MARINE RADIO

For PLEASURE CRAFT

HAROLD McKAY

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To Harold McKay

Home is the sailor
Home from the sea
—*Robert Louis Stevenson*

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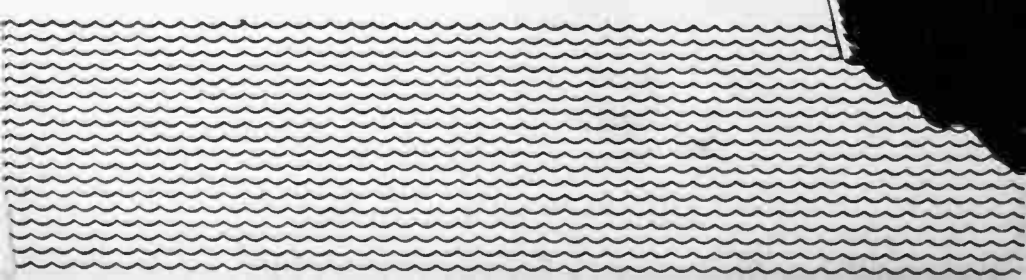

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introduction

THOUSANDS of years ago the Chinese used the magnetic properties of the loadstone to navigate their vessels. They were probably the first people to use an instrument for this purpose which did not depend upon celestial objects which could not always be seen.

A vessel today may have a baffling array of electric or electronic equipment, a far cry from the loadstone and its successor, the magnetic compass. The amount of such equipment is limited only by the ability of the vessel to carry it, and the owner's ability to pay for it. Devices which at one time were used only on ocean liners are being modified, transistorized, miniaturized or otherwise adapted for use on small craft.

The boating enthusiast who knows little about electronics may be perplexed at the number of electronic gadgets he can (or should) buy for his boat. Unless radio is also his hobby, he may have difficulty deciding which things he should get. A simple portable transistor broadcast receiver may guide him to port as readily as a radar outfit big enough to swamp his vessel. Which should he buy?

The purpose of this book is to describe the principal electronic apparatus available to the small-boat owner today, to explain methods of its operation and the proper technique for its use. It is not a technical book; electrical diagrams will be used only where necessary to explain operating principles.

A person who sets out to inquire about marine electronics will find himself in a bewildering whirl of people representing the

Coast Guard, Weather Bureau, Hydrographic Office, Federal Communications Commission, Superintendent of Documents, telephone companies and assorted manufacturers. This book contains appendices which either give the principal information needed by the small-boat owner or tell where it can be obtained. Some of the material included in this book is of primary concern to operators of vessels on the high seas. Other aids to navigation mentioned are mainly for aircraft; these are included because in some cases they may be utilized by the small-boat owner.

How much electronic equipment does the boat owner really need? If he stays within hailing distance of shore, he probably doesn't need any. But man's needs are often based on fancy and desire, rather than necessity, and there are electric accessories which you may "need" even if your craft remains tied to the dock (see Chapter 5).

We are reminded then by Shakespeare to ". . . reason not the need . . . allow not nature more than nature needs, man's life's as cheap as beast's." (King Lear II.iv).

HAROLD McKAY

chapter 1

operation

To use marine radio successfully you need a boat, a radio and a license. But most of all you need good manners. Although a marine radiotelephone may have a handset which looks much like your telephone at home, radio service is definitely not the same thing as land-line telephone service.

First of all, you can have a private telephone at home, if you wish. With radio, however, you will be on a giant "party line" which you must share with the more than 60,000 other boats. Further, radio transmission is not as reliable as the telephone. Atmospheric conditions, static, interference from other stations and other variable factors may render conversation difficult or impossible, at times.

Safety

The primary purpose of marine radio is *safety*. That is, the most important need for a radio transmitter aboard ship, is for the safety of the people aboard.

If a person becomes injured or ill or if for some reason the vessel is in distress, help may be summoned by radio, not only from nearby vessels, but from shore stations as well. Distress messages take priority over all other types of traffic, and operators of radio transmitters are required by law to get off the air if their stations can interfere with distress traffic.

The operator of any radiotelephone equipment must constantly bear in mind the foregoing limitations.

Secondarily, radiotelephone equipment aboard ship may be used for operational purposes (Fig. 101). This means the exchange of information pertaining to navigation, movement and management of the vessel. This would include such transmissions as those to another boat to tell a friend you will meet him at a certain place.

Fig. 101. *The primary purpose of a marine radio is safety, but it can also be used for operational purposes—such as making a date.* (Kaar Engineering Co.)

Marine radio also may serve as a business function. This includes transmission by commercial vessels to communicate with their shore headquarters, to receive new orders, report in, etc., as with tugboats or commercial fishing vessels.

Operating technique

The first thing to learn in using a radiotelephone is the actual operation of the equipment on board. Radio equipment is made by many manufacturers, and brands may differ in appearance. Just how your particular equipment is turned off and on, and changed from one channel to another is something you must know. You will get this information either from the manufacturer of the equipment or from the service technician who installs it.

It is quite important that you know the operation of the equipment so that you can use it without fumbling. It is too late to read the instruction book if the water is up to your knees.

Some radiotelephone equipment may use a microphone for talking and a loudspeaker for listening. Others use handsets similar to those on telephones. Some even have selective calling arrangements which will ring a bell when your boat is called. However, whatever the arrangement, marine radio operates on a "simplex" basis. That is, only one party can talk at a time. When it is your turn to talk, you must push a button on your microphone or handset. This is called push-to-talk operation.

Good manners

Good manners are imperative. When you operate your push-to-talk switch, you turn on your transmitting equipment, but you also shut off your receiver. Bear in mind that while you are listen-

Fig. 102. *You can keep your boat out of the headlines by having the proper equipment aboard and knowing how to use it.*

ing to the other fellow, his receiver is disabled; if you try to butt in, he will not be able to hear you. Thus, while breaking in on the other fellow is easy on a land-line telephone, it is not practical on a radio system.

Another place manners enter the picture is when you are about to place a call. Because there are so many vessels using radio, the channels are busy a good part of the time. Therefore, it is not only good manners, but it is also required by law that you listen on the air first, before you try to make a call. If the channel is busy, you must wait until it is clear. Next, keep your conversation short. The radio is not for holding a gabfest.

Remember someone could drown while you are holding down the radio channel with a pointless conversation. In fact, it has happened. A few years ago, 37 lives were lost as a fishing boat sank. Assistance could not be summoned because a pleasure craft would not get off the air and yield the way to distress traffic. And what were the pleasure boat operators talking about? They were inviting people to a party on board. (See Fig. 102.)

Your craft may be the next to need help. Do your part in helping to keep the radio system from being abused.

Making a call

A call is originated from a radio station in a manner quite different from that used on the telephone. Although systems are available by which outgoing telephone calls can be dialed directly from vehicles to land telephones, little use of this has been made in marine radio. It must be regarded, however, as a development sure to come in the near future.

For the present, calls from boat radios are made by first listening, to see that the air is not in use, then turning on the transmitter. In some units, time must be allowed for the transmitting equipment to get warm. The call is then initiated by speaking the name and call letters of the ship you want to talk to, followed by the name and call letters of your own vessel. Immediately stand by and listen for a reply. If no response is heard, make the call again after a short interval.

Normally, the call would be repeated three times, like this:

"(Station called) This is (call sign and name of your vessel).
"(Station called) This is (call sign and name of your vessel).
"(Station called) This is (call sign and name of your vessel). Over."

The word "over" is to be spoken each time you are ready to stop talking and turn the circuit over to the party you are talking to.

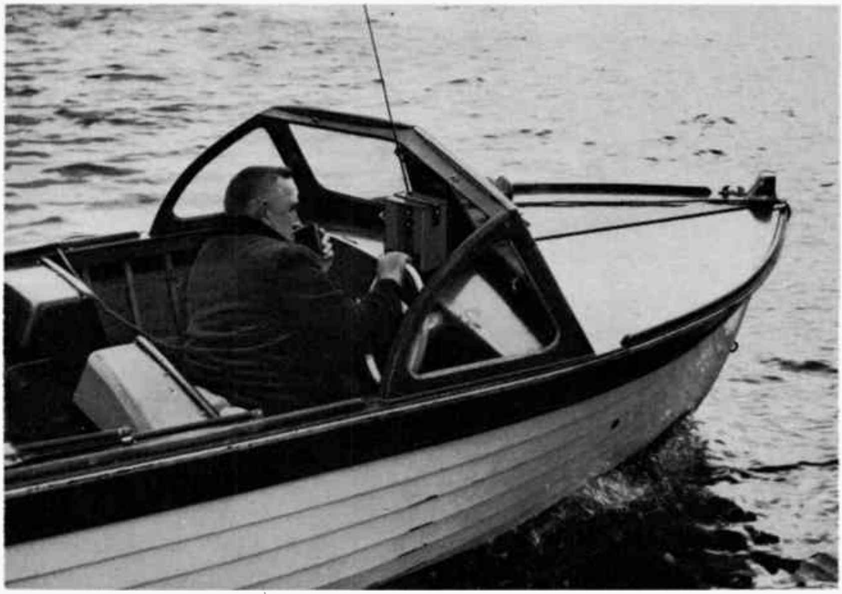


Fig. 103. *Radio channel space is limited. Don't use it to hold a gabfest.*

When a call is completed and you have said your goodbye, say: "This is (call sign and name of your vessel) signing off." (See Fig. 103.)

Ship-to-shore calls

If your radio is equipped to talk to land telephones through a telephone company coastal station, a call is made as follows:

Listen first to make sure the channel is not busy. If it is clear, put your transmitter on the air and say:

"This is (call sign and name of your vessel) calling the (coast station desired) marine operator."

When the marine operator answers say:

"This is (call sign and name of your vessel) calling (telephone number desired)."

Upon completion of the call, sign off as before.

Distress calls

Some of the rules and regulations pertaining to radio operation are fixed by treaty between the United States and other countries. Among these are certain practices relating to distress calls. Ships on the high seas which use telegraph rather than telephone operation transmit the letters "SOS" if they are in danger.

When using radiotelephone, the French expression "m'aider" is spoken over the transmitter. This international distress word means "help me." It sounds like the English word "mayday."

"Pan" is an international word which is used to precede a message of an urgent nature concerning safety of a mobile station or someone on board.

The word "security" is used preceding a message concerning the safety of navigation or weather warnings.

In making a distress call, be sure to state your boat's name, where you are, what is wrong and what help you need. A distress message might sound like this example:

> "Mayday, mayday, mayday, this is WZ-6789, the yacht Blue Duck. "Mayday, mayday, mayday, this is WZ-6789, the yacht Blue Duck. "Mayday, mayday, mayday, this is WZ-6789, the yacht Blue Duck. 133° true 12.miles off Montauk Point struck submerged object. Taking water fast, engine disabled, estimate cannot stay afloat more than 1 hour."

In acknowledging a distress call, be sure to state your boat's name, where you are and estimated time of arrival together with your course and speed to the scene.

An example of the acknowledgement of a distress message might sound like this:

> "The Blue Duck, the Blue Duck, the Blue Duck, this is WX-9876, the White Whale, WX-9876, the White Whale; your mayday and distress message received. We are 8 miles from Montauk Point on a bearing 82° true from Montauk Light, 10 miles from your position on a course to you of 175°. Our speed is 12 knots. Will reach you in 50 minutes. Over."

FCC requirements

Every radio transmitter must be licensed by the Federal Communications Commission, and, in addition, persons who operate these transmitters in the marine service must hold permits issued by the commission. Operation of the transmitter and the conduct of persons using the transmitter are governed not only by commission rules but by international treaties which our Government has signed and which we, as citizens, are expected to obey.

Every ship station is required to have on board a copy of Part 8 of the Rules and Regulations of the Federal Communications Commission. Any person who plans to operate a marine radio should also read Part 13, which explains the requirements for the operator. Infractions of FCC rules are subject to a maximum of 2 years' imprisonment and a $10,000 fine.

Because of the rapid growth of radio in the small-boat field, policing of this service has become difficult, and in some cases the service has become virtually useless because of improper operation. This has resulted in a ship telephony eduational program, sponsored by a group called the Radio Technical Commission for Marine Services. It has published a book, "Marine Radio Telephony," which contains valuable information on ship radiotelephone operation.

The foregoing examples of placing radio calls were taken from this book. It also contains a digest of the Ship Radio Telephone Rules. This amounts to a rewrite of the important portions of Part 8 of the FCC rules in language which is less legal-sounding than the original.

The person who operates a shipboard radio transmitter of the type used by small boats must have a permit issued by the Federal Communications Commission. Apply for one of these permits by filling out a form that certifies that you have studied the rules and regulations applicable. Application can be made by mail to any office of the FCC.

A list of books which you may find useful is given in the appendices.

Frequencies

Every radio station operates on a certain frequency. By this is meant the frequency of the alternating current (ac) radiated by the transmitting antenna. A receiver, to pick up a certain station, must be electrically "tuned" to its frequency. The frequency number means the number of complete alternations in a second. Thus, radio broadcast stations operate at a frequency in the range of from 550,000 to 1,600,000 times (or cycles) per second.

Instead of using these large numbers, it is customary to use the prefix "kilo-" for thousand, and "mega-" for million. Thus, 550,000 cycles is usually called 550 kilocycles (550 kc) and 1,600,000 cycles is called 1600 kilocycles (1600 kc). It is these numbers, 550 and 1600, which are marked on the dials of ordinary broadcast radio receivers. However, as frequencies get up into millions, either prefix may be used. Thus 1600 kilocycles (1600 kc) is the same thing as 1.6 megacycles (1.6 mc).

Many of the frequencies used for marine radio lie between 2,000,000 and 3,000,000 cycles per second. This may be referred to as 2000 and 3000 kilocycles or 2 and 3 megacycles.

Any one frequency used by a radio transmitter is usually called a channel, just as it is on television. This does not mean that the transmitter uses only that one frequency. Actually this is a center frequency. A broadcast station, while sending music, for instance, may send out a frequency which varies as much as 5,000 cycles above and below its center frequency. The center frequency, which is sent out as such when no sound is being transmitted, is called the carrier, because the message is superimposed or carried on it. The frequencies, above and below, caused by the transmitted message are called sidebands. If improper operation causes these sidebands to become too large, cross-talk to adjacent stations will occur.

A group of frequencies, considered together, is often called a "band." For instance, the group 550 to 1600 kc is called the broadcast band. The marine stations which operate in the region between 2 and 3 mc are said to be in the 2- to 3-megacycle band.

This does not mean that the entire region from 2 to 3 megacycles is reserved for marine use. Actually only a few frequencies are available for boats; police, government and others are also in this band.

The marine frequencies in the 2-3-megacycle band are:

2003 kc	For ship-to-ship communications on the Great Lakes only
2182 kc	For calling and distress
2638 kc	For ship-to-ship communications in all areas
2738 kc	For ship-to-ship communications in all areas except the Great Lakes and the Gulf of Mexico
2830 kc	For ship-to-ship communications in the Gulf of Mexico

For communication between ships and shore, a number of frequencies have been allotted which vary with the location. They are given in detail in Part 8.354 of the FCC Rules and Regulations. However, the frequencies for any given area can be obtained upon inquiry to the nearest FCC field office. These frequencies include those used by the telephone companies to provide telephone service to coastal vessels.

The calling-and-distress and ship-to-ship or "working" frequencies are part of a definite system which calls for a technique of operation which marine operators must know.

Normally, every shipboard station, when not actually using some other frequency, should be listening on 2182 kc, the calling and distress frequency. All shore stations should also monitor this frequency. When a call is to be made, the vessel calling should make his call as described previously with his transmitter on the 2182 kc frequency. When he has established contact, both boats should switch at once to one of the "working" frequencies given above.

Initial contact should not be made on the working frequency unless it is done by specific arrangement beforehand between the two vessels as to time and date.

If a distress call is necessary, it should be placed on the 2182 kc frequency. Others who may be using the frequency at the time for calling purposes must yield the air to the distress traffic.

Thus the 2182-kc calling–working system has a beautiful simplicity about it. All vessels constantly monitor the 2182-kc frequency, and are alert for any distress message that may be received. At the same time, the individual boat will not miss any of its own calls from another ship, because it too will call on this same frequency.

FCC rules require that a watch be maintained on 2182 kc by ship and shore stations all the time that the receiving apparatus is turned on. This may mean that ship stations which are to be called by shore stations on other frequencies may require two receivers, one tuned to 2182 kc and another to the frequency of the shore station.

Coast Guard frequencies

The Coast Guard maintains a number of coastal radio stations near the various harbors in the United States. They operate on different frequencies in different areas. Like other shore stations, the Coast Guard also monitors the 2182-kc channel in addition to its own frequency. Private vessels may communicate with the Coast Guard if necessary.

The Coast Guard radio station normally makes regularly scheduled broadcasts at definite times. These broadcasts may include important notices to mariners, hydrographic information, storm warnings and other urgent marine information. A list of the Coast

Guard radio stations, their call letters and frequencies and times of scheduled broadcasts appears in Appendix I.

Telephone company radio

Coastal harbor stations are maintained by the telephone companies. These, like the Coast Guard stations, operate on various frequencies in the 2–3-mc band. These stations also provide weather information at regularly scheduled times. In addition, they provide connection to land-line telephones. Normally, if you have a marine radio transmitter capable of transmitting on the telephone-company frequency, it is only necessary to register your boat in the telephone records to be able to make calls. Cost is on a per-call basis. That is, you pay the telephone company only for the calls you make through their coastal stations. Rates start at about a dollar for calls to nearby points.

Telephone-company radio service uses two frequencies for each channel. That is, the shore station transmits on one frequency, the boat on another. For instance, station WEH at Wilmington, Del., sends on a frequency of 2558 kc, but the ship must use 2166 kc. In making a call, a ship station would naturally listen on the shore-station frequency. If the operator were waiting completion of a call, and no one were speaking, the channel would appear to be idle. To warn prospective users that the channel is in use, the telephone coastal station sends out a busy signal sound while the circuit is being held.

Vhf channels

In addition to the maritime frequencies in the 2–3-mc band, another group of channels has been provided between 152 and 162 mc. The 2–3-mc band is regarded as medium frequency, the 152–162-mc band as very high frequency and is called the vhf band. Other services such as taxicab and other mobile radio as well as television stations are assigned vhf bands. The marine frequencies in the vhf region are:

156.8 mc—calling and safety frequency
156.3 mc—ship-to-ship working frequency

Additional frequencies are assigned to specific shore stations working in an area.

Operation of the radio is the same as in the 2–3-mc band. Calls are initiated on the calling frequency, and then switched to the working frequency. The 156.8-mc frequency, however, is regarded as a safety rather than a distress channel as such. It is expected that boat operators using vhf equipment will monitor this band as they would the 2182-kc band.

Any radio transmitter which is to operate in this band must be equipped to send on 156.8 mc, 156.3 mc and at least one ship-to-shore working frequency.

Inland waters

The boat owner in a coastal harbor area has a good choice of radio stations with which to communicate—the Coast Guard, tele-

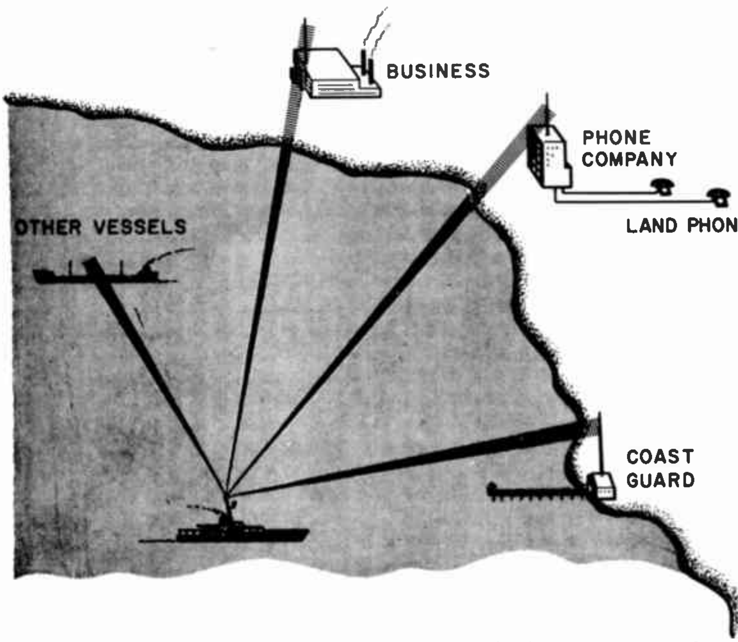


Fig. 104. *Marine radio can be used to enable the boat owner to talk to other vessels, a business establishment, the telephone company and to land phones, or to the nearest Coast Guard station.*

phone company and a number of other vessels (Fig. 104). The vessel on inland waters—lakes (except the Great Lakes) and rivers —may not be so fortunate.

As boating becomes more popular, vessels on inland waters may be equipped with radio for mutual protection. Boat owners may get radios so that they may call each other in times of need, even though no shore station exists. In some places, shore stations may exist, but may not be available for public service. For instance, the Coast Guard has a station at Lake Tahoe, Calif., but the radio is in use only when the Coast Guard's boat is out on the lake.

Vessels operating on such lakes and rivers are eligible for radio licenses, and may obtain them.

In addition to the radios which boat owners may acquire for mutual assistance, shore stations may be operated by boat liveries or service companies.

Another service sometimes found available for inland waters is that of the "miscellaneous common carrier." This is a class of radio operated by companies which provide mobile service to trucks, buses, autos or other vehicles. These stations operate in the 152–162-mc band, but not on the marine frequencies. However, they may furnish radio service to vessels on inland waters, if they are within communication range of the vessels.

Such a service operates on Lake Shasta, Calif. The main station for this radio is controlled from Redding, Calif., although the transmitter is located on a nearby mountain peak. It provides communication with the lake quite easily. The operator of this service can send or receive messages to or from boat operators and in addition, by means of an interconnection, permit the boat operator to talk on the land telephone lines.

Operators of equipment in this service also often lease radio units as well. Thus the boat owner does not have to buy an expensive transmitter and receiver. He can rent it from the operator of the common-carrier radio station. Rates for such rental and usage, at this writing, run from $25 to $40 per month or more, depending on the number of channels the set will handle and how many calls are made.

Another service available to the boat owner out of reach of coastal radio stations is the mobile service furnished by telephone companies. This is similar to the miscellaneous common-carrier service, except that it is performed by a telephone company instead of a private operator. Note that this is different from telephone company marine service. Basically a land mobile service designed primarily for communication with automotive vehicles, it can be extended to include water-borne craft, by modification of its license with the FCC. However, it is expected that if vhf marine radio is ultimately installed in the area, boat owners would switch their frequencies from the land to the marine radio channels.

An example of the use of telephone-company mobile radio is seen in Henderson, Nev. The telephone company has a mobile radio service for connection with automobiles and trucks, and several boat owners on Lake Mead, behind Hoover Dam, have equipped their vessels with radios in this service.

Still another type of radio available to boats is the business and industrial service operated by private companies for their own purposes. The business service can be set up by virtually any type of business enterprise. The office of a trucking company might use it to talk to its own trucks. A warehouse office might use it to talk to the fork-lift operators. Where a business qualifies

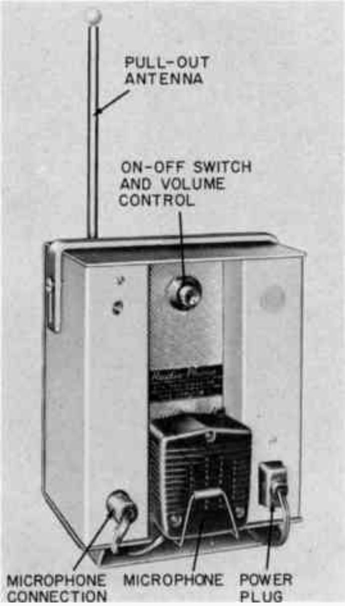


Fig. 105. *A Citizens' radio for use in the 27-mc band. It can be used in marine or land service.* (RCA)

for such radio service, and also has water-borne vessels, radios in this service can be placed on the vessels. For example, a company with dockside operations might have both trucks and towboats with which communication is necessary. The boat could use the business frequency rather than the marine frequency.

If no other service is available for a boat owner, he always can have recourse to the Citizens' radio band. The FCC rules allot a frequency in the 465-mc region, which can be licensed to any citizen who wants to operate a radio transmitter. It is not necessary to be in business or industry, or to own a boat, or even to have a license. You can buy a Citizens' radio outfit, send in a simple registration form to the FCC, and be ready to operate.

The equipment available for this service is in the same class as that used by business radio, police radio and taxicabs. In fact, it can be adjusted to operate in any of these services.

Smaller, less expensive units of low power can also be obtained for use aboard small boats—or anywhere else for that matter. Citizens' radio, because of the high frequencies used, is sometimes erratic in operation when very low power is used. Transmission may be prevented by the presence of hills, trees or buildings between the transmitter and receiver.

Commercial enterprises which use frequencies near this band overcome this by placing the main radio station on a hilltop or roof, and using wires to connect the radio voice circuits to a more suitable location. The boat owner who decides to use the Citizens' radio band must provide for two stations, one for his boat and one for whoever is going to listen for him to call.

In practice, this may mean one station in your car, cabin or other shore location, where members of your party may remain while you are out boating.

A modification in FCC rules has allotted a band of frequencies in the 27-mc region to Citizens' radio. This frequency has better propagation characteristics than the 465-mc band and probably will prove to be popular with boat operators. A typical unit for use on this band is shown in Fig. 105. However, because any citizen, boat owner or not, can operate a radio in the Citizens' band, these channels are likely to be very crowded and may not be the safest means of communication in an emergency.

The effectiveness of Citizens' radio in a given area should be checked by asking others or by actual trial before investing in radio equipment. It may turn out that one band is better than the other in certain places.

chapter 2

receivers

ANY vessel equipped with a radiotelephone transmitter will, of course, also have a receiver so that a two-way conversation can be held. However, while it is not likely that a small-boat owner would buy a transmitter only for his vessel, he may find lots of use for a receiver in his craft.

Although he cannot call for help on a receiver, he may obtain valuable information which can keep him out of trouble. Probably the first choice of many small-boat owners is a broadcast receiver and perhaps the principal use to which it will be put is entertainment. If you use your boat for fishing, sunbathing, entertaining others or just plain loafing, you may like to hear a little music at the same time.

However, in addition to its entertainment value, a broadcast receiver can be a real safety aid. Perhaps the most obvious function of the set would be to receive weather broadcasts. Most radio stations make either special storm-warning broadcasts or include weather information as part of their regular news broadcasts.

If you live in a coastal area, you can obtain Coastal Warning Facilities charts (Fig. 201) which show the various warning facilities in your part of the coast. These include the locations where storm-warning signals are displayed (flags by day, lights at night). They also have a list of all the broadcast stations in the area which include weather broadcasts in their news schedules, and also those which broadcast special marine weather forecasts. A list of these charts is given in Appendix VI.

The operator of a small craft who plans to use a broadcast receiver to obtain weather information should find out in advance just when each station gives weather information. This information should be kept with the radio set.

Another possible use of a broadcast receiver is receiving time signals, especially if there is a station in your area which gives

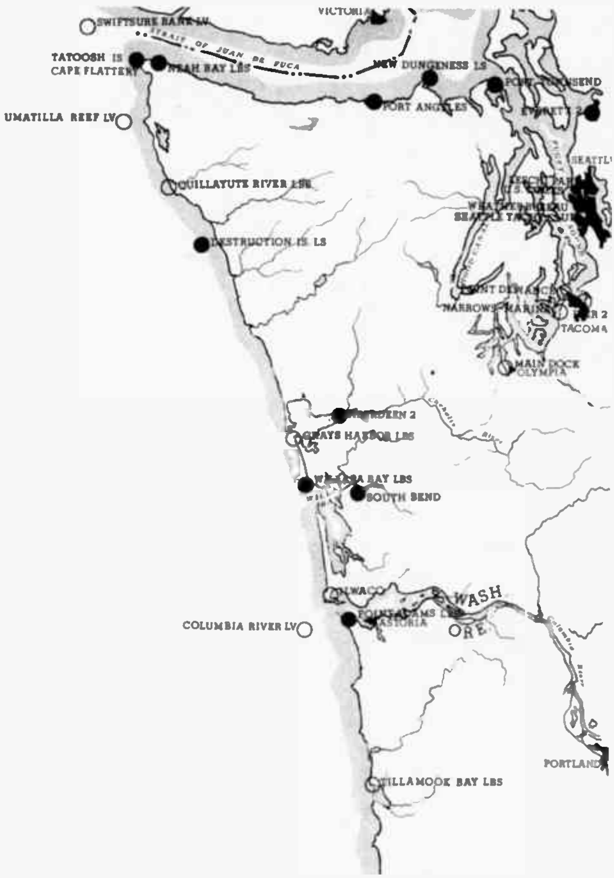


Fig. 201. *Section of a Coastal Warning Facilities chart.*

precise time. Accurate time is essential to navigation, particularly on the high seas, where the vessel's position is determined by "shooting the sun"; that is, measuring the sun's position with a sextant.

