, and then fasten the patch in place. Here again, you will have to use your ingenuity to come up with the best means of holding it in place. If you are lucky, you might be able to wedge it in place as in the illustration. Or you might nail or screw it into the planking-screws obviously are most effective. If you lack

these options, which will most likely be the case if you are dealing with a boat made of material other than wood, you are going to have to find some other means. Once again, what you do will be determined by what you have. Anything that can be used as shoring might help you out. A deck chair resting on the patch might be wedged in place against something else which is rigid. You might have to develop an entire system of interlocking pieces of shoring to hold that patch in place. (See figure 7-8)

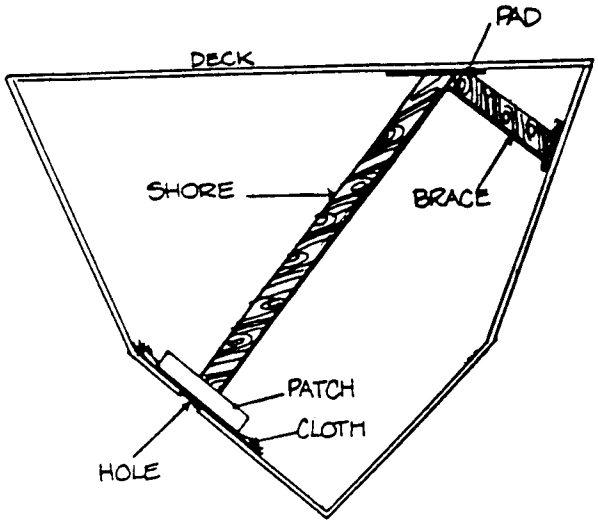

Figure 7-8. One way to hold a patch in place using shoring. The brace helps hold the end of the shore in place.

The leak may be slowed considerably by use of a "collision mat" which can be a tarpaulin or even a heavy sheet of plastic. Tie lines to the four corners and haul it under the boat positioning it over the hole, water pressure will make the mat conform to the hole. Tie off the four corners to hold the mat in position. This will give you time to proceed with the remedies before mentioned on the inside. Remember if you proceed to get underway, it should be at a slow speed so as not to lose the position of the mat.

For years concrete was used as a patching material for those ships far removed from repair facilities and this technique has been followed by the boaters and yachtsmen far from help and on their own. Aided by the epoxies we now have that will set under water it is possible to make a very enduring patch with this material. Once the leak is under control a two part mix of epoxy can be applied to the leak even though a small amount of water is coming in. When mixed, soak a towel or some similar material with the epoxy and apply to the hole, holding it there until it hardens.

<u>DEWATERING</u>. Assuming that considerable water leaked into your boat as a result of the hole or holes you had to patch or plug, you will need to get rid of that water. Pumping is the answer, of course, but it might not be that simple. There are definite procedures you should follow in a methodical fashion if you are going to do the job right.

If your boat is not swamped, that is, the water in the boat has not yet reached the level of the water outside the boat, you will be able to pump or ball. But your pump might not be operable if the water is too high and the pump operates on the engine or electrical power-the power source might be flooded out. If this is the case, you will have to somehow get the water down to a level where you can repair and operate your power. Here, a portable pump, if you have one, or a bailer will come in handy.

Some portable pumps are not necessarily hand operated, but might run on their own internal engines. In most cases, when a Coast Guard cutter or helicopter puts a pump aboard a boat in an emergency, it will be powered by a gasoline engine similar to that on a lawn mower. Be sure to put the pump in a secure place, and keep it out of the water.

Before you start pumping, be sure to clean up as much of the loose debris in the boat that you can find. Anything small, from a package of matches to a sock or undershirt can get caught in the intake of the pump and plug it up. Most portable pumps have a screen around the intake, to catch objects before they can enter. If yours does, be sure to examine the screen periodically when the pump is running to clear away the debris.