A portable broadcast receiver, equipped with a loop antenna either inside or outside of the case, can also be used as a direction finder. That is, it is possible to determine the direction of a broadcast station from your vessel. By making two or more direction locations on broadcast stations, you can find out where you are located, even in the densest fog. This method is explained at greater length in another chapter.

Inland waters

If the vessel is to be operated in inland waters, where Coast Guard or other maritime radio facilities are not available, the broadcast receiver may be the only useful kind of radio. Therefore, because of its importance to the safety of the craft, it should be selected carefully.

One of the first considerations is the power requirement. A decision must be made as to whether the radio is to operate from the boat's battery or from self-contained dry batteries. Many small boats are equipped with a 12-volt battery system, and 12-volt automobile radios will operate on such a system. In addition, as will be described later, certain marine radios will work on this voltage.

However, the boat radio, like its counterpart in the automobile, may be the means of inadvertently running down the battery. The battery may or may not be essential to the boat's operation. Some vessels may require the battery for starting the engine, as well as for the operation of auxiliary devices, running lights, etc., just as on an automobile.

Vessels which use an electric starter usually have some other means of cranking the engine if the battery goes dead, but be sure you know all of the consequences before using a radio which can run the boat battery down. Some vessels, such as sailboats, which have an auxiliary engine, use a battery charged from a generator on the engine. However, a sailing vessel may use the engine so seldom that the battery may not be fully charged.

Small craft propelled by outboard engines may or may not have charging equipment. Large outboard motors are now used to propel vessels of a size which formerly would have called for inboard engines. These vessels often have many electrical accessories, and the motors are equipped with generators for recharging the batteries.

Some boat owners carry an extra storage battery for their accessory needs. That is, the regular battery is used to start the engine; the spare is used for the radio or other devices.

Many boats, particularly small outboards, do not carry any battery. The engine is hand-started, and the running lights operate from small dry batteries. Some of the running-light equipment may use self-contained batteries. Actually the lights are equivalent to a special kind of flashlight. The boat operator, then, who wants a broadcast receiver in his vessel, must give consideration to all of these aspects.

Portable radios

One answer, of course, is the self-contained battery portable radio. This can be the kind that uses tubes, or one of the newer transistor models. While the type may make little difference in a radio that is to be used on land, additional considerations crop up in marine use. One important factor is how much power the set will deliver through the loudspeaker.

A low-volume receiver might be just the thing for a quiet picnic in the woods, but totally inadequate in the presence of a strong, noisy wind, or the roar of a marine engine. In a closed room, sound is easily heard, because it is reinforced by echoes from the walls. Out of doors, this reinforcement is not present. Perhaps you have noticed that you must speak louder when talking to a person in an open location, such as on the beach.

In addition, when the wind is blowing around your ears, it is difficult to hear. Small boats which have no cabin or covered portion—the vessels most likely to have dry-battery receivers—are subject to all of these drawbacks.

The portable receiver, then, may prove inadequate because, while it will still be good for entertainment while anchored, it may not be loud enough to let you hear a storm warning while you are under way. The transistor portable (although it would seem to be a natural choice from a standpoint of low battery drain and portability) may be the worst from a power standpoint. Most transistor broadcast radios have very little output power and cannot be heard very far from the speaker.

At least one attempt has been made to compensate for some of the shortcomings of the transistor receiver. Designed for use in boats, the receiver (shown in Fig. 202) is equipped with a special mounting arrangement so that it may be placed on the dashboard, or some other point close to the helmsman's ear. It can also be removed for use ashore. This set is equipped to operate either from its own inside battery, or from a 12-volt boat battery. It can be switched from one to the other as desired. Although its output, like that of other transistor receivers, is only about 1/3 watt, a plug-in arrangement permits the use of an additional speaker which may be placed where there is a better chance of it being

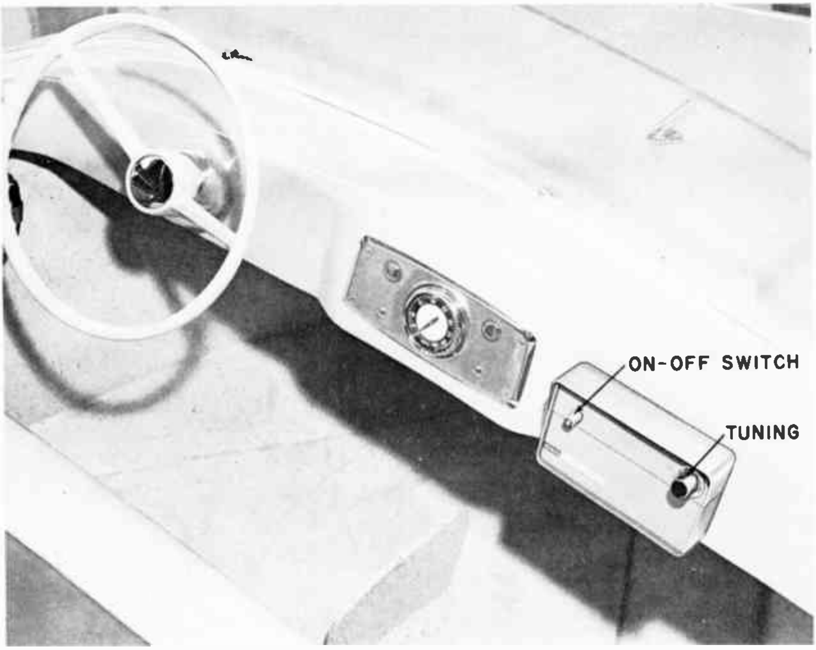


Fig. 202. *This is a portable radio receiver which can be fastened in a boat or removed for use on shore.*

heard. This radio also can be used with a whip antenna on the boat for greater sensitivity.

The matter of sensitivity is also of more concern to the boat man than it is to the landlubber. Sensitivity might be described as the ability to "pull in" stations. A set with poor sensitivity will receive only strong nearby stations; one with good sensitivity will get distant stations. However, it is more than this. It is probable that the boat owner will not be interested in getting long-distance reception when he is out on the water, but he is concerned with getting local stations all of the time. A set with good sensitivity will get the local stations with less possibility of fading or "dead spots."

Sensitivity is a quality that is built into a radio. The use of a longer antenna will often improve reception, provided the set is arranged to have an outside antenna connected to it.

When you select a broadcast receiver for your boat, consider the purposes for which you intend to use it. Make sure it will receive the stations you want to receive, in the locations where you plan to take your boat. If possible, try the radio before you buy it.

Moistureproofing

Anything which is used around the water is likely to become damp. Regular marine radio equipment is made to be moisture-resistant. The degree to which this is done varies widely. One company makes a life-boat transmitter which can even be tossed overboard. It will float around and can be retrieved and still put to use.

However, most marine radio gear is not protected as well as this. Generally, corrosion-resistant metal is used in the case and chassis, and a moistureproof lacquer of some sort on the internal wiring. This does not make the set waterproof. Unlike the lifeboat transmitter, you can't throw it overboard and still expect it to work. But these sets will stand up well in marine use, and will not corrode or become shorted under ordinary operating conditions.

A regular broadcast receiver will not usually have moisture-proof features. However, the exercise of good sense will avoid troubles when using one in your boat.

First of all, the fact that a boat travels on the water doesn't mean that everything in it must get wet. In fact, the interior of the boat, and its various furnishings and fittings should be kept dry. Metallic objects will corrode and nonmetallic ones mildew and rot if they are allowed to remain wet. Your radio equipment should be kept in the driest part of your boat.

Most corrosive water vapors come from spray. Thus, metallic objects such as fence railings along an ocean beach may corrode faster than metals on a vessel because the breakers on the beach cause a spray of salt water to saturate the air. It is this air-borne water and salt that causes the corrosion.

A vessel in quiet water is not subject to such a spray, and is therefore not likely to suffer as much damage. Under way, the vessel necessarily raises a certain amount of spray of its own, and it is this that you must protect against. Radio equipment must be placed in a location where splashes and spray cannot reach it.

The ordinary dampness in the air will not hurt a broadcast receiver while it is operating. The tubes generate a certain amount of heat which tends to keep the inside of the set dry.

When the vessel is moored and unattended, the radio equipment may be removed and stored at home, not only to prevent water damage, but to avoid theft. However, this is no substitute for keeping the inside of the boat covered and dry. This should always be done to protect the vessel itself and its contents.

If you own a small craft which is open to the elements, build a waterproof box or container of some sort in which to place your radio receiver while it is in the boat. A small transistor receiver might be protected by keeping it in a transparent waterproof plastic bag while it is aboard the boat. The sound can be heard through the bag, and the set can be tuned, but water can't get in.

One important word of advice! If your radio should get wet—turn it off at once. Disconnect it completely from the boat's battery system. If it is a portable which has batteries inside, take them out. Drain the water and ventilate the chassis by leaving the battery compartment door open. Dry it out as quickly as possible, but don't put it in the oven. A hair dryer or fan is best for drying out electrical equipment.

If you follow these directions the set may play again when it has completely dried, and no repairs may be necessary. If salt water got into the set, it may need servicing. Normally, water does not harm most electrical apparatus. Trouble occurs only when the electricity and the water are there together. All corrosion, on any metal, needs both electrical and chemical action, but chemicals alone will generate some electricity by themselves. That is why salt water may cause corrosion even if the electricity is shut off.

The quicker you dry a piece of wet electrical equipment, the better chance there is of saving it. But always completely disconnect the power *at once.*

Long wave sets

In addition to the medium frequencies (2 to 3 mc) which are used for marine service (Chapter 1), a number of marine "beacon stations" operate on the "long" waves; frequencies from 200 to 400 kc. In addition, 500 kc is the international distress frequency for the high seas.

Regular marine radio equipment is arranged to receive these frequencies. However, the increased popularity of small boats has resulted in the appearance of special long-wave radio equipment for use in such craft.

The "beacons" which operate on these long wavelengths are radio stations usually associated with lighthouses. These stations broadcast coded signals which identify their location, making it possible to determine the location of the vessel by direction-finding techniques which will be explained in another chapter. One advantage of tuning in a beacon is that it can be immediately identified; you might have to wait a half-hour to hear the call letters of a broadcast station.

A number of air navigation stations also use these long wavelengths, which is of interest to boat owners in inland waters who may not be able to receive coastal stations. These aeronautical stations also broadcast weather information at regularly scheduled intervals and are listed in the Coastal Warning Facilities Charts (Appendix VI).

Aeronautical charts for any part of the country can be obtained from the US Coast and Geodetic Survey (see Appendix VI). They show the radio ranges and stations which cover the airways of the country. The charts may be of advantage to the inland-water boatman who is equipped with a long-wave radio and who is in a territory which lies on an airway route.

Of particular interest to small-boat operators is a direction-finder unit available in kit form. A kit contains all the parts and wiring to make a radio set, but the purchaser must put it together himself. Step-by-step instructions are included, and no previous knowledge of radio is required to assemble it. The work can be done in a few hours' spare time.

Short wave sets

The 2–3-mc marine frequencies can be received on a number of sets equipped for short wave operation. These communications receivers are used at land stations and require 110 volts ac for their operation. They can be used aboard a vessel if a power converter is added to change the boat's battery voltage to the required 110 volts ac. This is usually an uneconomical method of operation, because the efficiency of such power converters is low. A great deal of battery power is necessary to operate a radio set under these conditions.

Of course, a regular marine transmitter usually comes equipped with a companion receiver which will pick up the frequencies in the 2-to-3-mc range. These are regular marine receivers, and are designed to use a minimum of power. This type of set will be discussed at greater length in the next chapter, along with the transmitters.

To receive the medium frequencies on a boat without special marine equipment or with a land type receiver requires the use of a frequency converter. This is a separate tuning dial with which you can tune in a maritime station, but make the sound come out of your regular radio. These frequency converters were originally designed to work with regular broadcast automobile radios. Where the broadcast receiver covers the frequencies of from perhaps 550 to 1600 kc, the frequency converter extends this from 1600 to 3000.

These outfits will receive certain police calls and amateur stations as well as ship-to-ship and ship-to-shore stations and can be attached to an auto or boat radio. They do not interfere with the regular operation of the set, and the radio can be switched back to broadcast reception readily.

Time signals

Any set equipped to receive the 2–3-mc band can be tuned into WWV, the station of the National Bureau of Standards in Washington, D.C. This station gives time signals and frequency standards. It broadcasts on a number of frequencies, including 2.5 mc. A schedule of its operation is given in Appendix XI.

Precise time signals are given only at certain times of day in Morse code on the long-wave stations, but the WWV signals are emitted continuously. The long-wave stations and their time broadcast schedules are contained in a book called *Hydrographic Office Publication No. 205,* published by the Navy. This book also contains information on other radio aids to navigation. (See Appendix VI).

Repairs

Unless you are a service technician by profession or hobby, or have built your radio from a kit, you are probably not in a position to fix it if it fails to work. If your radio goes dead while you are out of touch with the shore, you may be in a dangerous position. Therefore, it will be well if you learn a few simple things about getting a radio working again.

In battery-operated equipment of any type, the first thing to suspect is the battery. If the battery is dead, the appartus won't work, of course, but in some radio equipment even a lowering of the battery voltage will cause the set to fail. Therefore, when the radio quits, first find out if the battery is ok. If the set uses its own battery, put a new one in for trial. (Always have a spare battery on board.)

If the set runs from the boat's battery, check its voltage. If the boat does not have a voltmeter or battery condition indicator, try turning on the lights and then operating the starter. If the lights go dim, a run-down battery is indicated.

After checking the battery, check all wiring leading to the set. Check the wires from the battery to the set, from the antenna to the set, and also the wiring to any remote tuning dial or extra speaker. The wiring should be wiggled slightly wherever it fastens to the apparatus or a binding post. Make sure it is not loose or broken. Check the wire as it runs along the vessel. Make sure it is not submerged in water. Check that it is not warm or steaming anywhere. Check that the bare copper is not showing through. Check fuses.

Loose or broken wires must be tightened or replaced immediately. Bare wires should be taped, separately from one another. Submerged wires should be dried, either by pumping out water, or raising the wires above it. Warm or smoking wires should be disconnected from the battery until the short is found.

Probably most interior radio troubles are caused by failure of a tube. For that reason, you should know how to change tubes in your set. Have your radio service technician show you how to open the set properly so that you will not damage it by prying off the wrong thing. Carry a spare set of tubes on the vessel. Remember, you won't have a tube tester with you so you may have to change all the tubes to find the one that is bad.

A tube that is burned out will not get warm, and you can tell this by sight or touch. However, many tubes fail to work, even though they still light up. Note that modern radio tubes light up very dimly and their glow cannot always be seen in bright surroundings.

The boat owner without electrical training can safely do little more than try the ideas mentioned here. However, a number of electrical boat accessories are now being made available in kit form. The man who buys these kits and puts together his own electrical appartus will soon find himself qualified to make the necessary repairs when something fails.

Home receivers

Almost anyone who has a job which involves the use of radio soon acquires radio as a hobby also. In spite of the fact that ship-to-ship radio is supposed to be for business purposes, you can frequently hear fishermen discussing nothing but each other's radio reception and trying for long-distance records across the water. These people should probably get amateur licenses instead of using the ship frequencies, but the fact remains that the radio hobby is contagious, and quite easy to acquire.

Another factor is that most hobbyists like to have their hobbies near them. If boating is the hobby, it can be indulged in only while on the water. You may have a trailer with which to bring your boat home, but you can't sail it in the bath tub. Many boat owners find another way of bringing this hobby home with them. They get short wave radios.

Once you have had a radiotelephone in your boat, you will have learned the call letters and names of boats of new-found friends. Hearing the voices of people you know over the radio brings a sense of closeness. Many boat owners stay at home and listen to ship radios when they can't take their boats out for one reason or another.

These short wave listeners may keep tuned to the calling frequency, 2182 kilocycles, waiting for a call from somebody they might recognize. Others want to hear the marine weather reports at home before taking a boat out on the water. Others listen to the Coast Guard frequency, just like some landlubbers listen to police calls.

Therefore, it is quite possible that you will want a radio at home which will receive the ship frequencies. The problem is simple at home. You don't have to worry about speaker volume, sensitivity or battery power. You can get a set as big or small as you like, one that will get everything on the air from the local disc jockey to Radio Moscow. Nearly every type of short wave set has a band that will receive the marine frequencies.

You can buy whatever your fancy or purse dictates, but there are a few considerations worth keeping in mind. As in buying anything, the purchaser should first decide the extent to which he wishes to go. If you are not interested in broadcasts in a foreign language, there is no point in buying a radio that will get calls from the opposite side of the earth.

If you are going to stick with marine reception, the next thing to decide is the importance of the information to you. If your communications receiver is to be used at home, simply as a hobby and because you're fed up with television, a low priced outfit is best for you. If you are operating a coastal station which must listen for distress calls, then you would want the best.

Typical of the receivers for home use are sets which can pick up all the short wave bands, ship, police and international broadcast as well as domestic broadcast. These are true communications receivers—the kind the radio amateurs and professionals use.

Sets of this kind are often owned by the families of fishermen or other seafarers. This being an electronic age, waiting wives no longer have to stand on the beach and peer at the horizon. They listen to a communications receiver instead. They listen for the weather, and the ship-to-ship chatter, hoping to intercept a chance call from papa's boat.

A more expensive type of communications receiver, has all of these features, but is designed for use on ship board as well as on land. It will run on batteries as well as house current. In addition, it will receive the long wave beacons and aeronautical broadcasts and a direction finder is available for use as an accessory. The person who wants a radio on his boat and also at home might want to consider a set which can be used in both places.

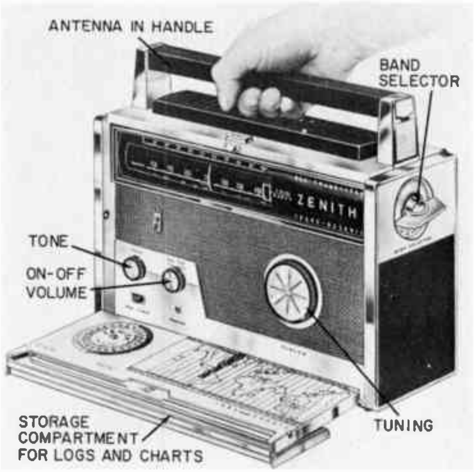


Fig. 203. *An all-purpose radio receiver. This set receives broadcast, long wave and short wave, and can be used at home or on board your vessel.* (Zenith Radio Corp.)

Very-high-frequency equipment

An increasing number of marine radio stations are being assigned in the vhf (152–162 mc) band. This band is still comparatively new to the marine radio business, and there is not as wide a choice of equipment as in the medium-frequency range.

Sets in this frequency range usually operate by frequency modulation (FM), like the FM broadcast stations. To receive FM stations properly requires a set with a few more parts than those required by AM receivers. Because of the higher frequencies used, tuning must be much more precise and stable. For these reasons, an FM set usually costs more than an AM receiver.

The vhf range is used by police, taxicabs, railroads and others besides boat operators, and a few receivers have been built for monitoring these services. They may be continuously tunable, or they may have fixed crystal tuning. That is, they may have a dial which permits you to tune to any station using vhf, and may in addition have a means of keeping the set tuned steadily on one frequency, such as the vhf safety frequency of 156.8 mc.

A receiver suitable for mobile service at these frequencies operates from a 12-volt storage battery. It would contain about

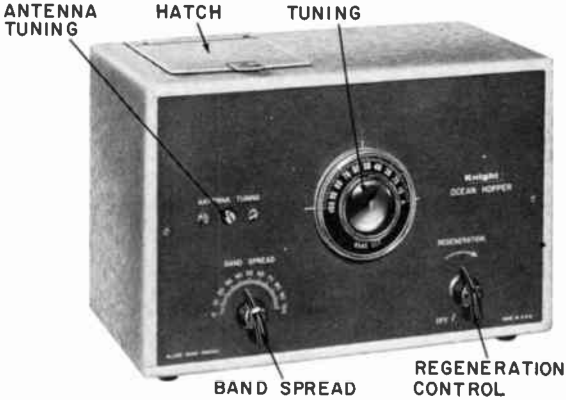


Fig. 204. *This is a "build-it-yourself" three-tube radio, available in kit form. It will receive marine frequencies.* (Allied Radio Corp.)

10 tubes and, like most mobile receivers, have a "squelch" circuit which shuts off the speaker between calls to avoid noise.

For armchair listening at these frequencies somewhat lower priced sets which operate from house current instead of batteries are suitable. They also are equipped with squelch circuits for quietness between calls. They will receive any calls in the vhf range—ships, police and telephone common-carrier services.

Some higher-priced models can be equipped with a crystal to keep the set tuned sharply to one particular station. This feature is of advantage if you desire to listen to one service only on a single frequency. The crystal provides precise tuning. Your set stays right on the station and will not drift, nor can you accidentally lose the station by turning the dial.

This type of set, while designed for land use, might also be used aboard a vessel if a power converter or other means of supplying 110 volts ac is available.

As in the medium frequencies, radio transmitting equipment in the vhf region usually comes equipped with built-in receivers. These will be considered in the next chapter along with the transmitters.

A set that literally "has everything" that a boat owner could desire is shown in Fig. 203. Known as the Transoceanic, this re-receiver is powered from self-contained batteries, and uses transistors. It will receive standard broadcast, short waves and the low-frequency air and marine navigation bands. It also receives international short wave channels. The set is treated for operation in conditions of high humidity.

The boat owner who wants to learn electronics can do well to consider a "build-it-yourself" set for his armchair radio. While at present there are no plain radio sets for marine use available in kit form, some available instruments adapt themselves readily to marine purposes. For instance, the Ocean Hopper (Fig. 204) is a kit for a three-tube radio that anyone can build. It will receive broadcast, long wave beacons and four short wave bands. The different bands are tuned in by means of "plug-in" coils which are put in place in the same manner as a tube is plugged in its socket. If the set is to be used only for marine beacons, only the beacon coil needs to be put in place. The set operates on 110 volts ac and is probably the lowest priced short wave set for use on marine frequencies. It is a good kit for learning the technique of wiring and fixing a radio set.

chapter 3

transmitters

A STORY from the early days of steamboats relates that a man put a large whistle on his vessel, to be sure that it could be heard on shore. Unfortunately, the whistle was so large it used all the steam in the boiler every time it was blown, and the boat would stop.

The operator of a modern vessel has somewhat the same problem with his radio transmitter. He must have a set strong enough to send messages to the point where he wants them to be heard, but not at the expense of killing the battery in his boat. Actually, the radio transmitter and the power supply for the boat must be considered together, even though they appear as separate chapters in this book.

Certain items about boat radio equipment are of prime importance. These include the power of the set, and the channels or frequencies it is to cover. Other items are secondary, such as remote controls and extension speakers.

The power or size of the transmitter needed is dependent principally on one thing—how far you expect to talk with it. For a small vessel which is going to stay in harbors and close-in coastal waters, low power is adequate. Indeed, low power is desirable. First of all, the cost of radio equipment goes up with its power. In the second place, the use of high power over short distances can prove quite annoying to others who must monitor their receivers and listen to you blast off.

Yet there is no economy in an under-powered radio transmitter. Your life and the lives of others on board may depend upon the radio. A radio with insufficient power to summon aid is worse than no radio at all. In selecting a radio, then, you must first make a decision as to where you intend to operate your boat, and how far you are going to be from stations you may have to call.

Wattage rating

The power of a radio transmitter is rated in watts, just like an electric light bulb. However, this does not mean the number of watts the set uses from the ship's power supply. A radio transmitter contains a number of tubes. Each tube and its associated wiring is called a stage. The transmitter must do two things: It must generate an alternating electrical current of the frequency to be used (such as 2182 kilocycles). It also must amplify your voice and mix it with the above frequency.

To generate the frequency to be broadcast, a quartz crystal is used to start with. This is a thin piece of quartz which has been polished and ground, in jeweler's fashion, until it has a certain precise size. In actual dimensions, it may be a tiny wafer, smaller than a postage stamp.

If you take an ordinary fork and shock it by striking it against the table, the tines will vibrate and you can hear the sound, or vibration, which comes from them. Almost any other solid thing will give off vibrations if struck or shocked.

Quartz crystals, when shocked electrically, will give off vibrations of thousands of cycles per second. By grinding them to precise dimensions, vibrations at high (radio) frequencies can be produced. A quartz crystal, then, can be the starting point for producing the required frequency in a radio transmitter. The crystal has the advantage that, within a normal temperature range, it will always vibrate at the same frequency, and thus keep the radio exactly right without the use of tuning knobs.

These crystals can be used in both transmitters and receivers to keep the set tuned exactly to the frequency you want. In the transmitter, the crystal does not produce enough power to send out a message, so its vibrations are amplified by vacuum tubes. The vibrations from the crystal (in the form of a voltage) are thus stepped up (or amplified) until an alternating current of sufficient power can be delivered to the antenna.

Several "stages" of vacuum-tube amplifiers may be used in the set to get up enough power. However, all of the power developed in a set does not always reach the antenna. This can be because of losses in the tubes and other circuit components, or inefficient coupling from one part of the circuit to another.

The power of a transmitter is usually rated by the amount of power put in by the power supply into the last (or final) amplification stage in the transmitter. This is an amount which can be measured easily by a technician using voltmeters and ammeters. The amount of this power which actually gets out from the antenna may be considerably less. Further, it is difficult to measure accurately.

A typical marine radio installation (Fig. 301) rated at 16 watts

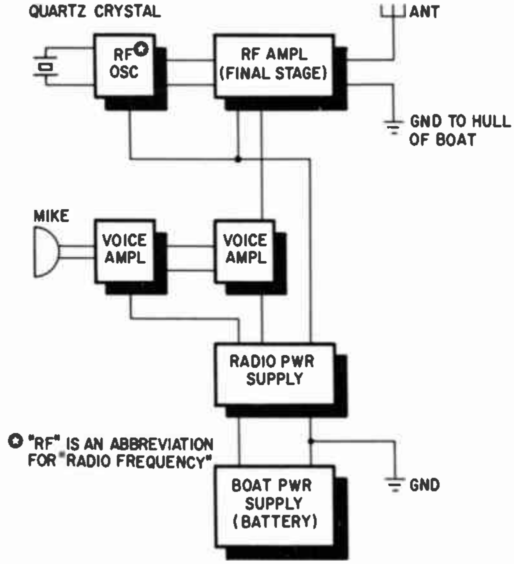


Fig. 301. *Block diagram showing the principal parts of a marine transmitter. The amplifiers shown consist of vacuum tubes and associated wiring.*

puts out only 10 watts to the antenna. That is, the final vacuum-tube stage uses 16 watts of power from the *radio's* power supply but delivers only 10 watts of radio-frequency power to the antenna. Losses on the antenna lead-in and the antenna itself further reduce this amount.

Actually, if half of the power generated in the final stage gets out on the air, it can be considered pretty good. However, this discussion has referred only to the power used by the final stage of the transmitter. In addition, the other tubes in the set use power and the receiver does also.

Because of this, in the 16-watt set mentioned, 84 watts are used from the *boat's* power supply. Note that the power rating of the set is only a fraction of the power the equipment will draw from the boat's power supply.

Most marine radio equipment is designed with features to conserve power. For instance, the boat operator will keep only his receiver turned on most of the time. Therefore the receiver power requirement will be a steady drain on the boat's battery. This is usually low, much like an automobile radio. Although it can run the battery down (just as an auto radio can, unless the battery is being recharged by the engine), the receiver can be used alone for reasonable periods.

Standby and transmit

A transmitter usually has two power-consumption ratings—standby and transmit. Any vacuum-tube radio equipment uses two

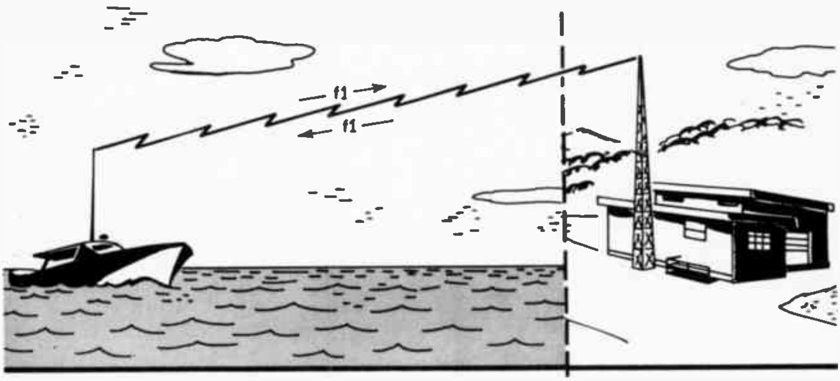


Fig. 302. *With simplex operation, only one party talks at a time.*

kinds of power in its circuits. The first is the "filament" or "heater" power. This is usually low—6 to 12 volts. It is the power which heats the tube, and causes the inside to glow. Another, higher voltage is required on other elements of the tube to make them operate. This voltage may be a hundred or so in a receiver, and may run to several hundred or thousands in a transmitter.

It is the heating of the elements of the tube on the low voltage which requires the warmup time in radios and television. Depending upon the construction of the tubes and the circuit, this may require from several seconds to several minutes.

Normally, unless you are conversing with someone, your ship's transmitter will be turned off. However, when you are ready to talk, you will not want to wait for the transmitter's tubes to warm up each time you want to say something.

Different arrangements can be made in radio equipment to take care of this situation. While the other fellow is speaking, you can disable your transmitter, without allowing it to cool off, by cutting off the high voltage within the set. This can be done with a push-to-talk switch on your handset or microphone. With this arrangement, turning on the transmitter would mean turning on the tube heaters only, so they can warm up.

Pushing the microphone button then would automatically turn on the high-voltage supply and thus put your transmitter on the air. Each time you release the button, the transmitter shuts down but the tubes remain lighted and do not cool off. Operation of a radio by this method is called *simplex* (Fig. 302) and it means

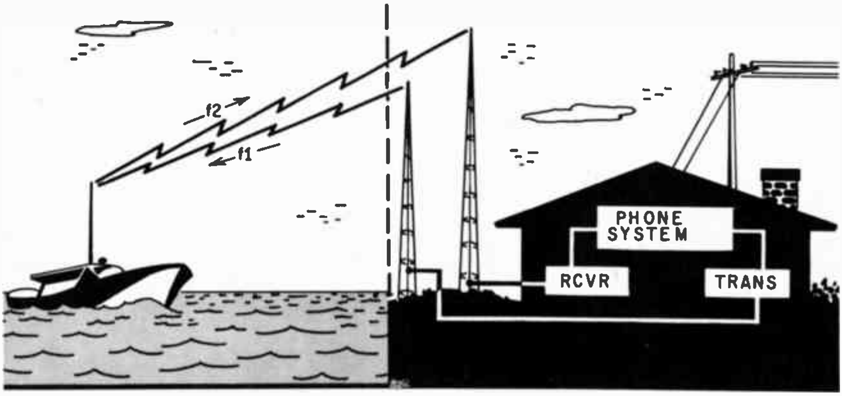


Fig. 303. ***Duplex operation is more like normal conversation. Both parties can talk at the same time.***

that only one party talks at a time and while he listens his transmitter is off the air. This type of operation is required in marine radio. A service in which both parties can talk at once (Fig. 303) usually on different frequencies is called *duplex*.

While you are listening to the other fellow talk, with your transmitter tubes still lighted, you are in a standby position. When you turn your transmitter fully on to talk, you are in transmit position. Marine radio transmitters have specification sheets which list the power drawn from the boat's supply for three conditions: receiver only, standby and transmit.

For the 16-watt set mentioned, these ratings for 12-volt operation are: receive, 2.8 amps; standby, 3.3 amps; transmit, 7 amps.

The watts in a direct-current circuit can be found by multiplying the volts times the amperes (or amps). Thus, in the above case, when transmitting, the set uses 12 volts $\times$ 7 amps = 84 watts load on the boat's power supply.

The push-to-talk microphone button may perform different functions in sets of different manufacture. In some cases, the high voltage is disconnected from the receiver tubes, to give more power to the transmitter. In any set, placing the transmitter on the air should result in the receiver being silenced. Otherwise, your own voice would blast back in the loudspeaker and cause the equipment to howl. On higher powered sets, overloading of the receiver might also occur.

This is usually prevented by a relay within the set which disconnects the radio receiver's voltage or the loudspeaker or both. Where the transmitter and receiver are separate units, provision is usually made for a cable to connect the two. When the talk button is pushed, an electrical condition is placed on this connecting cable which will shut down the receiver.

Distance vs power

In deciding how much power to use in your particular boat, your estimate should be based upon the distance you expect to cover. A rule of thumb advocated by some is based upon 2 miles per watt of power to the input of the final radio stage, while on salt water. A value of 1 to 1¼ miles per watt is suggested for fresh-water operation.

This, however, is no guarantee, and, if you are going down for the last time, it is too late to ask for your money back because the transmitter did not arouse help. The effectiveness of any radio transmitter depends upon many things, including the antenna, ground and other details of its installation. It also depends upon the ability of the boat's power supply to deliver enough electricity to make it work right.

There are also the vagaries of radio transmission. At some frequencies, transmission may be impossible at times even though the two stations are within shouting distance of each other. Some people resort to the philosophy that the more power, the better chance of getting the message through. This philosophy requires a bankroll to support it. Sets are made which use two power outputs, high power for ship to shore and reduced power for calling nearby ships.

The rule given is a good starting point for distances which can be covered by a set up to 50 watts in size. However, the power required for radio communications increases faster than the distance to be covered. Thus, to double the range of your transmitter requires four times the power. Hence, if you plan to travel over 100 miles out from shore, better not trust the rule of thumb.

Amateurs frequently talk halfway around the world with sets that have as little as 5 watts of power, but these conditions are exceptional. Sometimes a low-powered signal will bounce back and forth between earth and sky and travel thousands of miles. Radio signals can travel quite well over water. However, if you are on an inland lake which is hidden by hills from the station you wish to contact, these hills may block your transmission.

It is a good idea to check the experience of other boat owners in the area where you intend to operate. However, beware of the other fellow's bragging. No one likes to admit he bought the wrong kind or size of radio. You probably learn more if you make trips in the boats of others and see for yourself how the radios work.

Channels

Next to power, probably the next most important consideration in selecting a radio transmitter is the number of channels, or frequencies, that it will handle. Every vessel needs a certain minimum. You should be able to call and listen on the 2182-kc distress frequency and the Coast Guard and ship-to-ship frequencies for your area. You will probably want to be able to switch the receiver to the broadcast band for entertainment.

Each channel the set can handle increases its cost, so there is no point in paying for channels you don't intend to use. This might include the telephone company frequency. If you do not plan to call shore stations from your vessel, you don't need this channel.

However, note that the telephone company shore station can be used to enable you to talk to another vessel. The phone company usually has several receivers located along the coast. These receivers are all wired by land lines into the central point where the marine operator is located.

Your boat may be several miles down the coast, out of reach of vessels which are up the coast in the opposite direction (Fig. 304). With your comparatively low-power marine transmitter, your signals can be picked up by the telephone-company coastal receiver nearest you. The marine operator can connect this receiver to her powerful land-based transmitter and send out a signal which will reach the vessel you are calling. In addition, land-line connections can be made over long-distance circuits

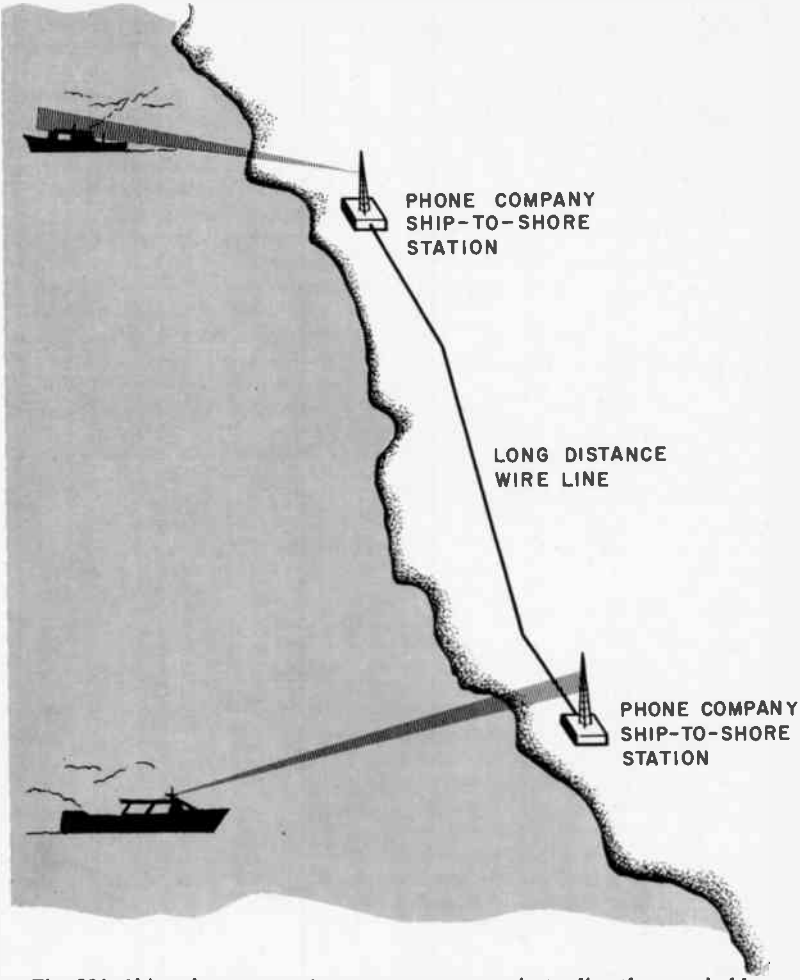


Fig. 304. *Ships that are too far apart to communicate directly may hold a conversation by means of telephone-company shore stations and connecting land lines.*

using two telephone-company transmitters. This would enable you to talk to another vessel hundreds of miles away.

Thus, a small boat within reach of the telephone station at San Pedro, Calif., could, over long-distance land lines, make a call which would be broadcast from the telephone-company station at Seattle or New York or wherever the other vessel might be located.

All this service will be at the telephone company's usual rates, of course, but it is a factor in considering the installation of a telephone company channel on your boat's radio.

There are also occasions when you may need other channels as well. If your vessel is in coastwise service, which it might well be in either commercial activity or in sporting events, you may need several channels. This is because the shore stations—telephone company, Coast Guard and others—use different frequencies in different ports.

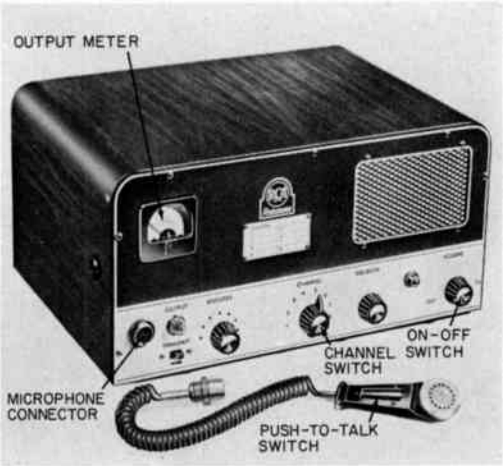


Fig. 305. *A radiomarine transmitter–receiver which handles eight channels that can be selected by the center knob. The microphone has a push-to-talk switch in the handle.* (RCA)

For instance, if you were traveling down the Atlantic Coast, you would want to be able to talk to stations from Boston, Mass., to Jacksonville, Fla. This would require 10 channels on your radio. See Appendix II.

Each channel on your transmitter requires a separate quartz crystal to generate the frequency required. Each crystal costs between $10 and $20 and, in addition, a lot more wiring must go into the set for each channel to be used. Not only must the crystal be switched for each channel, separate coil and capacitor connections must be switched also. Some savings can result if unused channels are not equipped with crystals. Fig. 305 illustrates an 8-channel unit.

Besides the transmitter, provision must be made for switching the receiver as well, so duplicate equipment is required for this purpose. In practice, the interior of the set contains a complicated collection of switches, usually fastened to one shaft. This shaft has a pointer connected to its end on the front panel. The set can be changed from one channel to another, just like a TV set, merely by rotating the pointer.

So again, as in the case of power, any decision as to the number of channels should be weighed carefully against the use to which you intend to put the boat.

All of the above applies to vessels equipped with radio because of voluntary action by the owner, but if you carry passengers for hire, Federal laws compel you to equip your craft with a radio, and both the minimum power and number of channels are specified by these laws.

Type approval

The Federal Communications Commission requires that marine radios meet certain technical requirements. If the manufacturer builds his set to meet these requirements, it is called "Type Accepted" by the FCC. These requirements relate to the performance of the set and are based upon frequency stability, absence of spurious radiation, performance under temperature variations, etc. The requirements do not constitute a Government guarantee that the set is worth the price charged. It means only that it meets certain requirements imposed for the good of the service.

However, on all new installations on boats, it is required that a set which has type approval be used. Vessels equipped with radios which are not type approved may have their licenses renewed until June 1, 1963. After that date, only type-approved equipment can be used in the marine service. Therefore, beware of buying a second-hand radio transmitter. If it was manufactured before certain specifications were put into effect by the Government, you may find that you will be unable to get a license to operate it.

Installation

Before the job is finished, the installation of a marine radio telephone aboard a vessel, in most cases, will require the services of a person who holds an FCC second-class or higher radiotelephone license. However, some of the hard work can be done by boat owners who are good mechanics, at a considerable saving. The job consists principally of mounting the radio in place, installing the antenna and running the necessary connecting wires.

Some portable sets, of course, do not require all of this. Equipment is made which contains the transmitter, receiver, battery and antenna all in one single case (Fig. 306). The battery can be recharged from the boat's power or from a charger on land. Other sets are in the "removable" class; that is, they must be in place in the boat to operate, but they can be easily removed for storage.

Such sets may have an advantage where protection against theft or exposure to the weather is a factor. The owner may wish to take the set home with him, or move it to a part of the boat which can be locked. Even the smallest vessels often have a compartment in the forepeak where things like this can be stowed. When in

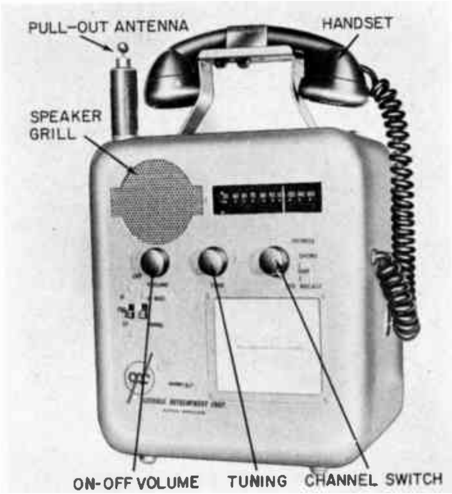


Fig. 306. *A complete portable radiotelephone for shipboard use. It uses a telephone type handset and a collapsible antenna and will operate on distress frequency, shore or ship frequencies, and the standard broadcast band, depending upon the setting of the knob at the right.* (General Development Corp.)

operating position the radio should be installed in a dry location with ready access to the controls and fuses.

The installation of the radio may require a new or larger power supply in the boat. In addition, a number of other modifications of the boat's electrical system may become necessary. The man who plans to do it himself should check carefully into everything involved before he starts the job. Among the things he may have to install are noise suppressors or shielding material on the boat's engine and electrical accessories. A grounding system must be included. Present wiring or other metal objects in the boat may have to be removed or relocated.

Some of the principal considerations involving the radio and its attachments are given here. Information on spark suppression is given in the chapter on power supplies.

Antennas

The length of a radio antenna bears a definite relation to the frequency being used. The antenna should be no more than a quarter-wavelength for the type of service discussed here. However, at marine frequencies, a quarter-wavelength would be nearly 100 feet. Large vessels can put up antennas approximating this length by stringing wires horizontally or diagonally between masts or other elevated structures.

The small boat must use a vertical antenna. In practice, the lack of length of this type of antenna is compensated for by the use of a "loading coil" placed somewhere in the antenna. It is usually partway up between the mounting base and the "whip" or top section (Fig. 307).

It usually consists of a coil of wire sealed in a plastic tube, so that it cannot be harmed by water. Antennas of this sort for small vessels may be anywhere from 12 to 25 feet high. They can be mounted on a base which is fastened to the deck or cabin, or mounted on a mast. The mounting includes a large insulator which prevents the power delivered to the antenna from leaking away. It is essential to good radio operation that this insulator be kept clean, dry and unpainted. The presence of dust or dried salt is bad, because either will absorb moisture from the air and short-circuit your antenna.

Mountings will vary with the type of antenna to be used. Also, some boats require a provision for lowering the antenna for passing under low bridges or other obstructions. Some antennas have pivots built into the mounts for this purpose; others are equipped with detachable whips which can be pulled out of a socket.

An antenna must be installed in a position where the water will not ordinarily splash on the mounting base. It is connected to the radio transmitter by a single heavy wire. The size and allowable length of the different wires connecting to a marine radio are usually specified in the installation handbook that comes with the set. Typically, because of its heavy insulation, high-voltage wire like that used in neon signs is good for antenna leads.

Certain general rules apply to most radio transmitters. First of all, remember that electricity always travels on two conductors. That is why there are two wires going to your vacuum cleaner, toaster or other appliance. You might say the electricity goes in on one wire and out on the other.

In a radio transmitter of the type being considered here, the antenna represents one of the two necessary wires, and the ground is the other. When the radio energy comes out of the transmitter

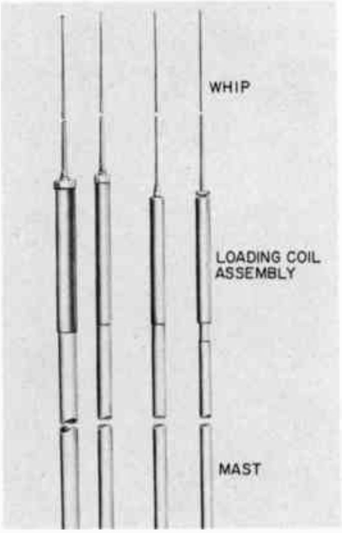


Fig. 307. *Marine radio antennas consist of a mast, a loading coil and a whip. The loading coil, contained in the large cylinder in the center of the assembly, has the electrical effect of lengthening the antenna.* (Webster Manufacturing Co.)

on to the antenna and the ground wire, it is ready to take off into space. For it to reach its greatest distance, the energy must be released as high above the water as possible.

Radio waves which might emerge from your ground wire are of no use in the bilges of your boat. Even the waves from the antenna lead wire are too low to be effective. When an antenna is correctly designed, installed and matched to the transmitter, more of the current will exist in its higher portions. Achieving this may require the services of a man with a second-class radiotelephone license. (The dealer or manufacturer usually can supply this service.)

If this adjustment is not correctly made, the antenna will not "take" the power your transmitter tries to force into it. In spite of all of the power in your set, you may not be able to transmit the expected distance. But, while it calls for a skilled technician to make the antenna take power, your job in installing it can help. Some equipment is factory-aligned and tuned to the antenna that comes with the set. If installed correctly, these sets should work without further adjustment.

The lead-in

The antenna lead wire, where it comes from the set, should not run alongside the set. It should branch away at right angles for at least 1 foot. In its run to the antenna, keep it at least 2 feet away

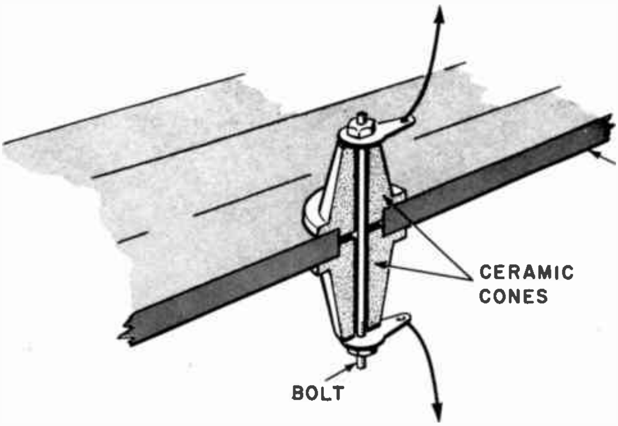


Fig. 308. *A feedthrough insulator is used when the lead wire must go through the deck.*

from other wires, pipes or metallic objects. If the hull is metal, the lead wire should be installed on standoff insulators and should not touch the vessel or any object aboard. The points where the wire connects to the radio and to the antenna should be clean and bright before the connection is made.

The lead wire should take as direct and short a route as is practical between the set and the antenna. If the wire that comes with the equipment is too long, it should be cut to fit; never coil up the excess wire. If the lead wire must go through the deck, use a feedthrough insulator. This is a double cone of ceramic material, one half of which goes below deck and the other half topside (Fig. 308). A connecting bolt goes through the insulator, and the lead to the set should be fastened on one end and the lead to the antenna on the other.

Ground

The ground wire is equally important. The radio set will have a binding post terminal marked "Ground." This is the radio-cir-

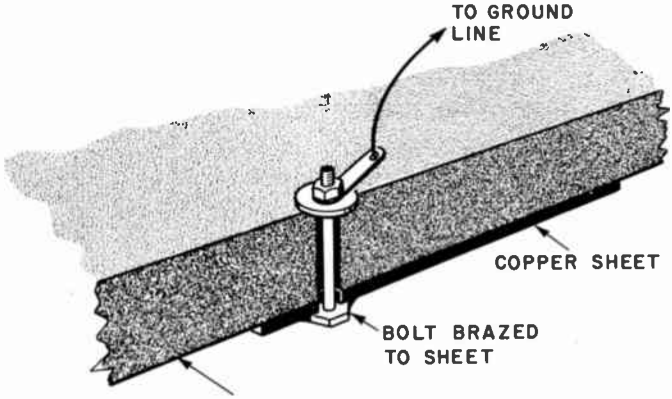


Fig. 309. *Method of setting up a good ground.*

cuit ground. For reasons of electrolysis, as explained in a later chapter, this ground terminal might not be connected electrically to the set's cabinet. A heavy copper wire should be run from this ground terminal to other grounded points on a vessel. Again, mating surfaces should be scraped clean and bright before a connection is made.

Everything that is to be grounded in a boat should be connected together with copper wires, securely fastened to the object. These objects include the motor and propeller shaft, strut, rudder, the neutral side of the boat's battery, the hull if it is metal, and any other wiring, cabling or piping on the vessel.

If the hull is not made of metal, a good electrical connection must be established to the water beneath the boat. Copper sheets, with a minimum of 12 square feet of surface, should be fastened to the underside of the hull. Bolts should be placed through these sheets to the inside of the hull. The bolts must make clean and tight contact with the copper, and should be silver-soldered to it (Fig. 309). If more than one piece of copper is used, each should be solidly connected to the other, and separate bolts run through the hull for each.

Inside the hull, the bolts must be connected together with heavy copper wire. This wire should be electrically connected to everything in the boat that is grounded—the radio, battery, engine, etc.

The connection that the copper plates or metal hull makes with the water is the true "ground" for your boat. For best radio operation, it is important that the connection between the radio and this ground point be as short as possible. Regardless of how the other grounded objects on the craft are wired together, it is a good idea to run a ground wire from the radio direct to the metal hull or to one of the bolts connecting to a copper plate by the shortest route possible.

Vhf equipment

These same general rules for installation apply to very-high-frequency (vhf) as well as the medium-frequency marine equipment. However, there are a few notable differences. Because of the high frequencies and short wavelengths used, the antenna is very short. To get maximum radiation, it is usually recommended that it be mounted on the mast or other high point of the vessel.

The equipment resembles mobile equipment in design—it looks like the two-way radios used in police cars and taxicabs. The FCC rules vary slightly for this service as compared to the lower band. Sets in the vhf marine service must be able to use frequencies of 156.3 and 156.8 mc, and in addition must be able to use one more frequency between 156.3 and 157.4 mc.

Telephone channels in this service operate duplex; that is, the ship and shore stations use different frequencies. This may require the use of an additional receiver if the boat owner intends to avail himself of this service.

Mobile radio for autos is ordinarily equipped for transmission on one frequency and reception on another, and works with a single fixed station. This equipment does not satisfy the requirements for vhf marine service, which, as mentioned above, must be able to work at least three frequencies. Because of this, telephone companies and others who rent vhf marine equipment to boat users must charge a higher rate. However, in locations where the vhf marine service has not yet been established, and where boat owners choose to operate as part of an industrial or limited common-carrier system, regular land type mobile equipment may be used.

Many of the large radio manufacturers make equipment for the land mobile service, but there is little choice in vhf marine radio equipment at this writing.

Citizens' radio

Citizens' radio may prove to be the best bet for the small boat operator in a region where radio communication does not exist. Two or more boat owners can equip themselves with sets for this service and maintain contact with each other. They might also arrange for family, friends, boat livery or marine attendants to receive calls on shore and send help when requested.

Whatever the arrangement, the operator of Citizens' equipment must take care of both ends of the line—he must not only equip

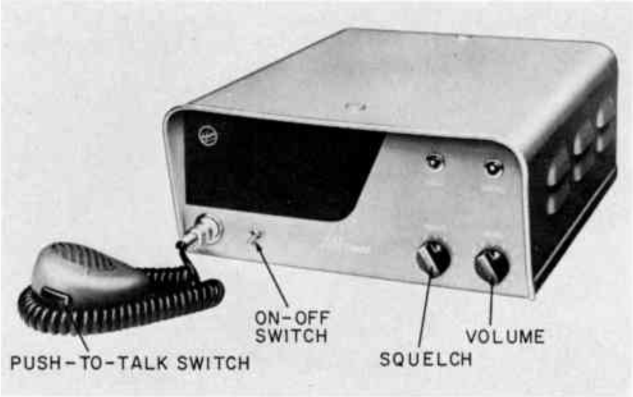


Fig. 310. *This transmitter–receiver covers a band of frequencies from 450 to 470 megacycles.*

his boat with radio, he must also arrange for another station with which to communicate.

High-quality equipment can be obtained for this service. Typical is the unit shown in Fig. 310. This transmitter–receiver combination covers the 450–470-mc region which includes the Citizens' band at 465 mc. It is crystal-controlled and will also operate in other authorized services in this region, including industrial, taxicab and other land services.

Equipment like the unit shown requires the same general installation instructions and power requirements as other marine radio equipment.

Transmission with 465-mc equipment is generally regarded as confined to line of sight only although, while some obstructions will block transmission. others will help it. For instance, if there is an island between you and shore, it may block radio reception. On the other hand, a radio signal may "bounce" or reflect off an island and reach into a hidden cove which it could not reach on a straight path.

Frequencies in the 450–470-mc region are also subject to fading in wooded areas or in locations where damp underbrush exists. This trouble probably will not occur with the 27-mc Citizens' equipment mentioned in Chapter 1. Before buying equipment in the vhf or Citizens' band for use in locations where obstructions exist, get a demonstration.

Trouble

Unlike receiving equipment, transmitting equipment cannot be repaired by the owner, unless he holds an FCC second-class radio-

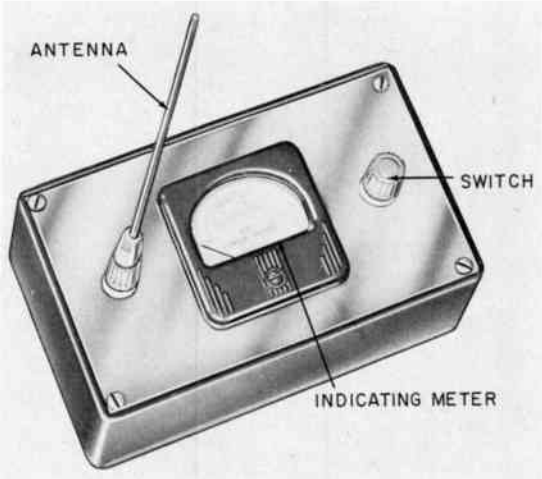


Fig. 311. *An instrument for measuring the power radiated from a radio antenna. When held near a ship's antenna, the meter will give an indication when the transmitter is turned on.* (Heath Co.)

telephone license or better. This is because even the slightest maladjustment of the inside apparatus in the set may cause off-frequency operation and serious disturbance to some other radio service. (One kind of trouble, for instance, can spoil radio reception in the aircraft service.) Even the changing of a burned-out tube may require realignment of the transmitter.

The proper alignment of a radio set involves several operations, considerable expensive test gear and a lot of technical know-how. Unless you are a professional radio operator, you just can't do it.

However, as with the receiver, there are a number of things you can do short of taking the set apart. A good deal of the trouble in any radio installation can be in the wiring outside of the set. Make sure the antenna is still connected. Make sure that all connections are tight. Check the ground wire. See that the battery isn't dead. Examine and test all fuses involved. Analyze how much of your equipment has failed—this may be a clue to the trouble.

The chapter on power supplies has detailed trouble-shooting information for the electrical system on your boat, but there are a couple of tests that apply to the radio alone. If the transmitter appears to fail, try to find out if it will work on another channel. Your failure to get an answer to a call may not be transmitter trouble—maybe you are in a location where no one can hear you on the frequency you are using. Also, maybe your trans-

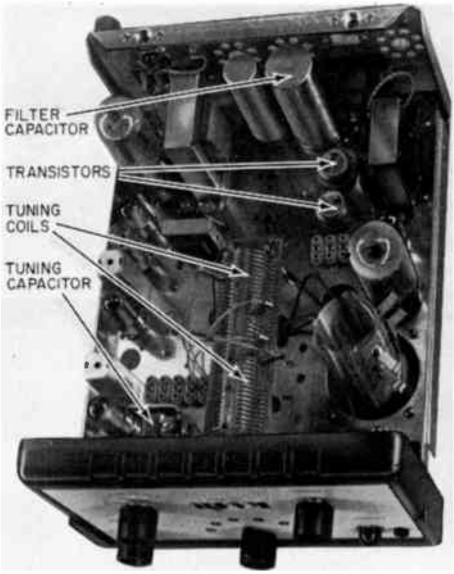


Fig. 312. *The inside of a marine radio transmitter looks just about like any other radio set. However, any repairs, even changing the tubes, requires that the repairman hold an FCC second class radiotelephone operator's license.* (Kaar Engineering Corp.)

mitter is working but your receiver may be dead, so you cannot hear the answer. The receiver also can be tested by trying it on another station or channel.