If your intake does not have a screen, and there is a lot of debris that you can't get rid of, you had best devise a screen of your own. You might take a bucket, punch it full of small holes all the way around, and punch a large hole in the bottom for the intake hose to fit into. Put the bucket in the water upside-down and insert the hose and you have a screen. Of course, you must be certain that the bucket stays upside down, against the floorboards or the bottom of the boat.

Before you start pumping, be certain that the outlet is projecting over the side and downwind if at all possible. If you are pumping in high winds, and have the discharge facing into the wind, you might find the water being blown right back into the boat.

Before you even start pumping, or bailing, you should try to plug or patch as many holes as possible. This cannot always be done, especially if there is too much water in the boat for you to work. In such a case, you will have to try to get ahead of the water coming in until you can reach the hole to patch or plug it; then you will be able to finish getting rid of all the water.

Once you have pumped or bailed your way down to the floorboards, the going gets a little more difficult. If your boat has frames, as in a wooden boat, unless there are limber holes, you will have to pump or bail the water out from between the frames. This will mean pulling up a lot of floorboards. But if your boat has limber

holes, or no frames (as in most fiberglass boats), the water will collect in the lowest part of the bilge. Find that spot, and insert the intake hose there, once again being sure to screen it well.

If your boat was full of water because of a hole or holes you had to repair temporarily, odds are that your patches or plugs will leak around the edges. This means on your way to shore you will have to pump or bail periodically, or even continuously if the leaks are fast.

Pumping out a boat that is swamped, such as a sailboat that has capsized, is infinitely more difficult than one that only has water below the gunwales. Most boats, when they are swamped, will lie with the gunwales or coamings level with the sea water. If there are any waves at all, more likely than not, new water will be sloshing into the boat as fast as old water is bailed out.

If you will be dewatering a swamped boat without the aid of another boat, your first move should be to get all the passengers out or have them hang onto the gunwales or coaming. This should give the boat more buoyancy. From outside the boat, start bailing. After you get a good quantity of water out of the boat and it starts to rise, one person can get in it to continue bailing, but be careful not to tip the boat while climbing in. Now continue pumping and/or bailing as above.

By towing a swamped boat with another boat, it is possible to drain out quite a bit of the water. You must be very careful, however, because a boat becomes extremely heavy when filled with water. Trying to tow a water-filled boat with a quick burst of power can result in torn out cleats or bitts, or even a broken tow line. Attach the tow line to something that is truly solidly affixed to the boat; a true sampson post, or the trailering stem eye. Have the crew of the swamped boat-sit in the stern to weigh it down, and slowly, slowly start towing. As the towing speed gradually increases, the water in the swamped boat will run out over the lowered stern. You will reach a point, however, when, no matter how fast you tow the boat, no more water will run out. Then is the time to start bailing and pumping.

STUDY QUESTIONS.

1. To assist in righting a sailboat, the crew should _____ _____.

2. In preparing to refloat a stranded vessel, one of the obvious things to consider is the _____.

3. What could happen if you throw the engine immediately into reverse upon going aground?

4. A stranded boat can use an anchor as a _____ to help pull the boat free.

5. How you make an approach to a stranded boat depends on the _____ and _____.

6. When attempting to tow off a stranded boat, use the _____ _____ ____ or _____ _____ _____ _____, or other secure factenings such as _____ _____

7. If a stranded boat is held in place by suction, how can that suction be broken?

8. You should always approach a burning vessel from _____.

9. When assisting a burning vessel, _____ is essential.

10. The four sides of the fire tetrahedron are _____, _____, _____ and _____ _____.

11. A Class A fire consists of _____ and _____ should be used to extinguish it.

12. A Class B fire consists of _____ and _____, _____, _____, or _____ should be used to extinguish it.

13. A Class C fire takes place in _____ and _____, _____, or _____ should be used to extinguish it.

14. What type of hole can be plugged?

15. Plugs and patches are most effective when applied from the _____ of the hull.

16. List some of the materials that can be used for an emergency patch.

17. The anchor that is set out immediately on grounding is called a _____; the act of using it to get the boat free is called _____.

18. When using a portable pump, be certain the outlet is _____ and the discharge is facing _____.

19. If a fire that takes place in an relatively confined space, you should _____ to keep _____ from feeding the flames.

CHAPTER 8

NAVIGATION RULES

INTRODUCTION. The reading material for this lesson may be found in the chapters covering **Navigation Rules** in the earlier editions of ***CHAPMAN Piloting, Seamanship and Small Boat Handling*** *and* ***Section 3, Chapters 6 and 7*** *of the later editions.* The student should read all indicated chapters paying particular attention to the topics and sub-topics in the following study outline.

STUDY OUTLINE

NAVIGATION RULES:
LIGHTS AND DAY SHAPES

The U.S. Inland Rules

Navigation Lights

Light Definitions
- Masthead Light
- Sidelights
- Combination Light--
  Sternlight
- Towing Light
- All-Round Light
- Flashing Light
- Special Flashing Light

Lights for Varying Sizes
of Power-Driven Vessels Underway

- *Masthead Lights*
- Sidelights
- *Sternlights*

Lights for Varying Sizes
of Sailing Vessels Underway
- *Sailboats Under 20 Meters*
- *Rowboats*

Lights for Vessels at Anchor

Lights for Vessels Aground

Lights for Towing
- *Towing Alongside or Pushing Ahead*
  - Exception
- *Towing Astern*
- *Small Boat Towing*

Lights for Special-Purpose Vessels
Fishing Vessels
Pilot Vessels

Vessels With Limited Maneuverability
Vessels Not Under Command
Vessels Restricted in Maneuverability

Day Shapes
Vessels Under Sail and Power
Vessels at Anchor or Aground
(Under 7 meters)
(Under 20 meters)
(Under 12 meters)
Vessels Towing and Being Towed
Vessels Engaged in Fishing
Vessels with Limited Maneuverability

International Rules of the Road

Applicability

Navigation Lights

Definitions
Lights for Power-Driven Vessels Underway
Lights for Vessels Anchored or Aground
Lights for Vessels Towing
Vessels Constrained by Draft

Day Shapes of the International Rules

Navigation Rules:
RIGHT-OF-WAY
AND SOUND SIGNALS

Definition of Terms
Whistle
Short blast
Prolonged blast

"Privileged (stand on)" and "Burdened (give way)" Vessels

The U.S. Inland Rules

Steering and Sailing Rules
Determining Risk of Collision
(All available means)
(Lookout)
(Constant bearing)
Safe Speed
Actions to Avoid Collision

Whistle Signals
- *Danger Signal*
- *Maneuvering Lights*

Rules for Power-Driven Vessels Underway
- *Meeting Situation*
  - Exception
  - Signals
- *Crossing Situation*
  - Exception
  - Signals
- *Overtaking Situation*
  - Signals
- *Use of Radio Communication*
- *Narrow Channels*
  - Exception
- *Don't Impede Other Vessels*
- *Rounding Bends in a Channel*
- *Leaving a Berth*

Rules for Sailing Vessels Underway
  - (Risk of collision)
  - (Each with wind on a different side)
  - (Both with wind on same side)
  - (Vessel with wind on its port side)
  - Signals

- *Encounters Between Sailing and Power Vessels*
  - (Right of way)
  - (Sailing vessel privileged)
  - (Sailing vessel burdened)

Sound Signals in Restricted Visibility
- *Power-Driven Vessels Underway*
  - (Making way)
  - (Underway but stopped and not making way)
  - (Towing or pushing another vessel ahead)
  - (Vessel not under command)
  - (Vessel restricted in its ability to maneuver)
  - (Fishing vessel)
  - (Vessel being towed)
- *Sailing Vessels Underway*
- *Vessels at Anchor*
- *Vessels Aground*
- *Exception for Small Craft*