Antenna current

Some transmitters have a small lamp that shows if the set is putting out power. If it is not, fuse and external wiring are about all you can check. If the set is putting out power but you cannot reach anyone, the power may not be reaching the antenna. You can check this with nothing more than a dry wooden lead pencil.

Hold a pencil by the wooden portion (not the metal cap) and touch the point to the antenna while the transmitter is in talking condition (talk button pressed and transmitter turned on). A spark can be drawn from the antenna if the antenna is receiving power. The point at which the spark will be greatest will be the point where the current is greatest. This will be part way up the antenna, not near the bottom, if the installation was made correctly.

Antenna current can also be tested by the use of a small fluorescent lamp. Hold the lamp by the glass portion and touch the metal end to the antenna. If the set is transmitting power, the lamp will glow. These are makeshift methods. Instruments can also be obtained to make this test. One such instrument, a build-it-yourself unit, consists of a meter with an antenna a few inches long (Fig. 311). This can be held near the ship's antenna. A meter reading will indicate that power is being radiated from the antenna.

Tests of this sort will at least tell you if the set is working. If it is not, you may be able to find the trouble in the antenna lead wire or the point where it connects to the set or antenna.

Tubes and transistors

Tubes and transistors are both used in marine transmitters as shown in Fig. 312. Note the clips that are mounted on the tuning coils. These should not be moved since their position determines the operating frequencies. Transmitting tubes develop a considerable amount of heat, so don't try removing them or touching them immediately after the transmitter has been turned off.

chapter 4

power supplies

THE words "power supply" mean different things to different people. Every radio set has a power supply of some sort. The battery inside of a portable set is a power supply. Your home radio or TV set has a power supply which develops the low voltage to light the tubes, and the high voltage needed in other parts of the circuit.

This kind of power supply is not really a "supply" at all, even though it is usually called that. The true "supply" comes from the outlet into which you plug the set (Fig. 401). Inside of the set may be a transformer which changes the 117-volt alternating-current (ac) power from your house wiring to the lower and higher voltages that your radio or TV needs. Sets like those used in boats, which operate from a storage battery, also usually contain a transformer for this purpose.

However, direct current (dc) such as that supplied by a storage battery will not work in transformer, so it is necessary for the set to include a vibrator or special power transistors, to change the dc to ac so the transformer will handle it (Fig. 402). Whatever voltages your radio transmitter or receiver requires to operate will be delivered by the "power supply" built into it.

Normally, the power supply within the set is not a source of trouble, except perhaps for the vibrator. The vibrator is contained in a small canister which plugs into a multipronged jack like a tube socket. It consists of a small spring which vibrates back and forth inside the can (Fig. 403). In vibrating it makes electrical con-

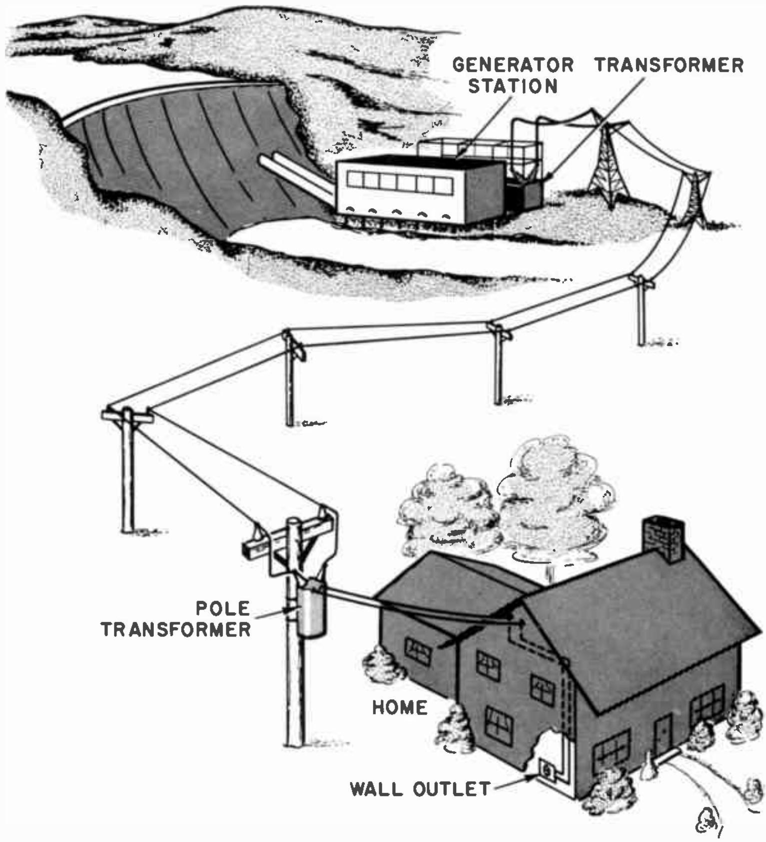


Fig. 401. *Ac all the way—from the power house to your home.*

tacts at each end of its swing. Because it "alternates" from one contact to the other, it can change direct to alternating current.

Automobile radios often use the same system. Usually the vibrator can be heard as a soft buzz coming from the set when it is turned on. This buzzing is an indication that the vibrator is working. If the radio does not operate, and the buzz is not heard, it may indicate a blown fuse, a dead storage battery or a stuck vibrator. The electrical contacts of a vibrator wear out as the set is used. Sometimes they will fail to make contact, and the vibrator will not buzz.

Often, too, the contacts can weld together and the vibrator will stick. This sometimes causes the fuse to blow. A boat owner, if he has a vibrator type radio, should carry a spare vibrator, just as he carries spare tubes. He should also learn in advance how to unplug the old vibrator and plug in a new one.

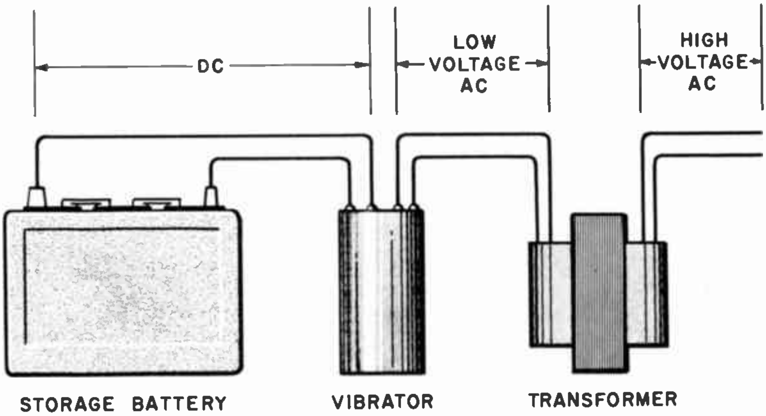


Fig. 402. *A vibrator changes dc to ac. The transformer steps up low-voltage ac to higher-voltage ac.*

Sometimes, if a spare is not at hand, a vibrator with a stuck or dirty contact can be made to work again temporarily by removing it from the set and tapping it against some hard object. The blow may clear the trouble and get it going again.

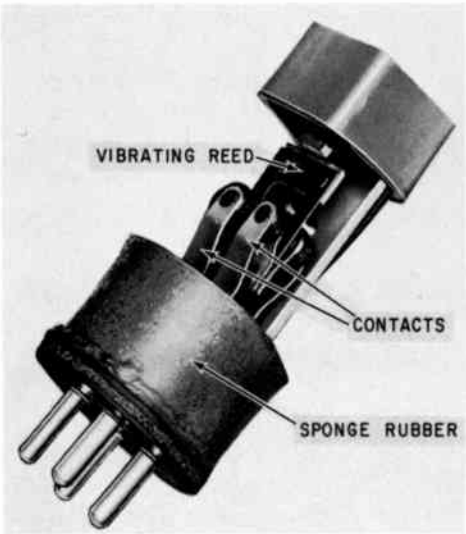


Fig. 403. *Inside view of a vibrator.*

Recently, the transistor has been applied to power supplies for mobile radio equipment. Two transistors are used in an electrical circuit which changes direct to alternating current silently, without the use of moving contacts. This does away with the need for a vibrator.

Some radio receivers, both marine and automobile, may use so-called "hybrid" tubes which work directly from a 12-volt storage battery. Since 12 volts are used to light up the tubes, and this voltage is also sufficient for the rest of the circuit, no high voltage is needed. Therefore, no inside power supply is needed in the set. Sets which use transistors only do not require an interior power supply. The transistors need only 10 or 15 volts to work, and this

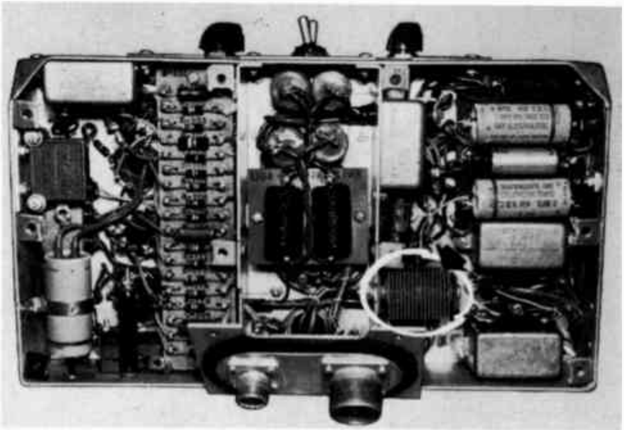


Fig. 404. *The rectifiers used in receivers and transmitters are either vacuum tubes, selenium or silicon units, or synchronous vibrators.*

is supplied by a small battery. Tubes, except the hybrid type, may require several hundred volts for proper circuit operation.

Transmitters

Large radio outfits, such as transmitters, require large power supplies. Up to a certain size, transmitters, like receivers, may use vibrators to convert the boat's battery power to ac so it can be stepped up with a transformer. However, radio sets do not actually use ac in their circuits. Ac is used only because you must have ac to step up the voltage with a transformer.

However, once a high voltage is obtained inside of the radio, it must be "rectified" or changed back to direct current. Some sets use a "rectifier tube" to do this; others have a special vibrator with extra contacts to change the ac back to dc. Other sets use selenium disk or silicon crystal rectifiers (Fig. 404).

Where voltage requirements are high, and only low voltage dc is available, such as the battery in a boat or auto, it is common to use a *dynamotor* to obtain the high voltage. This is a machine which consists of a small motor which will run off the storage battery. Built into the machine is a high-voltage direct-current generator. As the motor turns, it generates the high voltage needed.

Thus, a dynamotor is a machine into which you can put 12 volts dc and get several hundred dc volts out of it. It has an armature which turns, just like any other rotary motor. In addition it

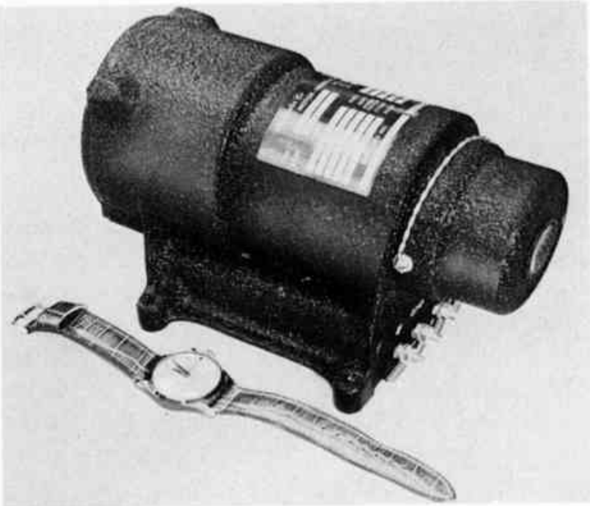


Fig. 405. *The input to a dynamotor is low voltage dc, usually 12 volts. The output is also dc, generally several hundred volts.*

has a set of "brushes," little carbon blocks which press against the commutator at each end of the shaft. These brushes wear, and require replacement or cleaning from time to time.

Radio equipment which uses a dynamotor usually identifies itself by the sound of the machine, which starts up like a miniature vacuum cleaner every time the transmitter is turned on. Some equipment is arranged so that the dynamotor runs only when the "push-to-talk" switch on the microphone is operated. This saves power. If the brushes are allowed to deteriorate, the dynamotor may fail to start. Dirty brushes will sometimes cause a whining sound to be transmitted along with your voice every time you use the transmitter.

Normally, it is a radio man's job to service the dynamotor. However, the brushes are easily removed for cleaning (Fig. 405). If you tinker with any dynamotor, turn the power off—otherwise you may get a jolt of several hundred volts. Get your radio service technician to show you how it is done.

A dynamotor power supply for a transmitter may be inside of the set, or it may be on a separate chassis and mounted at a distance from the transmitter.

Boat power supplies

Most small boats built today have provision for some sort of an electrical system. At a minimum, this may consist of only an electrical generator built into an outboard motor for the purpose of charging a small battery, which in turn is used to start the motor. Some vessels may not even be equipped with running lights if nighttime operation is not planned. In these vessels, electricity is a small problem.

However, as soon as you get interested in having a radio, you are going to have to study the boat's power equipment. If the vessel is equipped with a battery and a generator driven by the engine, the chances are that neither the battery nor the generator is any larger than it has to be to serve its original purpose.

That is, the power system will be enough for the ignition, the starter and the running lights and perhaps a horn or siren. However, as soon as you start adding other things to the circuit, you will have to make arrangements to get more power. There are different ways of doing this, depending upon your requirements.

In some cases, a spare battery is all that is needed. This battery would be charged on shore and brought aboard the boat whenever needed. It would be kept separate from the boat's system, and used only to run the radio. This way, if you ran the battery down, you would still have the boat's battery in good condition to start the engine. You can also connect the spare battery into the boat's electrical system with a switch to change over from one battery to the other as required (Fig. 406).

If you use this method, be sure to use a large heavy-duty switch if your engine starter is hooked up to work with either battery. However, remember that merely adding an extra storage battery will not increase your available power, unless you charge the extra battery on shore someplace. The reason for this is that the prime power source on the boat is the generator on the boat's engine, and this will furnish only a definite amount of power while the engine is running.

This is true of automobiles as well. While an automobile generator in a modern car is large enough to run an assortment of lights, heater fans and a radio, the generator on a boat may not be large enough for all this. Further, even in an automobile, a larger generator is needed in taxicabs, police cars and others which install radio transmitters. The amount of current needed by a radio transmitter is a great deal more than that required by a receiver.

Another factor is that while an automobile is running most of the time that the radio and other accessories are being used, a boat may be anchored for days at a time. For instance, you may take your boat to a sheltered cove and plan to live aboard it for several days. During this time you may want to turn on the radio,

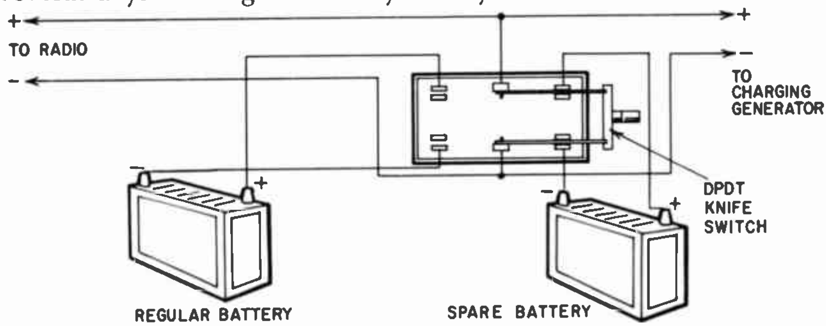


Fig. 406. *A fully charged spare battery is nice to have along. If the regular battery runs down, the spare can be connected in its place. A double-pole double-throw knife switch is needed, connected as shown. Note that the charging generator (driven by the boat engine) is connected across the battery in use. The generator cannot normally take care of both batteries. When back to shore, the dead battery can be recharged.*

the lights or other appliances, yet your engine will not be running to recharge your battery.

A great number of appliances can be hooked up on a boat nowadays—everything from TV sets to air conditioners. Americans like to bring all of their comforts of home with them wherever they go. This can mean a large demand for electric power and, unlike power on shore, this is something the boat owner must supply himself.

Auxiliary power

Several makes of auxiliary power systems are available to operators of small vessels. All involve some sort of a small electrical plant which can operate independently of the boat's power supply. Probably the first choice would be a gasoline-driven direct-current generator. Quite portable, it consists of a small one-or-two-cylinder gas engine coupled to a dc generator which supplies 6, 12, 32 or 110 volts.

Such a power system can be used to recharge the boat's battery or a separate battery for the accessories. In addition to being able to function when the boat is not running, it has the advantage that it will supply much more electrical power, and cost less to run, than would the boat's main engine. This type of installation is ideal for the boat operator whose needs include lights at nighttime, a radio or other small appliances, such as coffee-makers, bottle warmers and so on, that can be obtained for battery operation.

If, however, you take your TV set along, and also need an electrical hot plate or toaster or some other handy little gadget that uses from 200 to 1,000 watts of power, you will be better off with a different kind of power plant.

Also available in the portable class are small gasoline-motor alternators which furnish 110 volts ac instead of 12 volts or so dc. These ac machines (Fig. 407) cannot be used to charge your

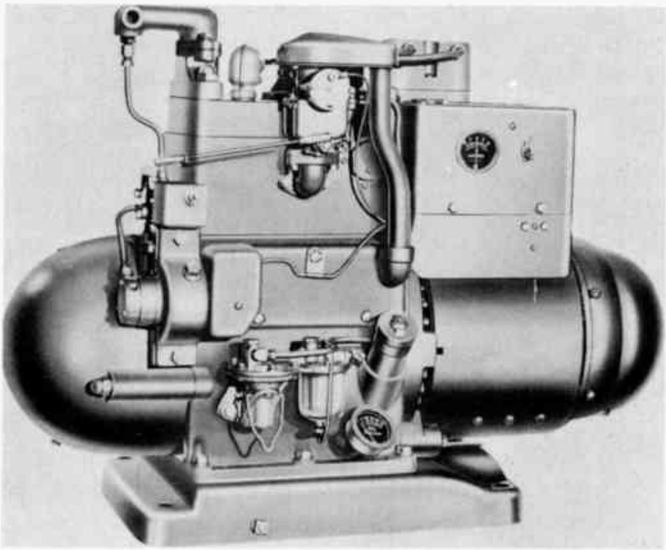


Fig. 407. *If you expect to bring all of your electric appliances along when you go boating, you may need a power plant like this. Gasoline-driven and water-cooled, this outfit supplies 3,000 watts of power at 110 volts ac. Some machines also supply dc for keeping a battery charged.* (D. W. Onan & Sons, Inc.)

battery unless you also have a battery-charging outfit. However, they do supply the current needed for household appliances.

These alternators also find favor with motorists and campers because, with them, appliances can be used anywhere. This kind of equipment is available in all sizes. Small units that look like a table model radio furnish about 750 watts of power. Typical of these is the unit of Fig. 408. About 19 x 12 x 13 inches, it weighs 50 pounds. It will run from 1 to 3 hours on 3/4 gallon of fuel.

Other units are large enough to light whole cities. Large yachts and other vessels may have motor-driven alternators of several thousand watts capacity to operate their lights, refrigerators and stoves.

Converters

If you have only an occasional need for ac power while you

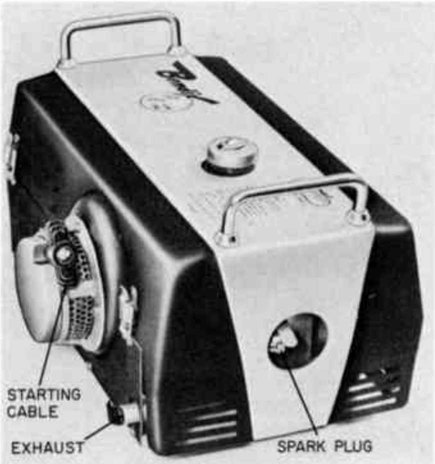


Fig. 408. *A portable electric power supply, which can be used in a boat, at a campsite or any place 110 volts ac is needed. It is driven by a small gasoline engine and delivers 750 watts.* (Bendix)

are on board, a power converter may be the answer. These units consist of a transformer and some means of changing the boat's direct battery current to ac. In operation, they resemble the power supplies found inside radio sets. That is, a vibrator or a pair of transistors is used to change the ship's dc to ac, then this ac is stepped up to 110 volts. Unlike the radio power supply, however, the ac is not changed back to dc after the voltage is raised.

Converters are available in various sizes, depending on the number of watts needed. They are also furnished with different input voltages, such as 12, 24 or 32 volts, for boats which have batteries with these voltages.

A converter of special interest to the small-boat owner is shown in Fig. 409. A build-it-yourself unit, it can be purchased for much less than an equivalent factory-built job. It is a simple device and can be put together in very little time by a person with no electrical experience. Kits of this sort feature picture diagrams to assist in the assembly—you follow a picture in hooking them up rather than studying a circuit diagram as such.

The unit shown is for a 12-volt battery. Transistors are used to convert the dc to ac. It will deliver 125 watts continuously and up to 200 watts intermittently. This is sufficient to run a small

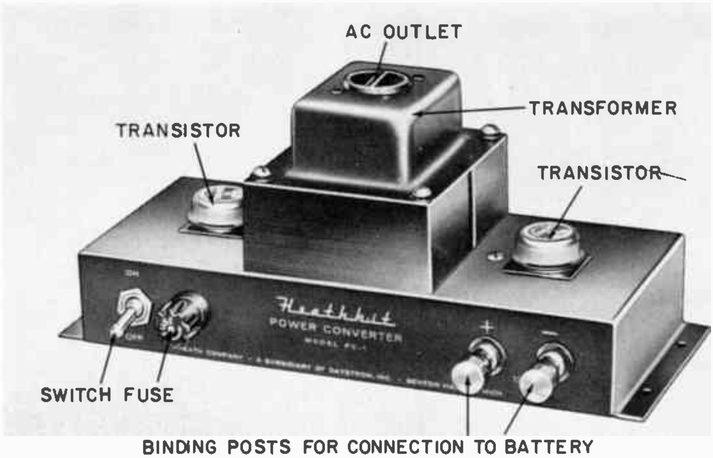


Fig. 409. *Up to 200 watts of 110-volt ac power can be obtained from your storage battery by means of a converter like this. It uses two transistors to change the battery power from dc to ac, and a transformer to step the voltage up to 110.* (Heath Co.)

hi-fi system, 110-volt lights, your electric razor or other low-power devices. It can also be used to run ac appliances in your automobile if the car has a 12-volt battery.

Although the power obtained with any of these devices is limited compared to the amount available from the outlets in your house, you can get by with a small plant and a little discretion. Do not try to run every appliance you have all at once. Knowing the amount of power you have available, use different appliances, one at a time, within the limits of your converter.

Remember, however, that any time you are using power from the battery, with no charger in operation, you are running down the battery. When you use 110-volt devices from a low-voltage battery, you are likely to run the batteries down fast, unless you have a charger running. Because many 110-volt appliances are made to be used in your home, where power may be unlimited, they are not designed to be conservative in their power requirements.

Equipment made to run on batteries, however, is usually designed to use as little power as possible. Another point is that conversion always wastes a certain amount of power. This is true whether you are changing from ac to dc or the other way around. Thus, when you run a 110-volt appliance through a converter from a 12-volt battery, you are using up power not only in the appliance but also in the converter.

Some boat owners, most of whose equipment is battery-operated but who want to use an occasional 110-volt appliance, may find they need a dc-to-ac converter for the appliance, and a gasoline-driven dc generator to charge the batteries. This may prove to be more practical in some cases than buying a gasoline-driven ac machine.

A boat owner who plans to add radio equipment to his vessel should ponder his future appliance needs. He should also give consideration to some of the other electrical accessories such as depth sounders, automatic pilots, etc., which he may want later. Unless the boat's power plant was designed with all of this in mind, the owner is going to have to increase the boat's electrical power supply.

He should then select electrical equipment which matches. In selecting a radio transmitter, he should compare the power requirements with the amount of increased electrical power he intends to provide in the vessel. It is unwise to get a transmitter so big that you haven't enough power to operate it. It is just as unwise to install a set of batteries and an auxiliary generator bigger than you need for the appliances and accessories you are going to use.

Transistors

The transistor is, without doubt, one of the greatest electronic developments of our time. However, like the wonder drugs, it has been subject to a lot of advertising hoop-la and false implications.

In one sense, transistors in a radio are like jewels in a watch. The right number of them in the right places can be a real advantage. In the wrong places, they can be a waste of money. A transistor is a tiny piece of mineral—a crystal which may be so small it cannot be seen without magnification. It possesses certain qualities, among which is the ability to amplify electrical signals.

At present, transistors have a few limitations. Many of them will not function at high frequencies; many of them will not handle large amounts of power. For these two reasons, transistors cannot fully replace vacuum tubes in a radio transmitter. They may be used in place of tubes in the part of the transmitter where the voice is amplified. They may also be used in parts of a transmitter where the frequency or power is low. However, when it comes to the "final" stage of the transmitting amplifier, tubes are usually used to get the frequencies and powers required.

Probably, as transistors are improved, a way will be found to use them at high frequencies and high powers. Some special ones do this now. In some radio equipment, transistors are used which will work at frequencies of millions of cycles. However, these are often hand-picked transistors, specially selected by the manufacturer from the factory output. Other high-frequency transistors are made to order for certain jobs.

On the other hand, many transistors are now being used in broadcast band auto radios and for voice frequencies. These are ordinary transistors and are readily obtainable.

The boat owner who plans on getting a transistor radio should consider this point well. If the set uses transistors of special or hand-picked character, replacements might be available only from the set manufacturer. A boat sometimes gets into isolated backwoods areas where the only source of supply for repair materials may be a garage or auto shop. If your radio uses automobile type transistors, you may be able to get your set fixed even though you are pretty far upstream. If it requires special transistors you may find yourself up the creek.

Transistors do not ordinarily burn out as will a vacuum tube. The tube has a heater or filament, much like a lamp bulb, which can eventually burn out. However, the tube has the advantage that it may be greatly overloaded and still survive. Operated at excessive currents which will cause the elements inside to glow red hot, the tube's life may be shortened, but it will not usually burn out at once from overloads.

A transistor, however, does not have this stamina. The tiny wafer which is the heart of the unit has a definite breakdown point—like a fuse. If anything happens to exceed the critical voltage, the little crystal will be punctured and, like humpty dumpty, cannot be put back together again. Some radio manufacturers steer clear of transistors for this reason. Electrical circuits are subject to "transients"—surges of voltage from accidental or natural causes. Such a voltage surge can be fatal to a transistor.

The purpose of marine radio is the safety of human life, the purpose of your home radio or TV is entertainment. Therefore, marine radio will always appear to be years behind the popular market. The latest tricks and gadgets developed for the home radio will not be used aboard vessels until years of service have proven them safe for marine use.

A type of "power transistor" is now being used with success in the power supply of auto and marine radios. Transistors of this type are also used in converters for changing the boat's battery supply into 110 volts ac. These transistors do handle quite large amounts of power, but they do so at low frequency —60 cycles or so. These appear suitable for marine use at their present stage of development.

It is often claimed that using transistors in a power supply will result in saving power. It is true that a transistor power supply can be made which will have greater efficiency than a vibrator power supply. However, the full efficiency of the transistor is not realized unless a specially wound toroid-coil type of transformer is used with it. If a radio uses transistors with a cheap transformer, the efficiency may be no better than that of a vibrator power supply. The transistor's only advantage, then, will be the absence of moving contacts to cause trouble.

Therefore, do not judge a radio set by whether it has transistors in it. A well designed radio with a vibrator power supply and tubes is a better investment than a transistor set that is cheaply made (even though its price might be higher).

Boat wiring

Installing a radio on a boat requires a certain amount of wiring. In addition to the antenna connection, you are going to have to make a hookup from your radio to the boat's battery. This may also require the use of another battery and an auxiliary generator. Because considerable wiring will have to be done, this is a good time to replace the existing wire in the boat as well.

Wiring on board a vessel is different from house wiring. The boat uses low voltage; hence, to get a given wattage, more amperes are used. (Remember: watts = volts × amps) The greater the amperage, the heavier the wire that must be used. If the wire is not heavy enough, the voltage will be reduced as the current goes through it. It may be so low at the end that it will not operate the radio or whatever other device it is connected to.

Wiring in a house is likely to be No. 12 or No. 14; wiring in a boat is likely to be No. 6 or No. 8—about as big around as a lead pencil. In your boat, you will need larger wire for greater distances. Devices which use lots of current, like a radio transmitter, will need heavy wire. You can use a smaller size if the transmitter is a short wiring run from the battery but the further you go, the larger the wire must be. There are formulas for calculating voltage drop and size of wire, but the makers of radio equipment usually specify the size wire needed for their apparatus for specific distances.

Wires carrying little current, such as that used by the running lights, can be much smaller, but a spotlight will require heavy wire or it will not shine to full brilliance. The wire used should not be extension lamp cord, or other wiring designed for interior use in homes. Wire of the type used in automobiles is satisfactory. This has heavy-duty insulation which is better prepared to stand moisture and chafing which will be encountered on board a vessel.

In wooden-hulled vessels, the wire is usually fastened in place with insulated staples. However, these quickly rust and, further, may not be large enough to hold the size wire needed in a boat installation. A good way to hold the wires in place is to put a loop of tape around the wire, and then tack the tape in place with copper nails. Whatever method you use, be extremely careful not to damage the insulation on the wire, either by crushing it, or driving the nail through it.

Space is usually at a premium in a boat, so very good judgment in placing the wires is a must. First of all, to avoid loss of voltage, the wire run should be as short as possible. Yet it must not be placed where people can walk on it and damage the insulation, nor where it will be submerged if a little water accumulates in the vessel. If the wire has to be run along bulkheads or in lockers, locate it where it will not be struck or chafed by doors, chairs or materials stowed in lockers.

Do not run the wiring along the inside surface of the hull, where it is likely to get wet. It may be run along the ribs of the vessel provided it is not subject to physical damage. If run below decks, the best location is the underside of the deck. Conduit, such as is used in shore applications, is usually unsatisfactory aboard ship, because the pipe will rust. Moreover, conduit may permit water to accumulate and rot the insulation on the wire.

If the wire requires metallic protection, lead-covered wire may be used. This consists of a copper center, a layer of insulation and a surrounding layer of lead. It is frequently used for underground as well as marine installations.

Fuses

Once you get a radio aboard your boat, the fusing system on the ship's electrical supply should be critically examined. A vessel which originally was equipped with only running lights connected to the battery may not have any fuses at all. However,

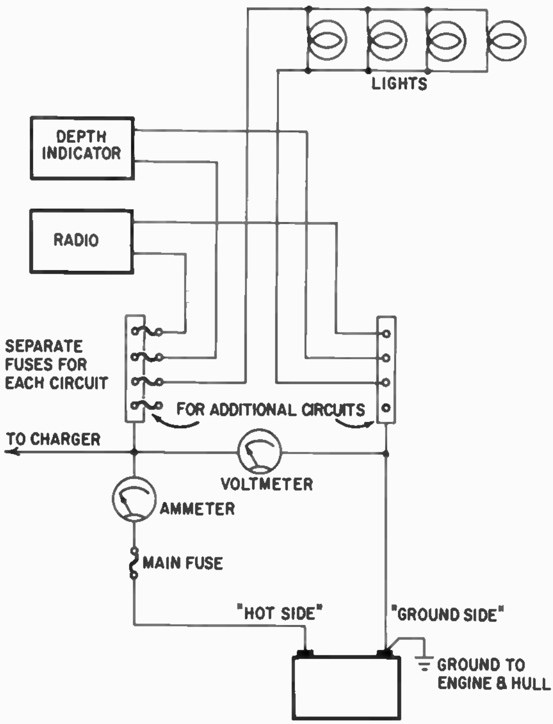


Fig. 410. *Typical wiring diagram for lights and accessories on a small boat. Wires to each device would actually be twisted together instead of parallel as shown.*

as you increase the number of electrical devices aboard, fuses become all-important. Perhaps the two greatest hazards to a vessel are running aground and fire. As long as you are afloat and not on fire, you are safe, at least for the time being.

However, a shorted electrical wire can start a fire, and you can't put out an electrical fire unless you can shut off the power. Fuses provide a convenient way for disconnecting the power to any electrical apparatus. In fact, if trouble occurs, the fuse will blow and disconnect the power before a fire can start. Just one fuse in the battery circuit would give you that protection. But fuses and fuse mounting blocks are cheap, and it will well pay you to fuse each circuit separately.

For instance, each wire that starts off from your battery should connect to a fuse. Thus there will be a separate fuse for the radio, the running lights, the cabin lights, the horn, spotlight, depth sounder or other accessory. With this kind of a hookup, if one of these devices develops trouble, only one fuse will blow and, by noting which one did blow, you will know which unit or branch wire is in trouble.

The fuse block (Fig. 410) should be mounted in a dry location, preferably near the battery. If it is necessary to put it some distance away, a main fuse should be located near the battery. This main fuse must have a greater capacity than any of the branch-line fuses. Thus, if your radio develops trouble, it will blow the radio fuse, and not the main fuse. When two fuses are in the same current path, the fuse with the lower rated value will blow first.

Normally you will not run the cable from the engine's starter through the fuses. The starter uses a very heavy current, and a fuse for this would be too bulky. Further, the starter is connected up only when the starter button is pushed. However, because of the heavy current, the starter cable must be as short as possible, preferably not over a foot or two. This, of course, will mean that the battery must be placed close to the engine.

Fuses suitable for marine use differ in size and shape. Fuses which clip into place are usually preferred to the screw-in type, because they will not be loosened by engine vibrations. However, any fuse is subject to corrosion in a damp or corrosive atmosphere. For that reason, a dry location should be chosen. Fuses which may never blow because of appliance trouble or wiring may fail because of corrosion. That is, the wire or strip inside of the fuse may break from corrosion and cause the circuit to fail.

A full supply of spare fuses should be kept on board, and these should be inspected from time to time and replaced if they show signs of corrosion.

The connection to the battery should be secure. It might be convenient to have a clip-on connection if you find it necessary to change batteries, but this stunt can get you in trouble if the clip falls off while your generator is running. The generator on a marine or auto engine develops a voltage somewhat higher than the battery. This is necessary because the generator must have a higher voltage to force a charge into the battery.

Normally, the battery loads down the generator and keeps the voltage within safe limits. However, if you should lose the connection to the battery, the generator voltage might rise and burn up a valuable radio transmitter or receiver. This can be avoided if separate wires and clips are used to the generator and to the fuse panel. The best system is to have all connections to the battery securely bolted in place, like the connections to an auto battery.

Of equal importance to the battery connection is the ground connection. Usually one side of the battery will be connected to it. The other pole of the battery, the one not connected to the ground, is usually called the "hot" side of the battery. The

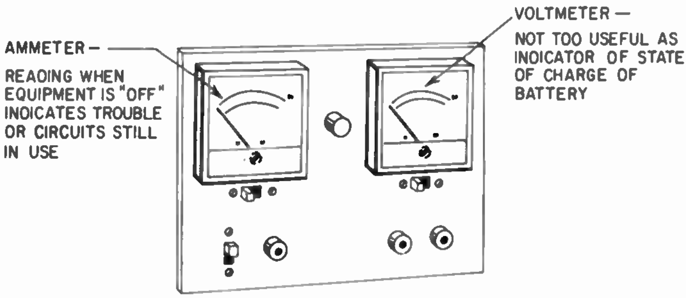


Fig. 411. *The correct voltage of a battery can only be measured when the battery is "under load" — that is, when it is delivering current to equipment. The position of the ammeter needle is an indication of whether the battery is charging or discharging.*

polarity (+ or –) used for the hot and for the grounded side may be different with different vessels.

With some electronic equipment, the polarity does not make a difference. However, the difference between the hot and grounded side, whatever the polarity, is of prime importance. Be sure you get the wire connections correct in this respect when connecting up a radio. The installation handbook for the apparatus will tell you how.

The grounded side of the battery should be connected by heavy wire to everything else in the vessel which is grounded—all electrical apparatus, the engine block, all pipes, any metal cables, and to the hull, if metal. Additional reasons for this will be given in a later chapter which deals with accessories, including electrolysis detectors.

The wiring system in a boat is just about the same as that used in an automobile. The connections shown in Fig. 410 are typical for a small boat.

Trouble

The boat owner who lacks electrical experience can nevertheless

Fig. 412. *A battery tester is a handy unit for getting a quick indication of the condition of a battery.* Courtesy Eico.

make certain emergency repairs aboard his vessel. Some of these, concerning radio receivers and transmitters, have been discussed in previous chapters. However, the nature of electrical circuits is such that the greatest trouble possibilities lie in the boat's wiring or power supply, rather than the radio apparatus.

In addition to proper fusing for each branch electrical circuit, a well designed wiring system will include a voltmeter and an ammeter. The ammeter may be of the type usually used on automobiles. It tells you two things: first, if the battery is charging or discharging; second, if any apparatus on the boat is drawing current.

A knowledge of the charging rate will warn you of generator failure. If you should notice the charging rate has dropped, it means either the generator is in trouble or the electrical apparatus on board is using current. If the meter shows discharge, it is time to find out why. If the electrical apparatus aboard is using more current than the generator can supply, it will only be a matter of time before the battery is dead.

The ammeter will also warn you of a forgotten radio or light which may be still using current when you think it is turned off

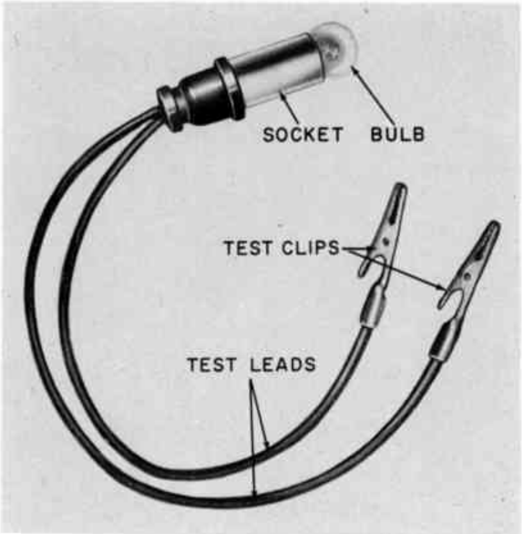


Fig. 413. *A "trouble lamp" consists of a lamp, a socket and two wires equipped with clips.*

(Fig. 411). It is easy to forget a radio if the volume is turned way down or if the station you were listening to left the air. The ammeter gives you a continuous indication of the current being used aboard. It also serves a purpose in searching for electrical trouble. If the ammeter shows current being used when everything is supposedly shut off, fuses can be removed one by one until the meter shows no current. This will tell you which branch circuit is using current.

A voltmeter gives some indication of battery condition, but the voltage limits between a charged and a dead battery are mighty small. Special meters are made to indicate battery condition (Fig. 412). These battery-condition indicators are available as finished instruments or build-it-yourself kits. They are valuable accessories for a boat's power plant, and they may keep you out of serious trouble by warning you of an impending dead battery.

In the event of an electrical failure on board, you will have to make some sort of repairs. Your boat's regular equipment should include spare fuses, vacuum tubes, vibrator, tape, long-nose pliers, diagonal side-cutting pliers, screwdriver, a length of insulated wire and a trouble test lamp. You can make up the trouble lamp yourself. It consists of a lamp (of proper voltage) in a socket to which is connected a couple of wires equipped with clips.

A trouble lamp of this sort is quite useful in lighting up a dark spot when you have to make a repair. However, it serves a quite different purpose in locating electrical trouble.

Continuity

A method widely used by electricians and radio men to locate trouble is called "continuity checking." This means testing

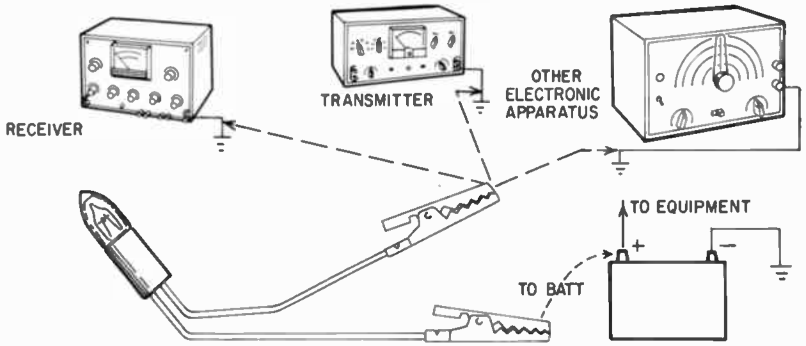


Fig. 414. *Method for checking the ground connections of all electronic apparatus.*

electrical circuits to make sure they are continuous, with no breaks. Of course, you can look at a wire and see if it is broken on the outside, and this should always be done when something fails. However, you can't tell if a wire is broken on the inside, under the insulation, and you can't always tell if a fuse is good by looking at it.

A wire fastened to a binding post may look and feel solid, but it may be corroded underneath where it is out of sight. This corrosion may prevent the current from getting through.

A trouble lamp (Fig. 413) can be used to locate such troubles. To use it, connect one of the clips to ground. Touch the other side to the hot side of the battery. This will make sure that the lamp lights, that the battery is good and that the place you have clipped on for ground is really grounded. This is one advantage of having everything metal grounded; it gives you places to hook your test lamp anywhere on the boat.

Suppose, for instance, that your radio wasn't operating. After hooking one clip of the test lamp to something which is grounded, touch the other end to the battery connecting post on the radio. If the wiring and the power board fuses are good, the lamp will light. This will tell you that the set is getting battery power delivered to it. If it still doesn't work, the trouble is either with the ground connection or inside the set.

The ground connection to any piece of apparatus aboard can be tested by hooking one clip of the test lamp to the hot side of the battery, or to the fuse board, and touching the other clip to the thing that is supposed to be grounded. The lamp will light if the ground is good (Fig. 414).

In attaching the clips to anything, make sure a good electrical

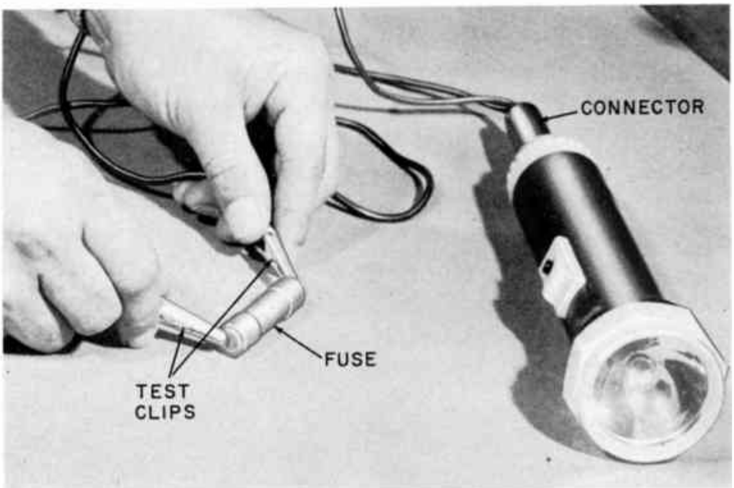


Fig. 415. *A continuity checker is a special flashlight equipped with two wire leads. If the fuse being tested is good, the light will glow.* (Ray-O-Vac Co.)

connection is made. The jaws of the clips usually are equipped with teeth. These teeth can be scraped around on a binding post to get a clean connection, by cutting through any dirt or corrosion which may be present. Make sure the side of the clip doesn't touch anything else.

Another important use to which a trouble lamp can be put is locating the cause for a blown fuse. Perhaps the most exasperating problem an electrician can encounter is that the fuse won't hold; that is, a new fuse blows as soon as you install it. You can rapidly use up your supply of spare fuses and still not find the trouble. When this happens in your home, you can find the trouble by screwing an electrical light bulb in the socket where the fuse is supposed to be.

You then can go around the house pulling every cord to lamps, appliances, etc., out of the wall until the lamp in the fuse socket goes out. When it does this, the device which you unplugged is the one with the trouble. All appliances should be switched "off" before trying this test.

The same thing can be done on your boat, except that the fuses are usually not of the screw-in type. So, instead of screwing in a lamp bulb, hook the clips from your trouble lamp across the fuse posts—one clip at each end of the fuse holder. If the fuse is blown and the trouble is still present, the trouble lamp will light.

Next disconnect whatever is on the other end of the wire, the radio, spotlight, horn, etc. If disconnecting the device puts out the light, the trouble is in the disconnected device. If the light still burns, inspect the full length of the wire, pulling it away from anything it may be touching. Look for bare spots, check carefully where it goes through decks or bulkheads. If necessary, pry loose wet or rusty staples or other fasteners. When the trouble lamp goes out, you will have cleared your trouble.

Another useful tool is a continuity checker (Fig. 415). This device looks like an ordinary flashlight, except that it is equipped with two leads with clips on the ends. These clips can be connected to each end of a fuse, wire or other electrical conductor. If the continuity is intact, the light will light. If a break exists, it will not. This gadget works independently of the boat's battery because it contains its own dry cells. Before using a continuity checker, touch the clips together and see if the lamp lights. This will test the lamp and the batteries and show if the device is ready for use. It should not be used on circuits connected to another battery, as this will burn out the bulb. The unit can also be used as a flash light.

Noise suppression

By noise suppression we mean suppression of noise caused in radio equipment by other electrical apparatus. You probably have had the experience of your home radio giving off a roar of noise when some appliance such as an electrical razor or the vacuum cleaner is turned on. The noise thus caused is called interference, and it plagues the operators of everything from television sets to guided missiles.

Noise in your radio or TV at home can be merely annoying.

Fig. 416. *A marine engine may require a shield to eliminate noise in the radio. This one is called a Tiffany Sparkshield.* (Pearce Simpson, Inc.)

On your boat it can be fatal. Therefore, it behooves you to make sure every piece of electrical apparatus aboard is treated for suppression of such interfering noise. Many appliances today have built-in interference suppressors, but not every electrical device is so protected. Modern automobiles equipped with radios have interference suppressors placed on the generator or ignition system as required.

The radio in your boat is much more sensitive to interference than is your radio at home. This is because the power of the stations you are going to listen to is not nearly as great as a broadcast station. The music being put out by some disc jockey might be loud enough to blast through a lot of noise. A marine station giving the weather may go unheard if the background noise is too loud.

Marine and other mobile radio receivers are usually equipped with a squelch circuit which silences the radio between transmissions so that the noise will not drive you crazy. The sensitivity of this squelch is usually adjustable by the operator. When listening for a weak station, the user may disconnect the squelch in the hope that he may hear the station over the noise.

Noise will always be present, from atmospheric conditions and other causes. You will not be able to prevent this, but you can help reduce it by taking the interference out of your own equipment. The boat's engine may need suppressors on the spark plugs or coil. The charging generator may need the same treatment. In some cases, the whole top of the engine and wiring may require shielding (Fig. 416).

Your radio equipment, particularly if it uses a vibrator or dynamotor, may generate interference all by itself without any help from other appliances. This is ordinarily taken care of by the manufacturer of the set: interference-suppression equipment is built right into the set. However, the suppressors can break down and fail, just like anything else. The sudden appearance of noise in your set may be due to the failure of the internal suppressors.

You can check this by pulling alongside a friend in another boat. Ask him to listen for the same noise when your radio is turned off. If his is quiet but noises up when you turn your radio on, it will indicate trouble in your radio. If he hears the same noise while your radio is turned off, the trouble will be coming from something else.

Every electrical device aboard your vessel should be checked for possible radio interference, and suppressors installed if necessary. Any device which uses a motor or an on-and-off contact, such as a flashing lamp, can cause noise in the radio.

chapter 5

accessories

PRACTICALLY every electrical automobile accessory can be adapted for use on a boat. In addition, there are a few more that are peculiar to marine operation. Of course, every boat owner will not want all of the accessories he can get, even if he can afford them. However, some devices can contribute greatly to safe operation.

Certain of these devices—radio direction finders and depth sounders—might be classed as major accessories, and will be described in a separate chapter. Others, which are of lesser importance, are discussed here.

Magnetic Compass

Perhaps the first-choice accessory, if it can be called that, is the magnetic compass. If you are likely to travel out of sight of land, or in an area where sight may be obscured by fog, you need a compass. The magnetic compass works on the principle that a magnetized piece of metal will line itself up with the magnetic poles of the earth. Any magnetized material will do this, if it is suspended so that it can move freely.

The ancient Chinese used a lump of magnetic ore called a loadstone, but the modern mariner's compass is a refined instrument. It consists of a circular card on which are printed the different directions, or "points" of the compass, and the degrees of a circle. The magnetic feature may be several magnetized needles or bars, attached to a circular card which is mounted so that it may turn freely on a pivot. The "wet" type compass contains a fluid upon which the moving part of the mechanism floats. This permits the card to remain relatively stationary, even though the boat may pitch or roll. This mounting method also prevents engine vibrations from affecting the compass.

The compass must be mounted in the vessel so that a center marking line inside the compass (called the "lubber line") is in line with the keel of the ship. However, even when correctly installed, the compass is subject to two kinds of errors. One is called *variation;* the other is *deviation.*

Variation

Variation in the compass reading results because the magnetic North Pole of the earth is not in the same place as the geographical North Pole. Thus, the geographic North Pole is at

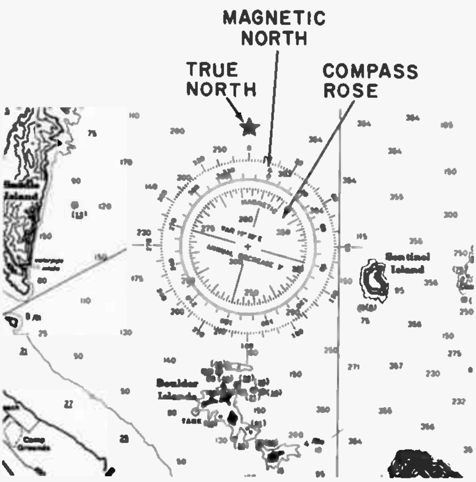


Fig. 501. *A portion of a US Coast and Geodetic Survey map of Lake Mead, showing the compass rose. This shows the magnetic North to be 15° 30' east of the true North.*

"the top of the world" where all meridians of longitude meet. The magnetic North Pole is in the Hudson's Bay region of Canada. Navigation charts, issued by the Government, each have a compass "rose" or circle printed on them which shows how much the magnetic North varies from the true North.

This variation is different in different parts of the world. Further, the variation may change from time to time. Therefore, always use an up-to-date chart. The magnetic compass, although it is said to point to the magnetic North Pole, actually aligns itself with the magnetic lines of force which cover the earth. While these lines ultimately end up at the magnetic North Pole, they are not straight lines. Hence the need for a chart which shows the variation in the waters where you are navigating (Fig. 501).

When using the magnetic compass to steer your boat, you must make the correction shown on the chart. That is, you must add or subtract from the reading shown on the compass the number of degrees of correction shown on the chart.

Deviation

The second type of error, deviation, is caused by other electrical apparatus in the boat, or by nearby masses of iron or steel. Any iron or steel object within 6 feet of a magnetic compass can cause the reading to deviate from the magnetic North. An object as large as the engine or as small as your windshield wiper can have this effect.

Electrical apparatus and wiring can also cause a compass error. The wiring going to your radio, spotlight or some other accessory sets up a magnetic field around it when the device is turned on. When it is turned off, this effect disappears. Therefore, a compass

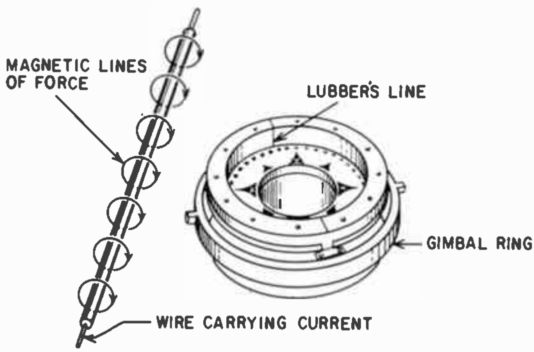


Fig. 502. *The magnetic fields around wires carrying electrical currents will affect a magnetic compass if close enough to it.*

which tests out to be accurate may develop an error when some electrical device is turned on (Fig. 502).

While the magnetic effect of the accessory itself may always be present, the magnetism sent out by the wiring can be corrected. Electrical circuits must have two wires. Every accessory or appliance must have two wires connecting it to the battery. In an automobile, the chassis and frame of the car are often used for one of the wires or as a so-called "ground return." When this is done, only one wire (from the "hot" side of the battery) goes to each lamp, horn or other device.

Electrically, this would be easy to do in a boat, also, if the hull were metal or if a ground wire ran around the vessel. However, the magnetic field set up around a single wire can cause the compass to deviate. If two wires are used instead of a common ground return, the two wires should be twisted around one another. This will cancel the magnetic influence of the wire.

The reason for this is that direction of the magnetic field is dependent upon the direction the current takes through the wire. On a two-wire circuit, the current goes out to the appliance on one wire and back to the battery on the other. Thus, on the pair

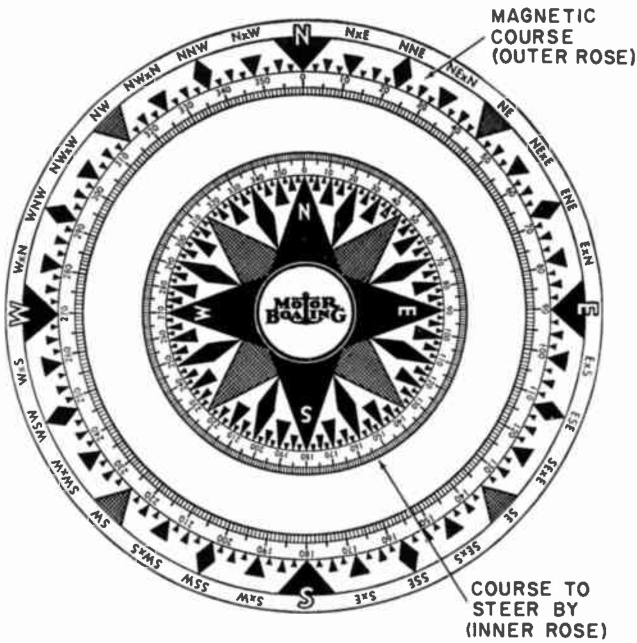


Fig. 503. *On this compass deviation card, lines should be drawn in the clear circle to connect points on the outer circle with points on the inner circle. The outer rose represents the magnetic course, while the inner rose is in the course to steer by. The connecting lines are to be placed according to the deviation of the compass.* (Copyright, Motor Boating. Used with permission.)

of wires, the current is going in opposite directions on each. Therefore, each wire sends out an opposite magnetic field, and the two opposite fields tend to cancel each other. Cancellation is most complete when the wires are very close together, that is, when they are twisted.

Correcting for compass deviation

A compass deviation caused by nearby iron or steel objects can be allowed for by making up a compass-deviation card to show the error (Fig. 503). This may be a card with two compass roses, one printed inside the other. Lines can be drawn from various compass points on the outside circle to points on the inside circle. This will show on one circle the magnetic direction your boat is taking when the compass reading is as shown at the other end of the drawn line on the other circle.

Deviation errors can also be corrected by placing small magnets

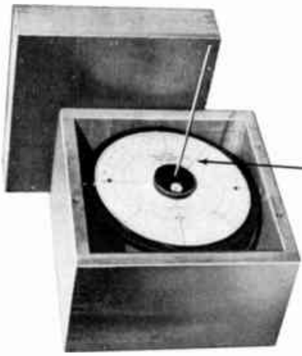


Fig. 504. *The DARRA compass corrector uses the shadow of a vertical wire on a circular card to mark the position of the boat while directions are being checked.* (Darrach Co.)

in several parts of the vessel which will counteract the effect of the metallic objects in the boat. The error can also be detected and corrected by using the sun as a reference point.

In practice, this method involves the use of a circular card, calibrated in degrees of a circle. From the center of the card, a wire projects upward. When placed in the sun, the wire casts its shadow on the card. This shadow gives you a reference point, which, if you don't wait until the sun moves too far, can be used to check the deviation of your compass.

The principle of operation depends upon the fact that deviations are equal and opposite on reciprocal headings. That is, if your compass has an easterly error of 20° on a north heading, it will have the same amount of westerly error on a south heading.

Thus, if you head your boat in a direction which you suppose is north, turning it around by 180° should show you are heading south.

To turn the boat exactly around, you use the shadow of the wire on the card, instead of the compass. If the compass has no deviation caused by interference, it, too, will show a 180° turn. If it shows a different reading, it will indicate a deviation error.

Professional equipment for the measurement of compass deviation is available. It is mounted on gimbals so that the chart and wire will remain level as the vessel moves. One such device is shown in Fig. 504.

Gyroscope compass

Large vessels use a gyroscope compass instead of the magnetic compass. The heart of the gyroscope is a small whirling flywheel. It is the equivalent of the gyro spinning top often sold in toy stores. It works on the principle that a spinning object resists having its axis of rotation displaced. Thus, the gyro toy can be moved up, down or sideways—any direction—as long as you don't try to make its axis point in a different direction.

The gyro toy can be set on a table, with the heavy flywheel projecting over the edge, yet it will not tip and fall while it is spinning, because it would have to change the direction of its axis in order to tip.

The gyro compass, after it has been spinning for a while, will line itself up with the axis of the earth. This is because, if it is not parallel to the earth's axis, the rotation of the earth will try to cause the gyro axis to point in a constantly changing direction. This forces the gyro to turn till it aligns with the earth's axis. Hence, the gyro points to the true North, not the magnetic North. This type of compass is subject to neither the variation nor deviation mentioned earlier.

A gyro compass is a complicated precision instrument. It usually requires a special electric drive mechanism to keep it up to speed and, in addition, an electronic system to transmit the readings from the gyro location to the helmsman. Thus, the gyro flywheel itself may be in a sheltered portion of the ship, but one or more indicators may be placed at convenient locations.