Basic Responsibilities

- *Rule of Good Seamanship*
  - Lookouts

- *The General Prudential Rule*

INTERNATIONAL NAVIGATION RULES

Steering and Sailing Rules
Whistle Signals

Maneuvering Lights

Rules for Power-Driven Vessels
(Meeting and crossing)
(Sound signal)

Overtaking Vessels
(Sound signals)

Use of Radio Communication
Narrow Channels

Sound Signals in Restricted Visibility

STUDY QUESTIONS

1. The U.S. Inland Navigation Rules are applicable inside the _____ _____ separating the inland and international waters.

2. A Power Driven vessel is _____ vessel propelled by machinery.

3. A sailing vessel using both sail and engine simultaneously is a _____ _____ vessel for the purposes of the Navigation Rules.

4. Underway means "A vessel not _____, made fast to the _____, or _____ _____.

5. Side lights show an unbroken arc of the horizon of_____ degrees, from dead ahead to _____ degrees abaft the beam on each side.

6. A power driven vessel less than 12 meters in length, when underway at night shall exhibit a _____ light and a _____ light plus _____.

7. Small boats propelled by oars may show the lights of a _____ or have handy an _____ _____ or _____ _____ to show to prevent collision.

8. On the Western Rivers and on waters specified by the Coast Guard, _____ lights are not required for a vessel pushing ahead or towing alongside.

9. At night, a vessel "not under command" will show _____ _____ vertically spaced when they can best be seen.

10. Vessels engaged in fishing by day must display a shape consisting of _____.

11. A short blast is a blast of about _____ duration.

12. A prolonged blast is a blast from _____ to _____ seconds duration.

13. The state of visibility, traffic density, your vessel's maneuverability, and the state of wind, sea and current conditions are factors in determining _____ _____.

14. Every vessel must use all available means to determine if a risk of _____ exists.

15. The Navigation Rules recognize three types of encounters between two approaching vessels - _____, _____, and _____.

16. A vessel in doubt must give the danger signal, _____ _____ on her whistle.

17. Under Inland Rules, 2 short blasts mean "I intend to leave you on my _____ side".

18. If the bearing of an approaching vessel _____ _____ _____ appreciably, a risk of collision exists.

19. Under Inland Rules, in a crossing situation, the vessel which has the other on own _____ side is the burdened vessel and must keep out of the way of the other.

20. At night, the overtaking situation exists when the vessel ahead can not see _____ _____ _____ _____ of the vessel ahead.

21. When two sailing vessels are approaching one another so as to involve the risk of collision and bothe have the wind on the same side, the vessel which is to _____ shall keep out of the way of the vessel which is to _____.

22. When in or near an area of restricted visibility, a power driven vessel making way through the water must sound _____ at intervals of not more than _____ minutes.

23. In an area of restricted visibility, a vessel at anchor must, at intervals of not more that _____, ring the bell rapidly for about _____.

24. The continuous sounding of a fog-signaling apparatus would indicate a _____.

CHAPTER 9

ANCHORING

INTRODUCTION. The reading material for this lesson may be found in the chapter covering **Anchoring** in the earlier editions of ***CHAPMAN Piloting, Seamanship, and Small Boat Handling*** *and* ***Section 3, Chapter 12*** *of the later editions.* The student should read the entire chapter paying particular attention to the topics and sub-topics in the following study outline.