Recently, a compact model of this instrument has been developed for use on small boats. The unit, shown in Fig. 505, is a self-contained miniature gyro compass but with the principal features of larger units — true North, nonmagnetic, and free from magnetic disturbances. The operation of the compass is controlled by two switches on the front of the compass control box. The fuses are also on the front of the control box, readily available for replacement. Access to the master compass is obtained by opening the hinged plastic dome. The amplifier and power supply are completely transistorized and complete sections or individual com-

Fig. 505. *True North heading is displayed on the compass card. The gyro compass is designed to be mounted on a pedestal or shelf near the steering station. No repeater compasses are needed.*

ponents can be removed for servicing. All major components are standardized and interchangeable.

Automatic pilot

Driving an automobile is a full time job for the driver, but because of its lower speeds and the wide spaces in which it travels, a boat can steer itself much of the time. That is, it can if it has an automatic pilot. When the boat operator wants to travel and fish at the same time, he can use an automatic pilot to steer the boat while he fishes.

Also, if the vessel is to be held on the same course for a long time, such as on the open sea or a large bay or lake, it can be quite tiring to the helmsman.

An automatic pilot (Fig. 506) consists of a magnetic compass and an electric eye to "watch" it. It is made up of a magnetic needle or equivalent, attached to a horizontal transparent disc. The disc has blackened segments on it like the blades of a propeller or shutter. Above this disc is a small lamp which aims

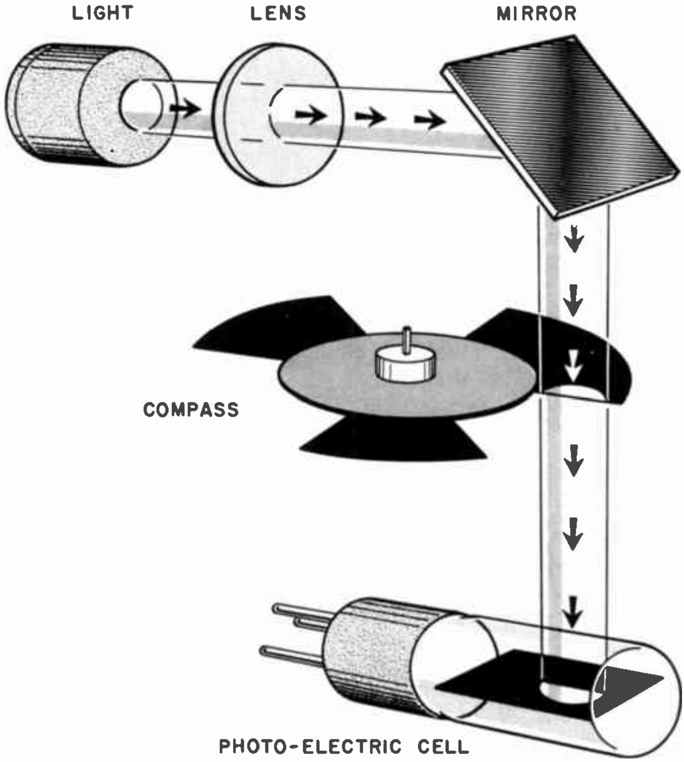


Fig. 506. *The heart of the automatic pilot is a unit consisting of a magnetic compass and an electric eye to watch it.*

a beam of light at a photoelectric cell (or phototube) below it. The photoelectric cell is a tube which converts light into electricity.

If the disc is positioned so that the light beam goes between the shutter blades, the light will generate a full amount of electricity in the phototube. If the dark portion of the shutter cuts off the light, no current will be generated. If the shutter blade cuts off part of the light beam, an intermediate amount of electricity will be developed in the phototube.

The phototube is electrically connected to a pair of sensitive relays which will operate or release, depending upon how much light falls on the phototube. These relays, by their operation and release, cause a steering motor to turn the rudder one way or the other. The main components of a typical unit are shown in Fig. 507.

In operation, the boat is put on its course and the compass in the automatic pilot is adjusted so that the light beam inside is partially cut off by a darkened portion of the disc. This puts the device in a "neutral" condition. That is, the sensitive relays connected to the phototube will not move steering motor one way or the other.

As long as the vessel remains on this heading, nothing will change. However, if the craft should deviate even slightly from

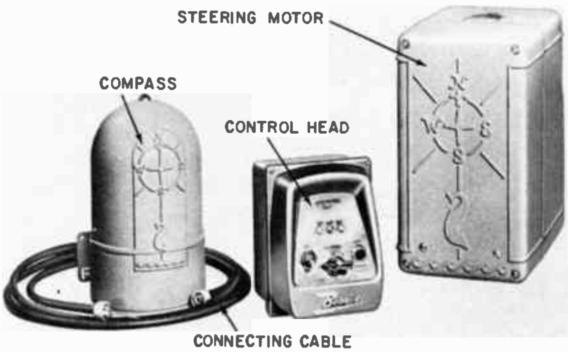


Fig. 507. *The three essential units of the automatic pilot are the compass, the control head and the steering motor.* (Bendix)

its course, the lamp and phototube, being stationary with the boat, will change position also. The disc through which the lamp shines, however, always points to magnetic North, so the movement of the ship will cause the shutter to intersect either more or less of the light beam.

If more light goes through, one of the relays will respond, the steering motor will be started and the rudder turned as needed. If less light goes through, the other relay will respond and the steering motor will turn in the opposite direction and move the rudder the other way.

This is a very simple description of the basic principle of operation; the automatic pilot is actually more complicated than this. For instance, if you have piloted a boat, you know it does not respond to the wheel as does an automobile. In fact, there seems to be a definite lag between the time you turn the wheel and the time the vessel responds. This could be confusing to an automatic pilot.

For instance, the simple device we have described would turn the rudder as soon as the vessel deviated from its course. Because the vessel would not correct its course instantly, the automatic pilot would continue to turn the rudder. By the time the boat caught up with the pilot, it would be going around in circles. The automatic pilot would detect this as a deviation in the opposite direction, and would immediately throw the rudder hard over the other way.

Thus an automatic device could "hunt" back and forth continually, trying to keep the boat on a straight course but actually sending it on a zig-zag path. To prevent this, automatic pilots are built with delay features in them, so that a steady course can be held.

The automatic equipment also is equipped with "limit switches" which shut off the steering motor when the rudder has been turned to maximum in either direction. In practical operation, the helmsman may want to change the course temporarily, and then return it to the original course on the automatic pilot. For instance, he may wish to turn slightly to pass another vessel or to avoid a floating object.

To accomplish this, the automatic pilot may be equipped with remote hand control. This is a hand-operated switch which will take control away from the automatic pilot. It may be located in any part of the vessel, not necessarily at the helm. For instance, it might be at the stern. A man could be fishing from this point and have with him the push-button box which controls the automatic pilot. If conditions required it, he could, by operating the buttons, divert the boat from its set course. He could return it to automatic control whenever he desired, without ever leaving his place at the stern.

The lamp and photoelectric cell in an automatic pilot use little current; the steering motor uses much more. In installing an automatic pilot, wire of a size adequate to supply the motor current should be used. Normally the steering motor will not be in constant operation but, when it is, it uses current from the ship's batteries. Therefore, allowance must be made for this, and the vessel must have a charging plant and batteries large enough to carry this added load.

Wind indicator

An accessory which finds a good deal of use on sailing vessels is the wind indicator. This may consist of two instruments, one for measuring the direction of the wind and the other for measuring its speed. The control elements for both are usually placed where they have free access to the wind, such as on top of a mast. The speed indicator can consist of the same sort of unit used at weather stations—a pivot containing three arms like spokes of a wheel (Fig. 508). On each arm a cup is mounted where it can catch the wind.

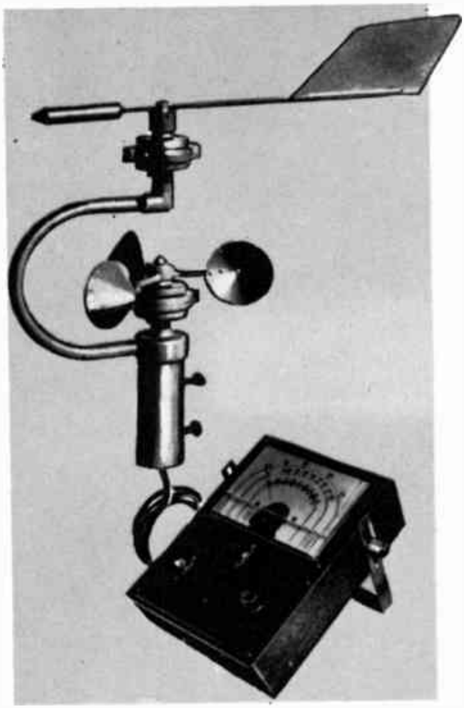


Fig. 508. *Wind velocity and direction indicator gives direction and velocity on one dial, indicating from 0 to 100 miles per hour.* (Lafayette Radio)

As the wind strikes these cups, it spins them around the center pivot. Inside the device is a tiny electric generator. As the cups whirl around, the generator is turned, and electricity is developed. This current is wired down to a meter which is in sight of the helmsman. This meter is actually the same thing as a voltmeter, and it measures the voltage being put out by the little generator on top of the mast.

In practice, instruments of this sort have the voltmeter calibrated in miles per hour instead of volts, so the helmsman can read the wind speed just as he would read the speedometer on his car.

The wind-direction indicator can consist of a weather vane which will blow around and point toward the wind. This also would be mounted in a high, clear place. In one type of operation, the movement of the pointer can turn a small rheostat which is electrically connected to the ship's battery. Turning the rheostat will change the amount of current being fed to another meter mounted in front of the pilot. The needle on this meter will move back and forth as the current changes, which will occur every time the wind direction changes. Thus the needle will show the wind direction. The electrical hookup for a wind-direction indicator can be much the same as that for a rudder-position indicator.

Rudder-position indicator

Normally the pilot of a vessel doesn't care where his rudder is pointing as long as his boat is headed in the right direction. The rudder may be pointing differently from the direction of the vessel's travel, because wind and tide may also be affecting the movement of the boat.

However, when a vessel is standing still, particularly when near another vessel or a dock, the position of the rudder becomes important. If the rudder is hard over right, for instance, and you accelerate the motor, you may crash into the dock. If you plan to move astern, the problem may be even more difficult, because a boat does not respond to the helm in sternway operation until perhaps 3 or 4 knots of speed is attained. This is because the propeller is then pulling water away from the rudder instead of forcing the water toward it.

Thus, the rudder will not turn the boat until the vessel is moving at a sufficient speed backward to cause the water deflection pressure to get up enough force to act on the rudder. If the rudder is pointed the wrong way when this happens you may get into trouble.

Of course, on some vessels, you will be able to turn the wheel all the way in one direction or the other until it strikes the stopping device. At least this will tell you if the rudder is then all the way left or right. However, the rudder gear on vessels, like the steering systems on some autos, does not always go to the same extreme in both directions. That is, the linkage may be such that you can make a shorter turn in one direction than you can in the other. In such cases, turning the wheel from one extreme to the other still would not permit you to guess accurately the middle or "straight-ahead" position.

An instrument which will solve this problem for you is a rudder-position indicator (Fig. 509). A little cylinder resembling a small tin can, it contains a rheostat or potentiometer. This is a small variable resistance which operates like the volume control on your radio set. When the shaft on it is turned, it varies the

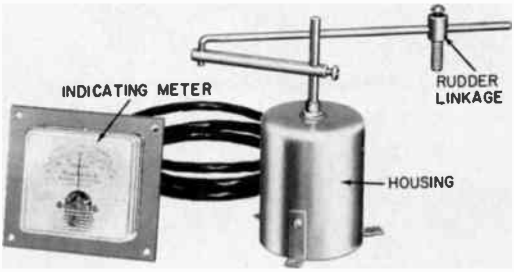


Fig. 509. *The parts used in a rudder-position indicator.* (Heath Co.)

electrical current going through it. This little unit is called a transmitter, because it transmits the position of the rudder to the receiving unit. The transmitter is coupled to the rudder by a linkage arm so that, when the rudder swings, the shaft on the potentiometer is rotated.

The transmitting and receiving units are connected by three wires. In addition, the system must be connected to the boat's battery. This device, as well as several of the other accessories, are available as "do-it-yourself" kits at a considerable saving of money. Every boat owner should try to learn something about electricity so that he can make emergency repairs when required. A good way to get this knowledge is by assembling some of these kits. A person without previous electrical experience can put one of these things together. And if you are able to build it, you will be able to fix it.

The circuit diagrams for several of these accessories are given here to show how simple they are to follow. The rudder-position indicator operates on the principle of a device known to electricians as a Wheatstone bridge. In the circuit shown (Fig. 510) electric current will come out from the boat's battery on the wire marked "—" (minus or negative). It will go back to the battery on the wired marked "+" (plus or positive).

The amount of current that flows in any circuit depends upon how much resistance the current meets. Electrical resistance is measured in *ohms*. The resistors used in radio and electronic circuits like this one are usually made of carbon. This is because

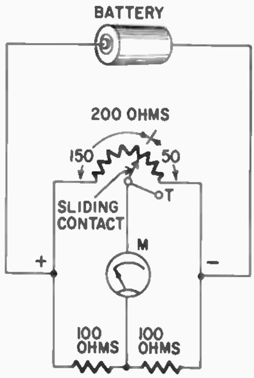


Fig. 510. *Circuit diagram for a rudder-position indicator.*

carbon offers more resistance to electric current than does copper. Thus, in the drawing shown, the zig-zag lines are resistors made of carbon, while the straight lines are wires made of copper.

The drawing shows two resistors at the bottom which are labeled "100" because the value of each is 100 ohms. Above these is a resistor of 200 ohms. This is adjustable. The arrow indicates a sliding contact can be moved around to touch different parts of the resistance. This is connected to the rotary shaft in transmitter T of the rudder-position indicator. Meter M is the receiving unit and is near the helmsman.

Normally, if the rudder is straight ahead, the arrow will be in the center of the 200-ohm variable resistor. Under these conditions, the current which comes in at "—" will divide equally through the 200-ohm resistor above, and the two 100-ohm resistors (which add up to 200) on the bottom. The current will then return to the battery on the "+" wire. No current will go through meter M if the pointer arm is in the exact center of the 200-ohm variable resistor.

If, however, the rudder moves to right or left, it will move this arm in transmitter T. If, for instance, the arm moves right in the diagram as shown, there will then be less resistance to the right of the arrow than there is to the left. Suppose it is at the quarter point. There will then be 50 ohms to the right and 150 ohms to the left (still 200 total).

Now, electricity favors the shortest path, the path with the least resistance. (Don't we all?) If the arm is at the quarter point, the circuit will still be 200 ohms from "—" to "+" on either the top or bottom branch. But the line of least resistance will be from "—", through the right side of the variable resistance which now has 50 ohms, through the meter, through the left-hand 100-ohm resistance in the lower branch, thence back to the battery on the "+" wire.

Thus, while the upper and lower branches still have 200 ohms of resistance each, moving the arrow at T created a path of only 150 ohms by steering the electric current through the meter. This causes the meter to move, which tells the pilot that the rudder has

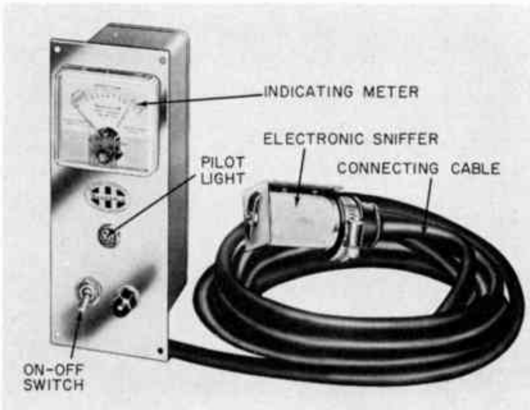


Fig. 511. *A fuel-vapor detector. It consists of an electronic sniffer on one end of a cable, and an indicating instrument on the other.*

moved. Normally a meter of this sort would have the zero point in the center, and the needle would move to the right or left as the rudder moved right or left.

Fuel-vapor detector

One of the greatest hazards to a vessel which must carry gasoline aboard is the collection of gasoline fumes in the closed portions of the boat.

If gasoline leaks in an automobile, it usually drips on the pavement and evaporates. But everything that is dropped or spilled in a boat may eventually end up in the bilges. A half of cup of gasoline has enough power, when vaporized and mixed with air, to move a 2-ton automobile ½ mile in about 30 seconds. This is more power than a lot of explosives have.

Even the slightest gasoline leak can cause the buildup of a deadly explosive gas mixture inside of your boat. A touch of the starter can ignite this mixture and blow the boat to splinters and kill everyone aboard. Different methods have been used to avoid this hazard. One method is to use a ventilating fan or blower that

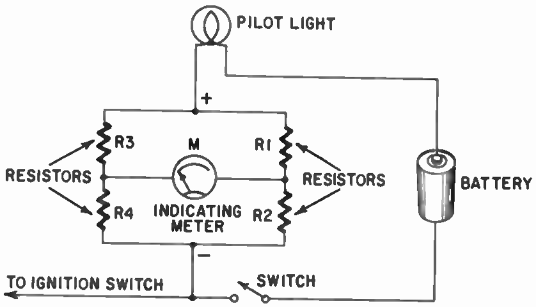


Fig. 512. *Circuit diagram of a fuel-vapor detector.*

will blow fresh air into the bilges before you start. The fan, of course, must be sparkproof or placed where it will not ignite the gas. That is, it should not be placed so that it will suck the explosive mixture into its own motor.

A simple protective device is a bilge gas detector (Fig. 511) which will constantly indicate if an explosive mixture exists below decks. Electrically this device works on the same principle as the rudder-position indicator—that of the Wheatstone bridge.

Fig. 512 shows the hookup. Assume that resistances R1, R2, R3 and R4 are equal. Current coming in at "—" will then travel through both branches of the circuit and leave at "+" and no current will flow through the meter.

Resistances R1 and R2 in the fuel-vapor detector are actually filaments in a tube that resembles a small electric lamp. One of these filaments is the actual gas detector; the other is used as a reference. The principle on which the device works depends upon the fact that combustible fuel vapor will start to burn if it comes in contact with certain other things, such as spongy platinum. As the vapor starts to ignite, even though no flame can be seen, the filament is heated by the combustion. Electrically this causes the resistance of the filament to change.

If, in Fig. 512, R1 represents the detector filament, and the vapor makes it get hot, its resistance will change. R1 will no longer be the same as the other resistances. As a result, a shorter path for the current will appear through the meter. The current will take this path and the meter will register, warning you of the presence of fuel vapors.

Normally, a detector filament, if it gets hot enough to ignite the gas, would do just that. To prevent this, the detector is enclosed in a small screen cage. Although air or vapors can go through a screen, fire cannot pass. You can demonstrate this by putting a piece of screen on top of a lighted gas stove. The flame will mushroom out under the screen, but will not come through it. On the other hand, you can make the gas from the stove burn above the screen, but not under it.

In the fuel-vapor detector (if an explosive condition exists) the vapor inside the detector may actually explode with small popping sounds, but the flame will not escape from the screen enclosure.

Because the detector works on the principle of heat changing the resistance, ordinary changes in temperature could cause a false indication were it not for the reference resistor, R2. This is the same kind of filament as the detector filament and is mounted right next to it, but it is sealed off so that the vapors cannot reach it.

If the temperature inside the boat rises, the resistance of both the detector and reference filaments will change by an equal amount. This will keep the electrical circuit "equal," and current will not flow through the meter. If vapor is present, however, the detector filament will change resistance but the reference filament will not, because it is sealed from the atmosphere. Thus a meter reading will occur.

In use, the vapor detector would be turned on before starting the engine and kept on while the engine is running. Some boat owners prefer to wire the ignition switch through the vapor-detector switch. Thus, the engine cannot be started unless the detector is turned on first. In the circuit of Fig. 512 a pilot light is shown. Notice that, to light this lamp, the current must pass through the detector. Therefore, if the wiring in or to the detector fails, the light will go out, which will be your warning that the system is out of order.

Battery-charge indicator

In the chapter on power supplies, the advisability of having a voltmeter on your boat's battery system was mentioned. Perhaps of greater use is a special type of voltmeter called a battery-charge indicator, which is also available in kit form. A brief reference to this was made earlier on page 72 and illustrated in Fig. 412.

This meter, instead of being calibrated in volts, is marked in "percentage of charge." Equipped with a multi-position switch, it can be flipped from one battery to another if you happen to carry several with you. The meter gives a direct reading which gives the approximate charge on each battery, and also tells if it is discharged or overcharged.

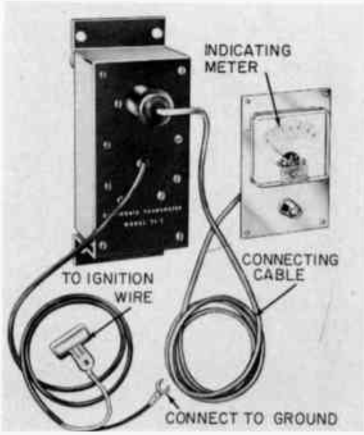


Fig. 513. *An electronic tachometer. It registers the engine speed in revolutions per minute.* (Heath Co.)

This type of instrument can get you more life from your batteries by helping you to avoid undercharge or overcharge. It can also warn you if your batteries are too low before starting out.

The condition of batteries can also be checked with a hydrometer, but this often means crawling in the bilges of the vessel and messing with sulphuric acid. The use of a battery-condition indicator lets you make a reading from a safe, comfortable location.

Tachometer

The pilot of a water-borne vessel cannot accurately measure the true distance it travels, or its actual speed, compared to the shore. However, these figures may be computed if certain other facts are known. Among the facts necessary to compute the distance you travel is the speed of your engine. The actual speed of the vessel may be affected by wind, currents or tide. A navigator knows how to allow for these variable factors, but he must also know the speed of the engine.

This speed is usually noted in terms of revolutions per minute. A speedometer, such as on an automobile, may operate by means of a rotating magnet which attempts to drag the indicating needle along after it. A wind-speed indicator operates by generating an electric current.

A tachometer, of the type used on small boats and some automobiles, is actually an electric counting circuit, which counts the rate at which the cylinders are firing. One make, a build-it-yourself kit (Fig. 513), uses three transistors in its circuit. It is connected to the engine merely by clipping a pickup lead to one of the high-voltage ignition wires. The spark-plug voltage is so high that it is not even necessary to connect the pickup clip to the bare ignition wire; it may be clipped around the insulation.

Each time the spark plug fires, a pulse of electricity is received by the pickup wire. These pulses are fed to a transistor amplifier which has a meter in its current supply. The more rapidly the pulses come through, as the plug fires faster, the more current the transistor amplifier will use. This can be read on a special meter which is calibrated in revolutions per minute.

While a speedometer requires a mechanical connection to a rotating part of an engine or transmission, a tachometer of this sort needs only a clip fastened to an ignition wire.

Electrolysis

In most cases when metal and water get together, corrosion of the metal results. This corrosion is both an electrical and chemical reaction. Actually, every time any metal corrodes—even when a tin can rusts in a vacant lot—electricity is being generated, even if in tiny amounts. Whenever metals and water get together, they form a battery cell. A battery cell in your flashlight, for instance, is made of two electrical conductors, a zinc cup and a carbon rod. A moist chemical fills the zinc cup. As the cell is used up, the zinc corrodes and electricity is given off.

The same thing can happen on the bottom of your boat. If two metals, or conductors of different kinds, are immersed in water, one will become a positive electrical pole and the other will become a negative pole. The metal which becomes positive will corrode. You may notice that in your automobile, the positive terminal of the battery frequently develops corrosion.

This action is called *electrolysis.* It can occur anywhere that different conductors are in contact with moisture. On a boat, the action can be very subtle. An expensive bronze propeller can be eaten away by the water, just as if it had been dipped in acid. Electrolysis can exist even if you have no battery or other electrical source on your boat.

A boat free of electrolysis may suddenly develop it when connected to a power supply on shore. The installation of a radio or other electrical device on board may cause electrolysis to develop where none existed before, if all grounded objects are not securely connected together.

Protection against electrolytic corrosion may be accomplished in a number of ways. For corrosion to occur, there must be moisture between the two metals. That is, the electricity must travel through water to get from one conductor to the other. The simplest way to avoid corrosion of this kind is to connect the two metals solidly together, by bolting, soldering or welding. If no water gets between the mating surfaces, corrosion will not occur.

When metallic pieces, like the ground plates on the hull required for a radio transmitter, and the propeller shaft or rudder cannot be brought into metallic contact outside the hull, the connection is made by ground wires inside the hull. That is why all grounded parts on the vessel should be connected together solidly. It prevents the electric currents which cause corrosion.

Electrolysis can also be prevented by the use of a "sacrificial anode," a piece of metal which is electrically positive to other metals. Zinc, aluminum and magnesium are positive compared to copper, bronze and some other metals. If such an anode is fastened to the vessel below the water line, and connected to other submerged metal parts, the zinc or magnesium or aluminum will corrode instead of the bronze propeller.

As this metal corrodes, it can be replaced. But the other metal parts will not corrode. Another method is to connect a source of direct current to the metal parts of the boat which are in the water. The negative terminal should be connected to the vessel, such as the metal hull. Its positive terminal should be connected to another plate immersed in the water. This will result in corrosion of the plate instead of the vessel. With this system, current must be kept flowing all of the time. This is the way the "mothball" fleets are preserved, but this method might be too expensive for the small boat owner.

Detection of electrolysis

Regardless of the method used to combat electrolysis, it is useful to know when it is occurring. Another instrument of the build-it-yourself type consists of a meter, one side of which is wired to the ship's engine and the other to a special detector plate mounted in the bilge water of the boat.

Fig. 514. *The electronic megaphone has a built-in amplifier.*

This meter will show you if electric current is flowing between the engine and the hull and the water outside, or to some metallic attachment on the hull. All of these points are supposed to be equivalent to ground and, if current is flowing between such grounded points, corrosion may occur. If the electrolysis meter shows a danger reading, it is time to haul the boat out of the water and remedy the trouble before your boat starts to fall to pieces.

When a boat is connected to shore power, electrolysis may develop if the grounded side of the shore plug becomes connected to the wrong side of the boat's battery supply and grounding system.

Instead of the shore ground and the boat ground being the same, one may be positive with respect to the other. This will cause the corrosion to start at once, on either your boat or the shore grounding system. If you leave the power plugged in, you may return to find the propeller corroded.

If you have an electrolysis detector aboard, you can be warned of this condition as soon as it starts. It may usually be corrected by reversing the plug to the shore power, or disconnecting it completely if necessary.

Megaphone

Any list of boat accessories should at least make mention of the electronic megaphone. This is merely a loudspeaking system. There are types which can be built permanently into a ship's electrical system. There are also portable types which are handheld; they have a microphone in the rear and a loudspeaker in the front, and a small amplifier. (See Fig. 514.)

Although devices of this sort will find application in water sports and simply as a plaything, a loudspeaker can also be the next best thing to a radio in times of distress. In fact, it may be better than a radio if you are stuck in the mud off shore and are trying to get help from the shore or a passing vessel which has no radio.

Some electronic megaphones designed for marine use are equipped with special circuits which enable them to be operated as foghorns also.

chapter 6

depth sounders

THE ancient Chinese did a fair job of navigation using a magnetic rock, but latter-day sailors have improved matters by adding a piece of line to their equipment. One use for a piece of line was to measure the speed of the ship. This was done by tying a piece of wood to one end of a line and then tossing it overboard. The drag of the wooden block caused the line to be unwound off a reel as the vessel moved forward.

Knots were tied in the line 47 feet 3 inches apart. As the rope paid out, a sailor would count the number of knots that went by in a fixed length of time, 28 seconds. If 10 knots went by, the speed of the vessel was then "10 knots." A "knot," therefore, means "nautical miles per hour." (The spacing between the knots on the line bears the same relation to a mile as 28 seconds do to an hour.) Therefore, the word knot automatically includes the thought "per hour." Thus, it is not correct to specify your speed in "knots per hour." It is correct to say "miles per hour," but it is "knots"—period.

A piece of line served one other important purpose, except perhaps for hanging an occasional pirate, to sailors of an earlier day. This was to indicate the depth of the water below the vessel. This information is a matter of more than mere curiosity. The depth of water has a great deal to do with the safety of the ship. It can also prove most useful in navigation and for locating fish.

The line which measured the speed of the ship was called a *log line*; the one used to probe the depths is called a *lead line*. It too uses knots tied at various intervals, some of which hold bits of cloth, leather or other things to identify one knot from another. Instead of a block of wood, it has a lead weight at the end to take it downward. The use of a line for measuring depth is by no means obsolete, but electronics has developed more sophisticated equipment.

Electronic devices for determining the water's depth are identified variously as depth finders, depth sounders, depth indicators and depth recorders. They work on the principle of sending a sound wave down through the water and measuring the length of time it takes for the echo to return. This measured time is then converted into distance.

Before the days of radar, skippers used the same principle for navigating through fog. They would sound their foghorn, then listen for it to echo back from a cliff or building on shore. In some locations, "echo boards" resembling giant billboards were erected in the water to guide ferries into slips. Sound travels about 1,100 feet per second in air. By counting the number of seconds from the time the foghorn blasted until the echo returned, the skipper could tell the number of feet from his vessel to the echo point *and back*. The one-way distance of course would be half the counted distance for the echo.

Radar uses exactly the same principle, but it sends out an electrical wave instead of a sound wave. The electrical wave travels at 186,000 miles per second, hence can be sent to great distances and back in an instant.

Electrical waves cannot be used under water, so sound is used in depth-finding apparatus. That is, the energy sent out is in a form of vibration in the water, just as sound is a vibration in the air. However, the frequency or pitch used is ordinarily much higher than the tones that we call sound. The human ear is doing real well if it can hear a "sound" which has a pitch of 16,000 cycles per second.

The pitch used for underwater sounding may be much higher than that—perhaps as high as 200,000 cycles per second. Therefore, it is not a wave which you—or a fish—can hear.

While sound travels 1,100 feet per second in air at sea level, it travels nearly 5 times faster in the water, but the speed varies with the amount of salt or other minerals dissolved in the water and with the temperature.

How they work

Depth indicators of different manufacture will have various design features, but a typical system will consist of an electronic oscillator or generator of the high frequency needed, a receiving amplifier, a transducer and an indicator. In operation, the oscillator will generate an alternating current which will have the high frequency needed. It will do this when triggered or pulsed by the indicator. The pulse of high-frequency electricity will be conducted to a transducer on the bottom of the vessel. This transducer is the equivalent of a telephone receiver or a loudspeaker; that is, it changes electrical vibrations into sound vibrations. A typical unit is shown in Fig. 601.

Because of the very high frequencies being used, neither a receiver or loudspeaker could respond to the vibrations, so the transducer is used. The transducer may consist of a ceramic material which will vibrate at the high speeds necessary. A quartz crystal and certain ceramics will bend or distort if an electrical

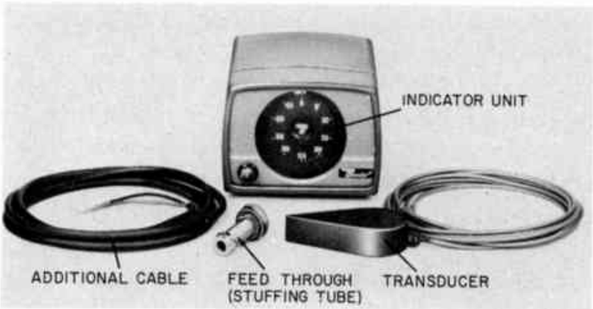


Fig. 601 *The principal units of a depth indicator are a transducer and an indicator. The cabinet with the indicator also contains the necessary electronic equipment.* (Bendix)

field is applied to it. If an alternating electric field is applied, the crystal will bend back and forth rapidly, and thus vibrate. If the crystal is in contact with air or water or anything else, these vibrations will be transmitted to the medium with which contact is made.

The reverse is also true with the crystal as well as the ceramic. If the material is mechanically distorted or vibrated, it will generate a tiny electrical current. The amount by which it bends or vibrates is too small to be seen, and the electrical current generated is very small, but it can be amplified and used. (Ceramic materials are often used in phonograph pickups because of this characteristic.)

When the transducer receives the electrical current from the oscillator, it vibrates and sends this vibration into the water. The vibration goes down to the bottom of the water and bounces or echoes back up to the ship. By this time the oscillator has stopped activating the transducer. The vibration coming back from the water then excites the transducer and causes it to generate a tiny electrical current. This current is amplified and is used to provide a reading on the indicator.

The indicator can be nothing more than a neon lamp on the end of a pointer or hand which sweeps around a meter face (Fig. 602). A small motor sweeps the hand around the face in a definite length of time. As the hand starts out at zero, it closes an electrical contact which makes the oscillator generate a pulse of high-frequency alternating current. This does two things. It causes the neon lamp to flash, thus establishing the zero mark. It also sends a spurt of vibrations into the water from the transducer on the keel of the vessel. In the next fraction of a second, the alternating current from the oscillator stops; the vibrations going into the water stop, the neon lamp winks out. But two things are going on. The first pulse is traveling to the bottom and back, and the hand on the indicator is moving around the dial.

When the vibration echo gets back from the bottom, it is picked up by the crystal transducer, changed into electricity and delivered to the neon lamp. The lamp again flashes, but this time the hand has moved away from the zero mark. If the dial is calibrated in depth, the point where the lamp is when it flashes the second time will register the depth of the water. It will do this because the instrument is designed so that the hand will move a certain amount in a certain length of time. The vibration and its echo take time also, so the time it takes for the echo to return can be converted into depth.

For instance, suppose the hand turns once per second. If it makes contact and sends out a pulse when the hand is straight up, the straight up, or "12 o'clock" position, is then marked "zero" feet of depth. As the pulse starts to the bottom, the hand moves around. Suppose the echo returns when the hand has gone a quarter way around, to the "3 o'clock" position. If the hand turns once per second, that will mean that the echo returned ¼ second later and the lamp will flash at the quarter point.

If the sound travels approximately 5,000 feet per second in water, it will travel one-quarter of this, or 1,250 feet in ¼ second. This means that the vibration from the transducer traveled 1,250 feet to the bottom and back in the ¼ second shown by the indicator. This was a two-way trip, so the depth of the water is half of this, or 625 feet.

The indicator dial on such an instrument would then be

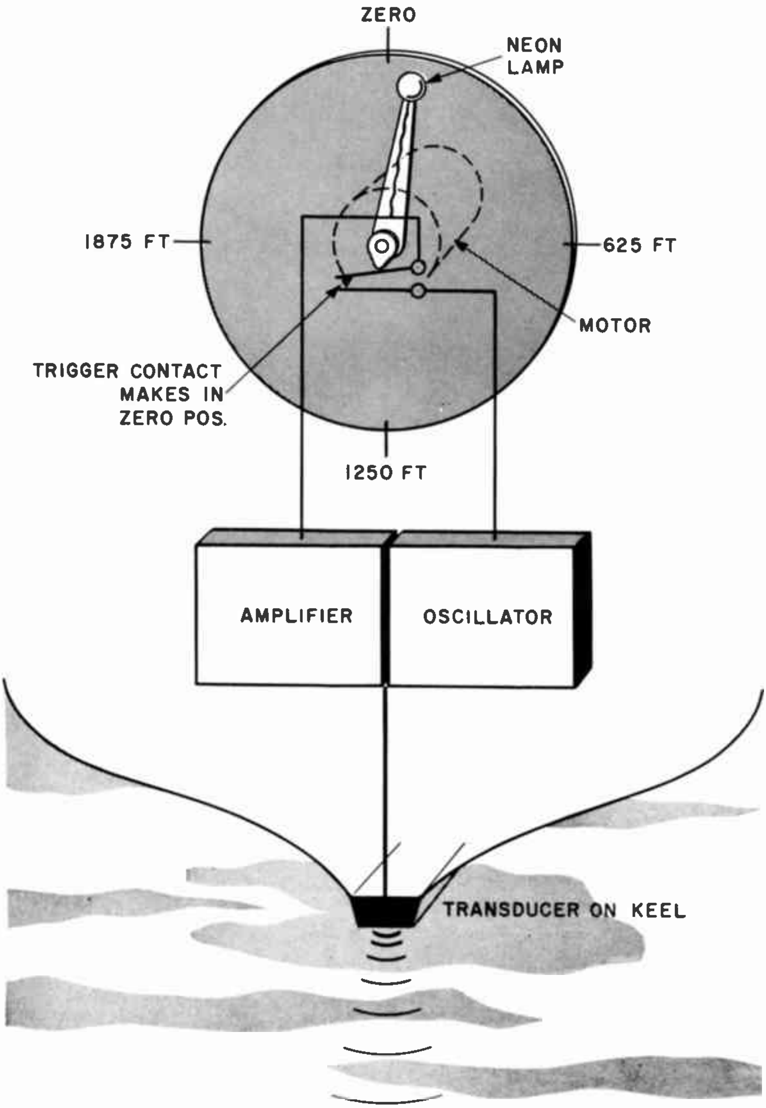


Fig. 602. *Diagram of a depth indicator. The indicating portion (top) consists of a motor-driven arm which carries a neon lamp around a dial.*

marked to show 625 feet of depth at the quarter point, 1,250 feet at the half point (6 o'clock position), 1,875 feet at the three-quarter point (9 o'clock position) and 2,500 feet for a full revolution of the indicator.

This is only a theoretical example. In the type of depth finders used by small boats, the indicator hand may travel three or four times as fast as this. Increased speed permits the instrument to measure shallower depths with accuracy. For instance, instruments for small boats may be obtained with maximum ranges of 100, 200, 300 feet, etc. Some depth indicators are calibrated in feet, others are marked in fathoms; some are marked in both. A fathom is 6 feet.

The method of marking is probably of little consequence to small-boat operators, but remember that navigation charts may also be marked in either feet or fathoms. Some marine charts are even marked in meters. The boat operator should make sure that his depth charts and depth indicator instrument are marked in the same terms.

Installation

The depth indicator, to be of most value, should be located where the helmsman can see it because, as will be shown later, it may be of prime importance in safe navigation. If there is a need for a depth indicator in more than one part of the vessel, a kind which uses additional indicating elements should be obtained. As with the gyro compass, the ship's radio and other accessories, it is possible to obtain remote indicating instruments. Thus, it would not be necessary to have two depth-sounder installations. Only one installation would be made, but it would be equipped with two indicators.

To read the indication of a depth finder, you must be able to see the flashes of the neon lamp. Therefore, the indicator should be placed where full sunlight will not shine on the dial. Some instruments are supplied with a hood or visor to protect them from the sun. Some are supplied with a swivel mount so that they may be tilted or turned.

If the indicator is mounted where it can be seen by the pilot, it probably will be close to the compass, which also must be seen by the pilot. If the depth indicator has any magnetic metal in it, it may affect the compass reading. For this reason some indicators are made entirely out of nonmagnetic material. This refers to the indicating portion of the equipment only.

When installing a depth finder on your vessel, find out if it is going to affect your compass readings and, if so, make or allow for the proper corrections.

The installation of the transducer also calls for careful work (Fig. 603). To function properly, the transducer must "couple" solidly to the water. That is, it must make clean and absolute

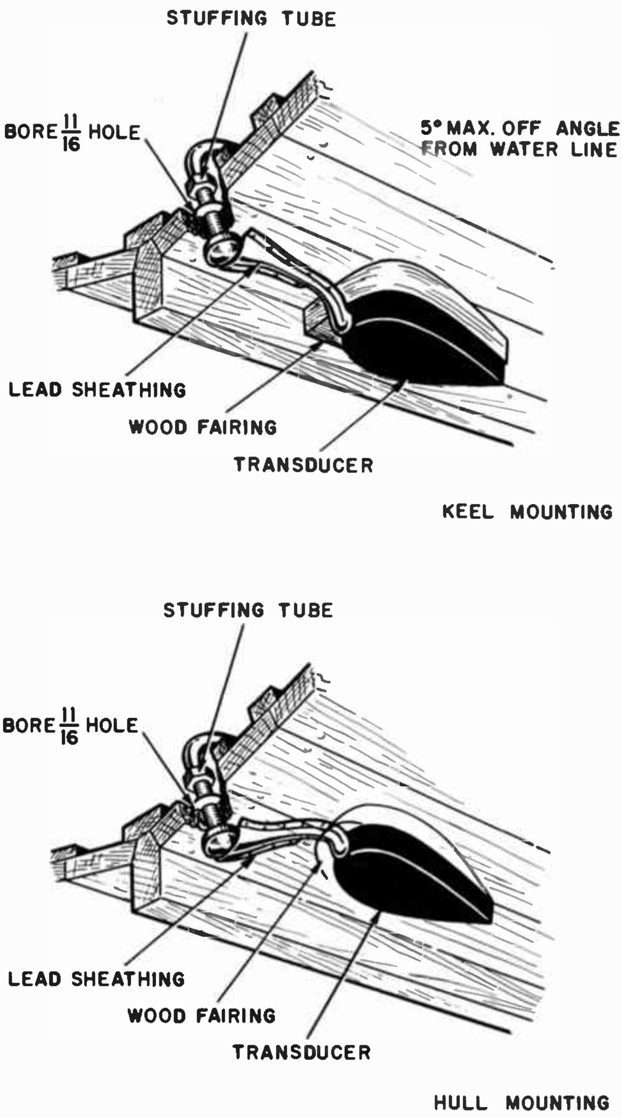


Fig. 603. *The transducer for a depth indicator may require a streamlined block or "fairing" to mount it to the hull.* (Bendix)

contact with the water. The presence of bubbles, oil or marine growth can cause erroneous readings. Many of these trouble possibilities can be avoided by careful installation.

The transducer normally should be mounted as close to the keel as possible. It should not be near anything that protrudes from the vessel which might cause turbulence in the water near the device. Generally it is best to fasten it amidships, far enough back where it will not be affected by the bow wave but not so far back that it will be influenced by propeller noises.

Grease or other contamination can cause bubbles to form or can prevent the water from "wetting" the transducer thoroughly. If this occurs, wrong indications may result. The transducer can be cleaned with household soap or cleanser and water.

It is important, also, that the transducer itself does not give rise to bubbles or turbulence as the vessel moves. To prevent this a "fairing" block can be placed around the unit. This is a carved piece of wood which streamlines the water flow around the transducer. Some models come equipped with a streamlined mounting which takes care of this.

The wire to the transducer should emerge through the hull of the ship as close to the unit as possible. Sheet lead can be tacked over the exposed portion of the wire, outside of the hull, to prevent abrasion. Inside the hull, the wire to the transducer should be run in a manner which will not parallel other wiring in the vessel, and it should be kept as far as possible from other electrical apparatus.

This is because, even at its best, the echo returning from the bottom of the water is very weak and must be amplified thousands of times to be strong enough to flash the neon lamp. The amplifier, then, is very sensitive, and any tiny electrical impulse which might be picked up by the transducer wire will be greatly amplified. This can cause false random flashes on the instrument, which can be most confusing.

The wiring from the amplifier to the ship's battery should be placed in accordance with the same good practices which prevail for the installation of any electrical apparatus aboard. The wire should be of adequate size, and the size should be increased if the wire run must be made longer than recommended. The manufacturer's handbook for a given unit usually will tell you the size and length of wire permitted for the particular installation.

The depth-finder equipment uses very little current but even so an extra long wire run may cause a reduction in voltage which will cause faulty operation. Also, although the current is small, it must be reckoned with in figuring the capacity of the vessel's power supply.

Interpretation

To use a depth finder to fullest advantage, you must be able to interpret the indications correctly. All the instrument does is to give you flashes of light at different parts of the dial. It is up to you to figure out if these flashes mean a rocky or muddy bottom, a sunken wreck, a school of fish or a patch of seaweed. A depth finder is usually equipped with sensitivity controls. Reconciling the setting of this control with the flashes received can tell you most of the things you want to know.

To get a good idea of how soundings are made, think of the transducer as emitting a cone of light, like a spotlight. This will shine down to the bottom, as in Fig. 604. If the bottom is hard and mirror-smooth, the beam will reflect straight up to the boat.

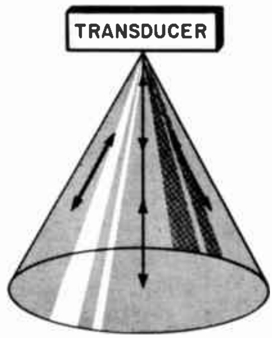


Fig. 604. *The signal emitted by the transducer may be thought of as resembling a conical beam of light.*

However, if the bottom is rough, as is more likely to be the case, many reflections will result. Some will return directly to the transducer. These will be the first echoes. On the indicator, they will register as the first, or shallowest, reading. This reading indicates the true bottom. Other reflections will bounce about, striking the surface of the water, then back to the bottom, then up to the ship again. These multiple reflections take longer to travel and register deeper on the indicator. They are of course, false indications (Fig. 605).

Many conditions can prevail at the bottom of the water; there may be sand, gravel, loose rock, mud, clay, seaweed or a pile of rubbish. A soft bottom usually will not return a clear, sharp indication. Several echoes may come from different depths in the mud, but there will be no single sharp pulse to start with, as will be obtained from a hard bottom. Further, to get an indication at all, it will be necessary to turn up the sensitivity control.

As far as the navigator is concerned, the highest point is the true bottom. That is, the shallowest point shown on the indicator is the point you have to contend with. Therefore, you should always read the leading edge of the light on the indicator. If several reflections are being presented, the first one is the one that counts.

Adjustments of the sensitivity control can clear up a reading on the depth indicator. If the adjustment is too high, random flashes may occur from seaweed, fish or electrical disturbances. If this is the case, the sensitivity can be turned down sufficiently to avoid showing the unwanted echoes, but still kept high enough to show the depth to the bottom.

Fishing

A depth finder will return echoes from single large fish and schools of smaller fish. At best, fish do not provide a good echo. This is because it is only the bladder, not the body of the fish, which returns the echo. Ordinarily it will be necessary to increase the sensitivity of your instrument to spot fish. This will also cause random flashes from other causes to register on your dial.

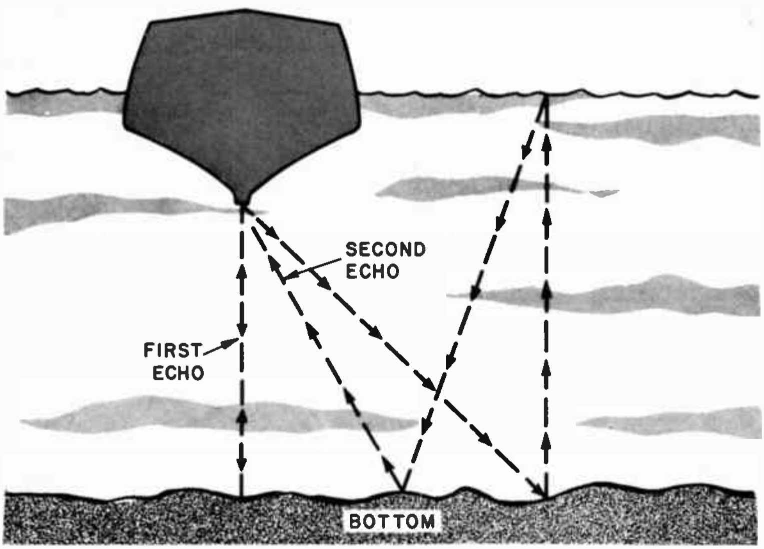


Fig. 605. *Multiple reflections cause second echoes which give false indications of depth.*

However, fish can usually be distinguished because of the fact that they move about and swim to different depths, and thus will show a changing indication on the dial of the instrument (Fig. 606).

The random flashes caused by fish will not interfere with bottom readings but, if the fish are close to the bottom, it may be impossible to identify the echoes returned by the fish. Whether you get any indication from schools of smaller fish will depend on the sensitivity and range of your instrument, the depth of the water and the size of the school. You probably wouldn't have any trouble spotting a tuna, however.

The best way to look for fish with a depth finder is to set the instrument for high sensitivity and operate the vessel at a very low speed.

Navigation

Perhaps the most important use for a depth finder is for navigation. Many boat owners declare that a depth finder is the next best thing to a radar set. Others say that if they could have only one accessory aboard, they would want a depth finder. These opinions spring from the philosophy that while you are still afloat, you are safe. You face a certain number of hazards whenever you decide to travel by any means of transportation.

Travel by water includes such hazards as running out of food, water or fuel or becoming disabled, getting lost and similar nettling situations. These things can happen even if you are traveling on horseback, but they are more serious if you are miles from

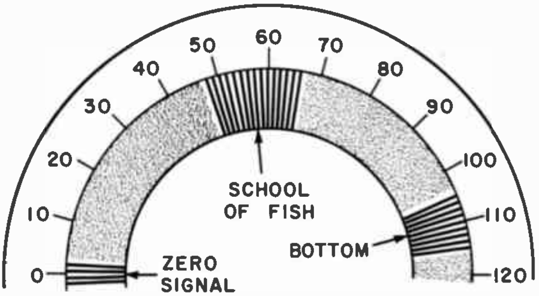


Fig. 606. *The flashes of light, represented here by the radial lines, show the zero signal, a school of fish and the bottom reflections.*

shore. However, while there is life, there is hope, and in a boat you are all right as long as you are above water. You may be cold and hungry, but you still have a chance to see better days.

Therefore, the first consideration in piloting a vessel is to keep it floating. This means not tearing the bottom out on a submerged rock or sunken wreck, and it also means keeping it off mud flats, from which you can neither walk nor swim home. It also means keeping the vessel on your charted course and traveling safe waterways to your destination.

This may be easy to do on sunny days when you can see the shore, but it may be difficult at night or in foggy weather. To pilot your vessel safely—indeed, for you to go any place at any time—you must know where you are. All of the aids to navigation are designed to answer the question, "Where am I?" The depth finder is one of these aids; others will be discussed in the next chapter.

To use the depth finder for navigation requires the use of a chart for the waters on which you are traveling. These charts, prepared by Government agencies, are readily available. A list of places where they may be purchased is included in the appendix.

It is important that you use up-to-date charts. They are cheap enough and it is poor economy to use old ones. Conditions are constantly changing. Sand bars build up and make the water more shallow. Dredging operations may change ship channels. Vessels sink and become underwater menaces to navigation. Pipe and cable laying operations often alter conditions. New bridges or suspended wires may make new obstacles to water travel. Buoys and other aids to navigation are changed.

These things go on continuously. The masters of large vessels are apprised of such changes by a publication called *Notice to Mariners,* which is received by all steamship companies. It is usually received also at marinas or boat liveries where there is small-craft activity. In addition to this publication, the information is being constantly brought up-to-date by radio broadcasts by stations on marine radio frequencies.

On vessels which are constantly manned, it is easy to keep the charts up to date by making the corrections called for by the *Notice to Mariners* and the radio broadcasts. The weekend sailor hasn't the time or facilities to do this, so he should check on present conditions at the marina before he starts out. He should also make it his business to get a new chart every time one is reissued.

With an up-to-date chart and a depth finder, a small-boat operator is reasonably safe. In darkness or fog, he can avoid running aground by staying out of shallow water. If he does not know his own location exactly enough to proceed under poor visibility conditions, he can learn his location by making a "line of soundings." This consists of proceeding in a definite direction and keeping a record of the various depths registered by the instrument. When you have a series of such readings, you can check for your approximate location on the chart by noting where the bottom readings are approximately the same as those which you recorded.

Your location can be further confirmed as you travel if you meet the depths shown on the chart. In a great many cases the character of the bottom will be sufficiently different in different locations to enable you to bring your vessel safely back to port, just as easily as if you could see your way. However, allowances must be made for differences in depth caused by the tide, and the chart must be the correct one.

A knowledge of how to distinguish between different bottom conditions is also useful in navigation, because the Government charts often show the condition of the bottom at various spots.

Portable instruments

While a depth indicator has been thought of as a permanent installation on the boat, portable equipment is also available (Fig. 607). The great increase in the number of small boats,

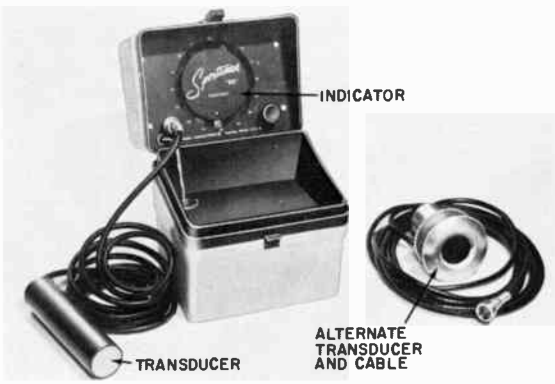


Fig. 607. *A completely self-contained depth indicator. The case and indicator can be set up anywhere on board the vessel, and the transducer placed over the side, below the water line.*

particularly ones which cannot be locked up when unattended, has accentuated the need for equipment that can be removed and stowed somewhere. Portable radio transmitters and receivers are now made and the development of improved transistors has accelerated this trend.

Transistor depth finders are made which are not only portable from a standpoint of being easily movable, but are completely self-contained, with no permanent attachment to the vessel. Operating on a self-contained battery, they can be used on an outboard or other vessel which has no ship's electrical system.

Further, they require no permanent attachments to the vessel. Although a through-the-hull type of transducer connection can be supplied, these units may be equipped with a transducer which is portable also. The transducer consists of a small cylinder which can be fastened to the side of the vessel below the water line. The indicating dial is built into the cover of the case which contains the amplifier and batteries.

Depth recorders

An improvement over the depth finder is the depth recorder (Fig. 608). This is a device which, like the depth finder, sounds the depths of the water beneath your boat, but instead of displaying the result as a flash of light on a dial, records it on paper. The depth recorder operates on the same principles as the depth finder as far as the sounding methods are concerned, but it is equipped with a roll chart of paper and a marking stylus.

The roll of paper is printed with lines which correspond to the depths to which the instrument will respond. As the echoes return

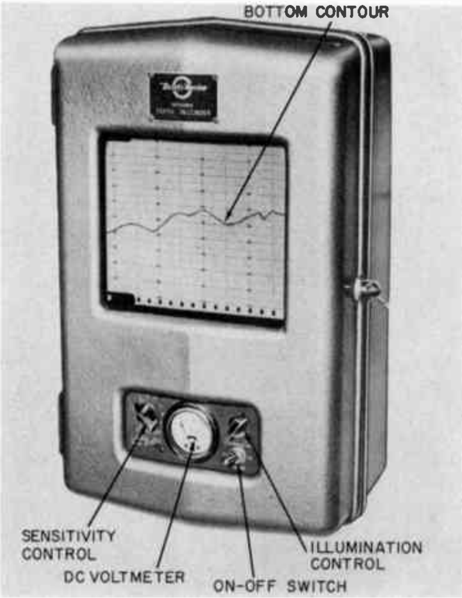


Fig. 608. *A depth recorder prints a drawing of the bottom contour on a strip of paper.* (Bendix)

from the bottom, the stylus makes marks on the chart at the proper depth. Thus, in addition to giving a continuous report on the present depth, the instrument also keeps a record of the depths passed over. This is of exceptional advantage if the pilot is using the information for navigation purposes.

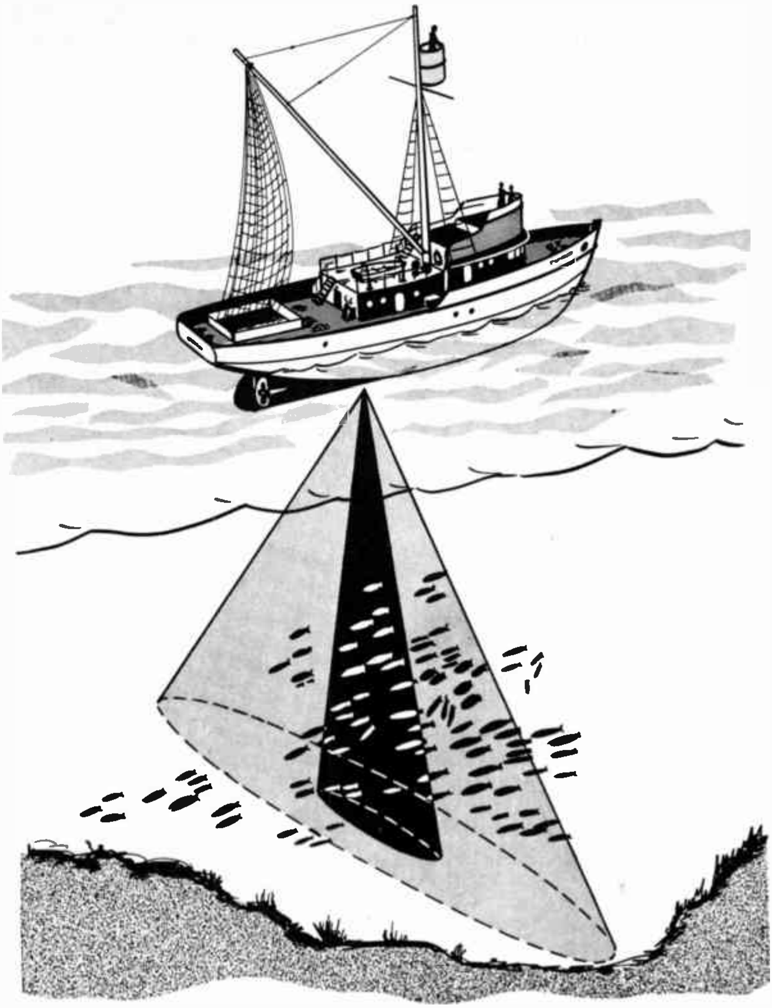


Fig. 609. *A dual sweep beam on a depth recorder permits the use of a narrow beam for navigation and a wider one for finding schools of fish.* (Bendix)

If he goes off his course, the chart gives a clue as to how far back he made his mistake, and it also helps to make a prompt return to the correct course. It also eliminates the necessity of running a line of soundings, because this information constantly appears on the chart in the recorder.

A number of optional arrangements are obtainable with depth recorders. Some make provision for an auxiliary remote indicator. Thus you may have a dial at one location in the vessel which will give you the standard flashing indication, and also have a unit recording on a paper chart in another part of the vessel.