STUDY OUTLINE

ANCHORING

Ground Tackle

Types of Anchors in Use
- *Lightweight type*
- *The Plow Anchor*
- *The Bruce Anchor*
- *The Kedge Anchor*
- *Stock and Stockless Types*
- *Other Anchors*

The anchor line
- *Twisted Nylon*
- *Braided Synthetic Line*
- *Manila Line*
- *Chain*
- *Nylon-and-Chain*

Securing the rode
- *Eyesplice, Thimble, and Shackle*
- *Anchor Bends and Bowlines*

How Many-and How Heavy?
- *Size and holding power*

Scope

Anchoring Techniques

How to Anchor
- *Approaching the Anchorage*
- Letting the *Anchor Go*
- *Setting the Anchor*
- *Making Fast*
- *Increasing Holding Power*

When the anchor drags

Getting underway
- *Clearing a Fouled Anchor*

Using two anchors
- To Reduce *Yawing*
- *Guard Against Wind or Current Shifts*
- *Stern Anchors*
- *At Piers and Wharves*

Rafting

Some cautions
- *Chocks, Bitts, Cleats, and Other Fittings*

Permanent Moorings

(Type anchor used)

- *Systems Used by Typical Yacht Clubs*
- *A Multiple-Anchor System*
- *Mooring Buoys*

STUDY QUESTIONS

1. The lightweight type anchor is excellent in _____ and _____ bottoms.

2. All gear, taken collectively, that lies between the boat and its anchor is called the _____.

3. The most widely used material for the anchor line is _____.

4. The three kinds of chains used as anchor rode are:

5. Chain is designated by the _____ of the material in the links.

6. The ideal rode for most average conditions is a combination of _____ and a short length _____.

7. When anchoring under favorable weather and sea conditions, and using nylon line a scope of _____ might be considered a minimum.

8. When anchoring, the anchor _____ be lowered when the boat has any _____.

9. If an anchor drags, the first step in trying to get it to hold is to:

10. When chocks, bitts, cleats, and other fittings are used on deck the must be _____ and reinforced with a _____.

11. The type anchor traditionally used for permanent moorings is the _____.

CHAPTER 10

DUTIES AND MANNERS

INTRODUCTION. The study questions at the end of this lesson are based on the readings in this chapter and not on any outside reading.

DUTIES. Your vessel or the vessel you may be invited to crew on may have very few items to watch and operate, or it might have many responsibilities. The operator is always in charge and will ask you to assume certain duties. If you are not familiar with how to carry them out, ASK; that is the way to learn and will save you and the operator embarrassment, if not big trouble. With a small boat or small crew all below listed duties should be carried out by whatever crew is available. Remember that crew is a team effort and each crew member is dependent on proper coordinated action of all the others.

Deck Hand. The deck hand is responsible for line handling, fender stowing, tow watch, and most anything else that may come up, so be available. The deck hand should know marlinespike seamanship and be well versed on towing and assistance and the use of mooring lines. This knowledge will make your job of deck hand easier.

Radio. As you gain experience you may be asked to stand a radio watch. Take every opportunity to sharpen your skills. Know your radio procedures i.e. how to use the mike, the call up, the prosigns such as over, out, (never use over and out together) roger, wilco, say again, affirmative, negative, phonetic alphabet, Greenwich time and local time. In other words, take the Communications Specialty course.

Navigator. A good navigator is always welcome and provides a real help in conditions of poor visibility and strange waters. The navigator must be able to determine position and maintain a plot of course. The Auxiliary Navigation Specialty Course is excellent way to learn this subject.

Engineer. Larger vessels may have a crewman designated as an engineer to take care of the engines and machinery. Generally on the smaller boats, however, this duty falls on the owner-operator.

Lookout. By law, a lookout is required at all times when underway. This job sounds very simple and most of the time it is, until needed, and then it can become very important. Learn the proper way to scan and report what you see. Scan in about ten degree sectors around the boat or in that sector to which you are assigned lookout.

Report, in a loud voice, the relative bearing of the object and the distance to the object. The relative bearing should be given in degrees around the boat starting at the bow and going around, clockwise, for 360 degrees just like the compass, but using the bow as north. Some use the clock system of reporting using the twelve hour-clock face system of giving the bearing. Be sure the helmsman answers your report so you know it was heard.

As lookout you are responsible for your assigned sector. For surface lookout direct your eyes just below the horizon, start in the part of the boat nearest the bow in your sector and move your eyes about ten degrees every second. Do not sweep with your eyes as you might miss an object. When your sector has been scanned, rest your eyes for a few seconds.

Night lookouts should keep someone advised where they are and wear a life jacket preferably one equipped with a light. Remember to keep one hand for the ship and one for yourself and don't fall overboard. It's lonely out there at night alone in the water. Avoid looking at bright lights, and get your night eyes before going on watch. The technique for night scanning is a little different due to the construction of the cones in the eye. You will use "off center" vision to see objects that you cannot see if you look directly at them. One good way is to scan about 5 to 10 degrees above the horizon and objects on the horizon and below will be seen. You may also look to one side of the target and do the same thing.

Binoculars are useful for identification of an object but not for scanning as you will get skips. A good pair of colored glasses will also be of assistance in reducing glare.

Lookouts in fog should scan slowly and rely to a great extent on their ears. Stay clear of radio and conversation noise as well as engine noise if possible.

General rules for lookouts are to:

1. understand your duties,
2. remain alert,
3. give your full attention to your duties,
4. remain as lookout until relieved,
5. do not become distracted,
6. speak loudly and clearly when making a report,
7. be sure your report is acknowledged, and
8. report everything you see.

<u>Helmsman</u>. In taking over this duty be sure you are fully instructed as to the course, speed, operation of the throttle, gear shift and any special conditions that may exist at the time. Repeat the course and orders to the person you are relieving, also any orders to change course or speed. Let there be no misunderstanding. The lookout is there also as your eyes, listen and acknowledge.

Steering may be directed by the compass or by reference to objects i.e. mountain, point of land, lighthouse etc. The helmsman must understand the compass as well as the characteristics in handling of the boat at various speeds. Know how far to turn the wheel for various degrees of turns and do not steer a zig-zag course. Remember it takes a few moments for a boat to respond to the helm in making a turn. Be prepared for this. Also be prepared to stop the turn, or "meet her", so as not overshoot your new course.

Be alert for any special instructions of course and speed, repeating all commands given by the operator, acknowledging these commands and executing them. Remain at the helm until relieved and instruct your relief all instructions you are following. Every crewmember should learn to be a competent helmsman.

Radar. Radar is another form of lookout and is very good giving you relative bearing and distance to an object. Radar is a great navigational aid in times of darkness or reduced visibility. Use of this device as lookout for traffic as well as a valuable tool for piloting makes for safer boating, but does not replace the lookout. Each crewmember should learn to use the radar and improve skills in identifying land masses, buoys, vessels, jetties and other objects in your operating area.

Towing Watch. At some time you will probably be called upon to render assistance and this may call for towing another boat in. After the tow line is secured it becomes the duty of the towing watch to keep the tow under constant observation and report to the operator any change in how the tow is riding, i.e., is it in step, listing, veering, or yawing. Ensure that chafing gear is protecting the lines and the bridle is performing as it should. Do not stand in line with the towline in case of a towline failure, stand clear in case of "snap-back", the towline breaking. Be ready to cut the tow in case of emergency and watch aft for overtaking vessels, building seas, etc.

MANNERS. Common courtesy on the water as on the highway makes life easier and much safer. The mark of a good seaman is readily apparent by your general deportment with the crew as well as neighboring vessels and environment. You should be considerate and thoughtful and demonstrate safety and good seamanship.

As a boat owner/operator -

Slow down in channels, you are legally responsible for your wake and any damage it may cause and that can become expensive.

If anchoring for the night near other boats, check for clearance so you don't swing into them. Keep the noise down, your neighbor might be trying to escape the hectic life ashore. Don't forget to check the scope of the anchor rode, and see if the anchor is holding.

Inform first time guests what clothing to bring (keep it warm but minimal, with baggage easy to stow) and any other items you feel will add to their comfort, like seasick remedies. Don't forget sunglasses and sun block lotion.

Show your guests the location of the PFD's (life jackets), fire extinguishers and other emergency equipment. Brief guests on safety procedures: propeller dangers, man overboard procedures, one hand for the boat, and fire hazards. Also instruct guests on the use of the head and the operation of any other appropriate gear.

As a guest -

Do not go aboard a boat without first hailing the boat and asking permission, just like knocking on a door ashore.

Do not ask irrelevant questions of the operator when running a tight channel, at night, or in other circumstances that require full attention. Do not stand in a manner that will block the view of the helmsman.

Do not smoke where it will offend others. There is a big outdoors and in this day and age take care not to start a little mutiny.

Do not wear shoes that will mark up the decks you might be asked to scrub the marks off.

When arriving back at the dock ask what you can do to secure the boat, leaving it clean and ready for the next time you might like to be invited. Any operator really appreciates this and it will be another learning experience. A THANK YOU is always proper.

<u>POLLUTION</u>. A mark of good seamanship is the increasing concern for the waters upon which we sail. We need to insure that in the future we are not simply floating around in a cesspool devoid of marine life and covered with unsightly, and smelly garbage. Treat the water the same as your living room.

It is illegal to discharge pollutants into the water. The law is very broad. Included are items such as oil, waste, plastics, and other non-biodegradable material.

Vessels 26 feet and over must have a <u>DISCHARGE OF OIL PROHIBITED</u> placard displayed in the machinery spaces as a reminder not to pump oil or oily waste over the side.

Vessels 26 feet and over, except those on inland lakes and sole state waters, must also display, in a prominent place, a <u>TRASH DISPOSAL</u> placard. This is to remind all those onboard what is not to be dumped over the side.

In addition, vessels 40 feet and over with a galley and berths must post a written trash management plan. The person in charge of the plan is to be named. The plan must state how and where garbage will be collected and disposed.

Be sure to observe all federal and local laws regarding the pumping of holding tanks. Holding tanks are used aboard to hold the effluent from the toilet and any other drainage that may be environmentally harmful. Other methods of treating harmful material have been recommended and legalized from time to time such as electric devices to break down the chlorine ion in the water thereby chlorinating the affluent. Other means such as macerators with chemical pills to be added have also been used. There will be no attempt in this course to set a standard as new methods continue to be legalized and recommended.

COURTESY BOARDING A COAST GUARD VESSEL. When boarding a commissioned U.S. Coast Guard vessel, stop at the top of the gangway, face the quarterdeck (stern), and salute the National Ensign. Then salute the OOD (officer of the deck) and request permission to come aboard. The OOD will grant permission. State your business and proceed. Remain covered (cap on) in areas other than the Wardroom which is the living room and dining room for the ship's officers. Upon leaving the ship, request permission from the OOD, salute the OOD, then salute the quarterdeck and depart.

STUDY QUESTIONS

1. Name two duties of a deck hand.

2. The navigator must be able to _____ and _____.

3. The crewman who takes care of the engines is called the _____.

4. What crew duty is required by law?

5. As a lookout, you are responsible for your _____ _____.

6. How many degrees do you move your eyes each second when scanning?

7. Do you look directly on the horizon for night scanning?

8. Binoculars are used for _____ and not for _____ .

9. You must remain as lookout until _____.

10. Lookouts should remain _____ and give _____ _____ to your duties.

11. Lookouts in fog rely to a great extent on _____.

12. Steering may be by _____ or by reference to_____.

13. The helmsman will _____ all commands.

14. The term "meet her", means?

15. Radar is _____ of lookout.

16. Radar is a great navigational aid in times of _____ and _____.

17. The tow watch must not stand in line with the _____ in case of it _____.

18. You are legally responsible for your _____.

19. When anchoring near other boats check for _____.

20. It is illegal to discharge _____ into the water.

21. What is a holding tank?

22. When boarding a Coast Guard vessel _____ the National Ensign and _____ from the Officer Of the Deck.

23. Remove your cap when in the _____ of a commissioned Coast Guard Vessel.