Another feature, such as is found on the instrument shown has a beam switching arrangement. This permits changing the width of the beam emitted by the transducer. A sharp narrow beam aimed at a small spot directly below your ship is used for navigation. Flipping a switch changes over to a beam 80° wide which scans a much wider area beneath the ship and is better for identifying schools of fish (Fig. 609).

The 50-fathom range is used for shoal fishing for herring, sardines, etc. The 200-fathom range is better for trawling, dragging and long-line fishing. Portable instruments are also made, and some are built to a high accuracy for use in survey and dredging operations.

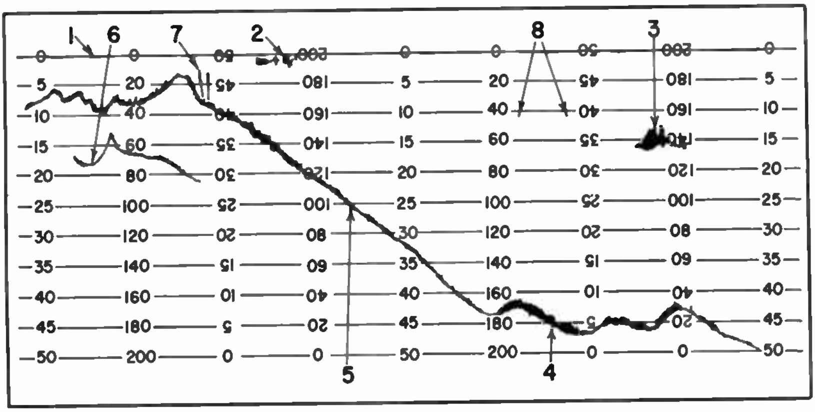
With a depth recorder aboard, you can plot your course from the regular charts and draw a profile of the bottom you expect to pass over. By comparing this to the actual contour as shown on your depth recorder as you proceed, you can determine if you are on your expected course.

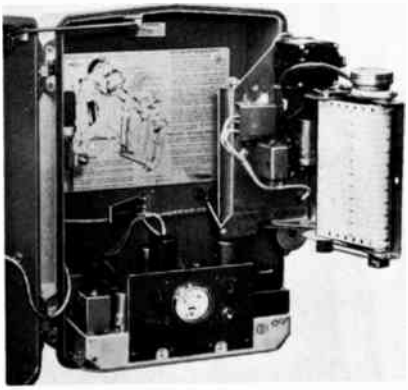
The chart recorded by one of these instruments (Fig. 610) is actually a contour drawing of the bottom of the water on which you are traveling. It is just as accurate as a map would be. In fact, charts and maps are made by just these means. The same principle is used in aircraft surveys of the surface of the land.

The choice of a depth sounder or recorder, like so many other things, depends on the use to which it is going to be put. The range the instrument should have depends on the depth of the water on which you intend to travel. While an instrument with maximum range or a dual range is nice to have, the deeper the instrument will reach, the more power will be required. This may mean a more elaborate and expensive piece of equipment.

If you are going to pilot your vessel in shallow lakes and bays, there is no point in buying an instrument designed for commercial ocean fishermen. A shallow-water instrument is effective to a degree even when in deeper water. For example, if you have a portable instrument good only to 80 feet, it will tell you when you are in deeper water than this by giving no reading other than the zero flash, which is a check that the instrument is working.

You could not, of course, engage in "bottom navigation" by sounding your way along the bottom. However, if you should accidentally get into shallow water, a short-range indicator would warn you at 80 feet and give you a chance to avoid running





1. Reference or "0" line.
2. School of surface fish—bait, etc.
3. School of fish.
4. Soft bottom—mud—vegetation—silt.
5. Hard bottom—rock—sand.
6. Second echo—caused by sensitivity control being advanced too far.
7. Seaweed—kelp.
8. Small scattered school of fish.

Fig. 610. *Depth recorder and composite chart showing typical recordings of underwater conditions.* (Bendix)

aground. Therefore, a portable set may be adequate in deep waters as far as safety is concerned, but may be of no help in finding fish or in navigating.

Maintenance

Like most other electronic equipment, depth finders are not easily repaired while under way. Spare radio tubes should be carried, of course, and the boat operator should know how to change them without wrecking the set. Along with the extra tubes, a spare neon lamp should be carried. Usually neon lamps of this sort give warning as they near the end of their life—the bulb becomes blackened. However, as they age, their operation becomes erratic, and flashing may become irregular and unreliable.

The lamp is in the indicator portion of the depth-finder apparatus and is ordinarily easily changed. These instruments may use voltages of around 300 or more, and so present a hazard to anyone working on them while they are connected. In working or testing, or even merely changing tubes on any electrical apparatus, *always turn the equipment off first.* The safest way is to remove the fuse which connects the device to the battery supply.

Electronic trouble on the depth indicator is best left to a technician skilled in the repair of these devices. In any event, no attempt should be made to operate these sets if the transducer is disconnected from the rest of the apparatus. This is because the transducer is the natural "load" for certain equipment within the set. If the transducer is not connected, interior voltages, without the load to hold them down, may rise excessively and burn up certain components.

In the event of sudden failure of a depth-indicating apparatus, the usual exterior inspections should be made, just as would be done with the radio or anything else. Fuses should be checked, and the wiring from the battery to the equipment and from one unit of equipment to the other should be checked to make sure it hasn't been damaged.

chapter 7

direction finders

> The good mate said: "Now must we pray,
> For lo! the very stars are gone. . . ."
> —*Joaquin Miller*

TRADITIONALLY, mariners have navigated by celestial bodies, the sun by day and the stars by night. From early crude instruments grew the sextant, which along with a precise chronometer enables the navigator to determine his latitude and longitude. But when, like Columbus in the poem, he can't see the stars he has to do something else.

When a pilot takes his vessel through weather which prevents him from taking his bearings accurately, he must calculate his speed, direction and distance from his last known point. To do this, he must allow for wind and tide as well as engine revolutions and compass errors. But if he considers all things, he may be able to deduce his position with a good degree of accuracy.

According to one story, the abbreviation in the ship's log "ded. reckoning" referring to this type of navigation became, in the course of time, "dead reckoning." An experienced pilot can take his vessel through miles of fog and reach port accurately and safely by using dead reckoning and the aids to navigation which are available.

Harbor entrances, dangerous shoals, menaces to navigation and other features of waterways are marked for the benefit of those who pilot vessels. Floating buoys warn vessels away from shallow areas and mark channels to be followed in order to stay in safe waters. These buoys are equipped with lights of different colors, so one can be distinguished from another. They also have bells or whistles, which can be heard when visibility conditions prevent the buoy from being seen.

Lighthouses flash a light which is coded. The lights may be fixed, fixed and flashing, group flashing, quick flashing, interrupted flashing, short–long flashing, or may be occulting (in which the light periods are longer than the dark). In addition, sirens, horns, diaphones and whistles are used during foggy weather, and underwater sounds and radio also are used.

The audible sounds used in foggy weather, like navigation lights, are coded, so that the pilot may tell one from another (Fig. 701).

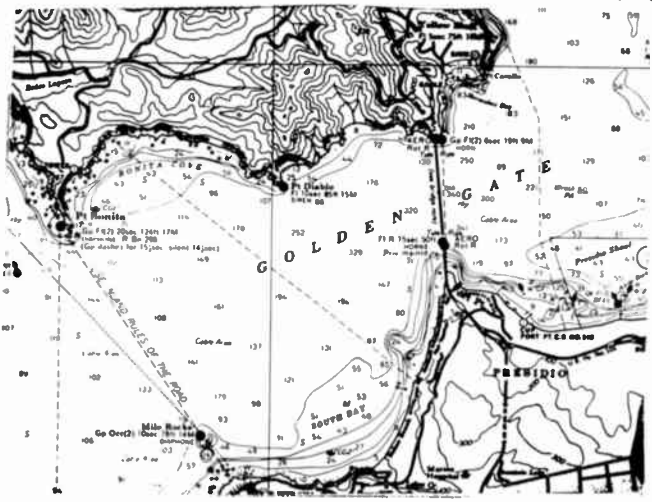


Fig. 701. *A mariner's chart showing the entrance to San Francisco Bay. The depths of the water and various aids to navigation are also shown.*

For instance, at the entrance to San Francisco Bay, just outside the Golden Gate, stand Point Bonita Light to the north and Mile Rocks Light to the south. Point Bonita has a light which flashes a group like this: 1-second flash, 2-second eclipse, 2-second flash, 15-second eclipse.

Mile Rocks Light sends 4 seconds of light, 2 seconds eclipsed, 2 seconds of light, 2 seconds eclipsed.

Foghorns

During foggy weather, Point Bonita sounds a two-tone diaphone (the bee-oh kind of foghorn): 1-second blast, 2-second silence, 2-second blast, 25-second silence. Mile Rocks Light sends a 3-second blast every 30 seconds.

As a vessel proceeds into the harbor, it passes other lights and horns on Point Diablo, Lime Point, the Golden Gate Bridge, Alcatraz Island and other locations. Each of these uses a distinctive combination of light signals or horn sounds. Thus a pilot, in fair weather or foul, has a series of navigational aids to help him find his way into the harbor. Once inside, a large number of similar aids will guide him around the bay, or into a port, river or slough.

In addition to the lights and fog signals, the lighthouses usually transmit a radio-beacon signal which can be used for navigation and direction finding. In some cases, the radio signal is synchronized with the foghorn. A pilot can determine his distance from the lighthouse by counting the number of seconds from the radio signal to the time he hears the horn.

The Coast Guard publishes a series of books which contain detailed lists of these facilities. In this *Complete List of Lights and Other Marine Aids,* there are separate volumes for the Pacific Coast, Atlantic Coast, Great Lakes and Mississippi River areas.

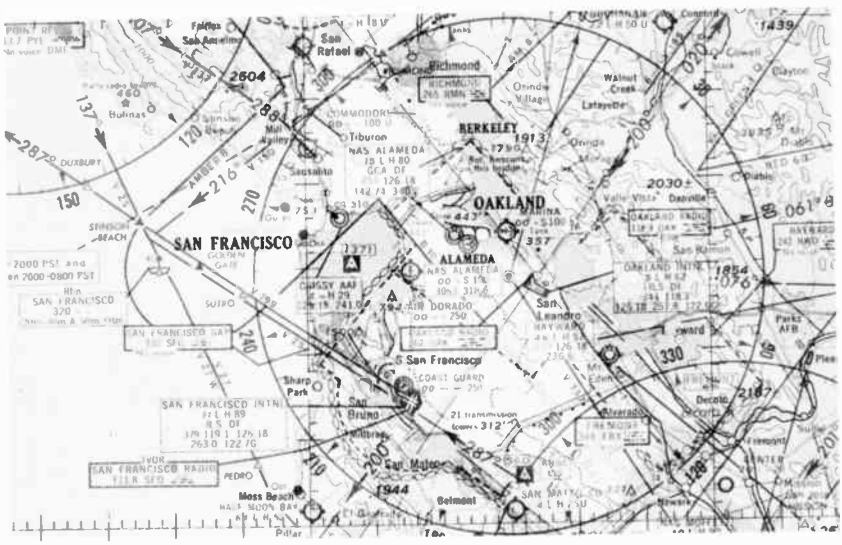


Fig. 702. *A sectional aeronautical chart contains lots of information — perhaps too much for the small boat operator. Compare this with Fig. 704 on page 125.*

Some inland waters are included in these. They are sold by the Superintendent of Documents, Washington 25, D.C.

The Hydrographic Office *Publication No. 205* also lists the radio beacons mentioned above. This publication is available from agents listed in the appendix of this book.

Any operator of a vessel, in addition to an up-to-date chart of the waters on which he is traveling, should also have the Coast Guard book on lights and other marine aids, if one has been printed for his area. However, there are many locations on inland waters where the Coast Guard has not established radio service, but where other marine aids have been installed. The US Coast and Geodetic Survey issues the charts which navigators use, and many have been prepared for inland waters, even though there may be no Coast Guard facilities there.

A catalog of these charts (*Serial No. 665*) is published by the Coast and Geodetic Survey, US Department of Commerce. This catalog may usually be inspected at the office of any sales agent for maritime publications, or may be obtained from the Coast and Geodetic Survey.

Aeronautical charts

Also available from this agency and its sales agents are the sectional Aeronautical Charts (Fig. 702). These are charts of the land areas of the United States, showing principal topographic features. They also show the airways, and the radio beacons used by airplanes. To the small-boat owner, the information on these charts may prove to be at least as valuable as that on the nautical charts.

Primarily for the use of airplane pilots, these charts show various topographic features that are visible from the air, such as buildings, roads, railroads, transmission lines, rivers and lakes. The heights of different parts of the terrain are also given. Of principal interest to the boat owner are the radio facilities shown.

Many of the radio aids used in aerial navigation are of no use to a boat operator. However, the radio beacons which the airplanes use to locate an airport operate in the low-frequency radio band, and therefore can be used by vessels which have radios equipped to receive them. The frequencies used are in the 190–415- and 515–544-kc bands, which include the band used by the marine radio beacons.

The aeronautical radio beacons have a number of advantages over the marine stations as far as the small-boat owner is concerned. First, the marine stations are usually on the seacoast, but the aeronautical stations are located all over the United States—wherever there are airports. Thus the operator of a small boat on an inland lake may have access to an airport radio station, even though his radio would not pick up a coastal station.

The aircraft stations have another big advantage. They report weather conditions at their own and nearby airports. They do this every half hour, at 15 and 45 minutes past each hour. In addition, the station's call letters are transmitted in Morse code every 40 seconds, very useful in radio direction finding.

On the beam

Before discussing the use of a radio beacon by water craft, a short explanation of how the aeronautical beacons are used by aircraft is necessary.

The aeronautical beacon has a special antenna system which divides the signal sent into four quadrants (Fig. 703). Into two of

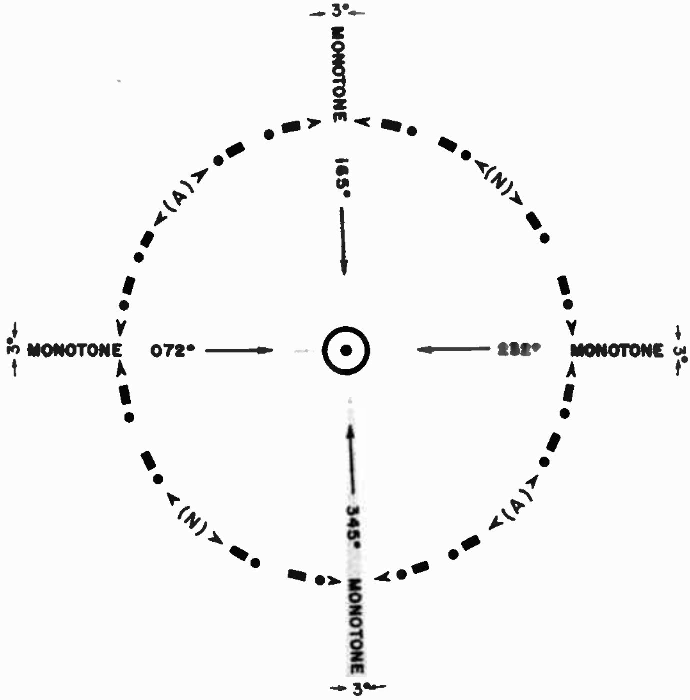


Fig. 703. An aeronautical beacon sends out a beam in four directions. The beam sounds a steady tone in the receiver. Between the beams the Morse letter A or N is heard.

these sectors, the letter A is sent in Morse code. The letter A in code is a dot and a dash (· –). On the radio it sounds like "beep be-e-e-ep." The radio beacon sends the letter N in code in the other two quadrants. N is a dash and a dot (– ·) and sounds like "be-e-e-ep beep." On each of the four lines where these four quadrants meet, both the A and the N signals can be heard together. The separate sounds seem to merge, the silent periods between the dot and the dash of the A being filled by the dash and the dot of the N.

The result is a steady "be-e-e-e-p" which does not vary. Aeronautical charts show these areas with markings that look like searchlight beams radiating from an airport. Each "beam" has a number on the chart which indicates the bearing of that particular beam. If a pilot is "on the beam"—that is, flying straight toward the airport on the path shown on the chart—his radio will receive the steady "be-e-e-p." If he gets off the beam in one direction, he will hear the letter A; if he gets off in the other direction, he will hear the N.

On the chart, the sector transmitting the N has a heavy line marking that side of the beam between A and N. The quadrant in which true north lies is always an N area.

This feature is of virtually no use to the boat owner, unless this "beam" happens to lie over the water route he wants to take. Even so, the chances are that following it would only lead the vessel aground. However, with direction-finding apparatus aboard, the signal from the aeronautical station can be used to find the boat's location. This will hold true whether the vessel is in the A or N sector or on the beam.

In addition to the Sectional Aeronautical Charts, Radio Facility Charts are also available from the US Coast and Geodetic Survey. Known also as Instrument En Route Charts, these maps give the radio information for an area, without the topographic features (Fig. 704). That is, they have the bare outline of the geographical region, but the radio beacons, airports and call letters are plainly shown. Some people prefer this type of chart for the radio information, because it is easier to read, not having the topographical features on it.

Directional antenna

Finding directions by means of radio is based upon the fact that a radio antenna will work better when it is pointed in one direction than it will when pointed in another, relative to the station tuned in. This is why television antennas must be pointed correctly to get the station best.

The antenna on a marine direction-finding radio consists of a loop of wire. This may be a coil several inches in diameter, mounted on the radio itself or outside on the top of the vessel's cabin. It can also be a small coil wrapped on a core of special material no larger than a lead pencil.

To understand the principle, picture the waves sent out by a radio station, as you would the waves sent out by a stone dropped in a pond. The electromagnetic lines of force from the station spread out in expanding circles in all directions. If you have a receiver with a loop antenna, you will get this station the strongest if you turn the loop so that the circular lines of force from the station will link with your loop like the links of a chain. This will give you the strongest signal in your receiver, because the amount of signal you receive depends on how much of the power from the broadcast station you are catching. When your antenna is turned to "link" with the waves from the station, you catch the most signal from the air.

Under these circumstances, the edge of your loop would be pointing at the station whose signal you were tuned to. However,

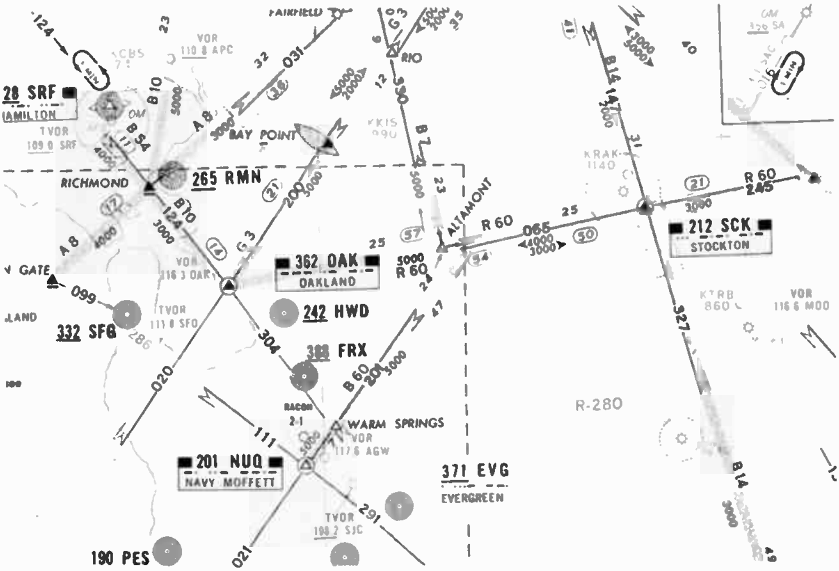


Fig. 704. *This Radio Facility Chart is used by planes flying by instruments. It covers about the same territory as shown in Fig. 702, but contains radio information only.*

you couldn't be sure of this because, even if you turned your antenna around quite a bit, you would still get the station, and it would be difficult for you to tell at just what position the signal was the strongest.

However, if you turn your antenna at right angles to the station —that is, so that the flat side of the loop faces the station—the received signal will practically disappear (Fig. 705). This is because the edge of the loop presents a much smaller area to catch the signal. Also, the wires in the loop, because they are wound in a circle, naturally go upward on one side and downward on the other. When the loop is broadside to the station, a signal received by the wire in the upward side of the loop is cancelled because the same wire goes downward on the other side. The signal just can't go in two directions at once on the same coil of wire.

The null point

The point at which the signal disappears when you turn the antenna is called a "null." It is usually quite sharp—there will be only a fraction of an inch where the signal fades out completely. Moving the loop ever so slightly from this point brings in the station again.

If this loop antenna had a pointer sticking out in its broadside direction, it would point right to the radio station it was receiving when the null point was reached. This information can be used by the pilot of a vessel to find his own location. Although the procedure is relatively easy, it is not too simple and it is not completely accurate. However, the system is good enough to find yourself if you are lost.

One of the difficulties is getting a true null. In the case of a strong station, such as a broadcast station, the signal may still come in, even when the loop is broadside to the received radio wave. A radio direction finder, which is made for the job, has a small meter on its panel. The meter, in a sense, measures the strength of the received signal. As the signal gets stronger, the needle moves one direction; as it gets weaker, it moves the other way.

As you rotate the antenna, if you cannot find a spot where the station signal disappears entirely, you can judge by the meter where the weakest signal is received, and this will be the null. This feature is desirable because your eye, in watching the needle, is better qualified to judge the lowest point than your ear is able to judge the weakest sound.

Another shortcoming of this method of direction finding is that it will permit you to establish a line on your chart, but it will not tell you whether the station you are tuned to is before you or behind you. In other words, the radio will tell you that the station is in one of two directions, but it won't tell you which. This may be no disadvantage in most cases. For example, if you were off the Pacific Coast and your direction finder, tuned to the Los Angeles airport station, showed you to be on a northeast to southwest line, you would know that northeast was the correct direction, because for Los Angeles to be southwest you would have to be somewhere on the Mojave Desert.

However, if the situation is not as simple as this, the true direction may be obtained by tuning in on another station. The relative positions of the two will usually get you straightened out. Still

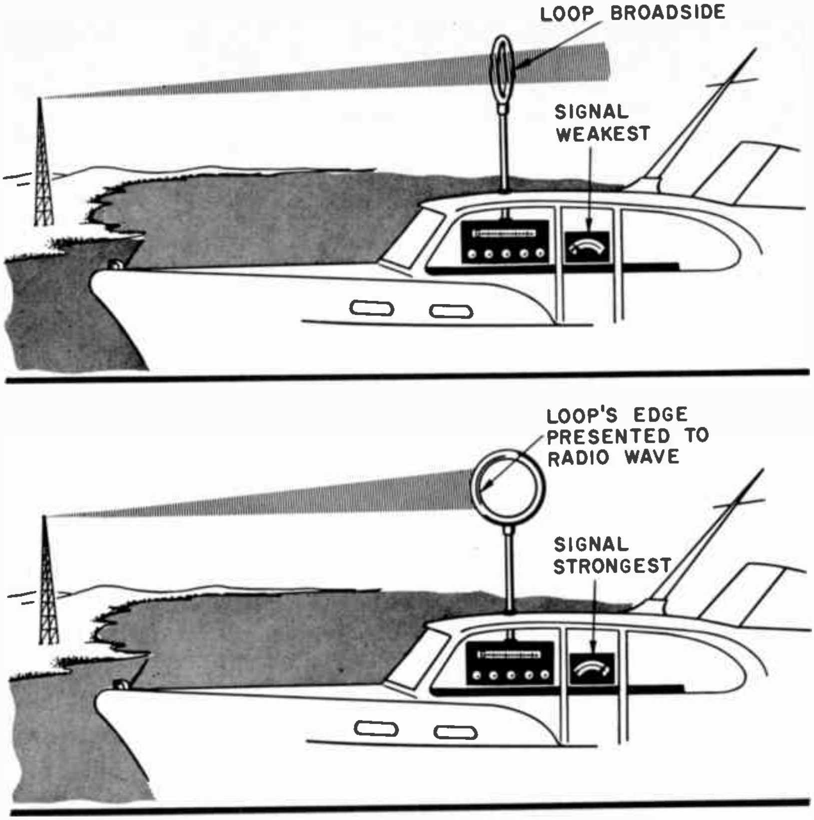


Fig. 705. *The received signal is strongest when the edge of the loop points toward the station.*

another method involves moving your vessel on a straight course for a while, at an angle to the line on which the station appears. This will require that you take a new reading of the null spot, and the direction the new null bears to the old reading will show you the direction of the station and the direction you are traveling.

For instance, suppose you tune in a radio-beacon station and find it lies exactly on an east–west line, but you can't tell if it's east or west. Suppose you then start to travel north. If the station is to the east, it will drop behind you to the right and, to get the null point again, you will have to turn your antenna to the right, or clockwise, so that it will point in a sternward direction to your right. If the station is to the west, it will appear to pass astern on your left, and you will have to turn your loop antenna to the left to regain the null point.

Choice of equipment

A wide variety of radio equipment is available to the boat owner who wants a radio direction finder. Even a simple portable radio which has a loop antenna in its case will show a null spot on most any station, if the cabinet is turned around while it is playing.

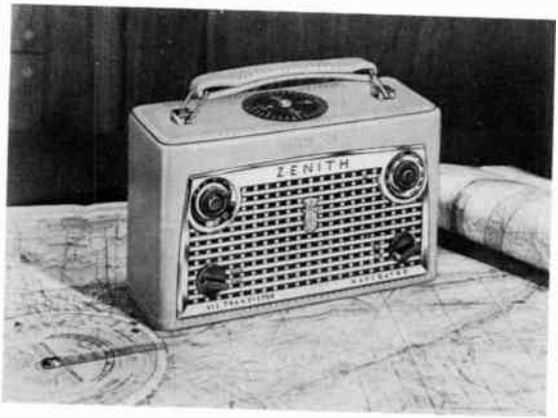


Fig. 706. *A transistor portable radio which receives the beacon frequencies and doubles as a direction finder.* (Zenith Radio Corp.)

However, these sets have the drawback that they tune only to the broadcast band, and they do not have a means for accurately positioning them in the vessel.

Broadcast stations can be used for direction finding, but they have the disadvantage that they are often so loud a true null cannot be obtained. Further, they give their call letters at long intervals, and their antenna locations may not be accurately known to the boat owner. Radio beacons in the aeronautical and marine service have their exact locations published in aviation and marine literature. Further, they give their call letters frequently—every 40 seconds in the case of the aero stations.

Portable radios

Some new portables which tune to the radio-beacon bands have found acceptance with the pilots of small boats and planes. An example of this is shown in Fig. 706. A two-band all-transistor set, it covers from 540–1600 kc and 150–400 kc. It contains its own batteries, and is suitable for navigation or for pleasure use. The top of the case bears a dial calibrated in degrees, which will give the relative bearing of the station from the boat. This set also has an earphone attachment which permits its use in noisy locations.

Another popular type of set for this service is shown in Fig. 707. Another of the build-it-yourself units, it is a complete two-band radio which will receive both the broadcast and radio-beacon frequencies. It is equipped with a meter for locating the null point with precision and is powered by a self-contained battery.

The rod type antenna is mounted outside, on top of the cabinet. It is coupled by angle gears to a knob and dial on the front panel.

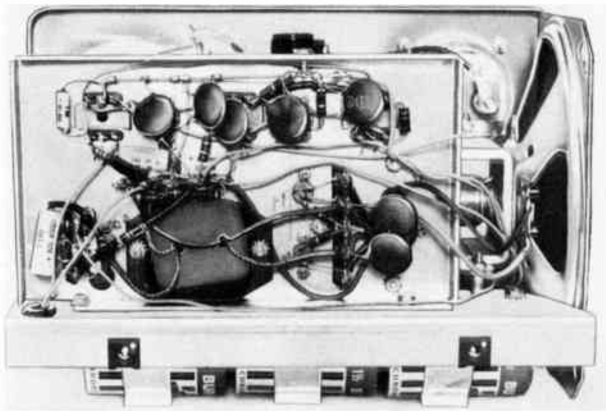


Fig. 707. *Inside view of portable receiver for broadcast- and radio-beacon frequencies.*

This dial has a face which is a compass rose. It can be grasped by the rim and turned to any position by hand. A knob in the center of the panel carries a pointer. When this knob and its pointer are turned, the antenna rotates on top of the cabinet.

In use, the dial face, with the compass rose on it, is turned to coincide with the ship's compass. When the knob is turned and the null point found, the direction to the station can be read directly from the dial. In these operations, the direction-finding radio must occupy a fixed position in the vessel, and only the antenna, not the set, should be moved. The kit comes equipped with a mounting bracket, so that the radio may be dropped into place in a fixed position, but quickly lifted out when it is to be taken ashore.

A fully portable set, it is just as useful for pleasure as it is for direction finding aboard ship. That it is a build-it-yourself unit is a big advantage to the boat owner. While no knowledge of radio is needed to assemble one of these kits, a good knowledge will be acquired before the job is done. This will be of much use to the boat owner, who will find, as he gets more radio equipment, that he will be able to make emergency repairs when needed.

Automatic direction finder

Perhaps the ultimate in direction-finding equipment is the automatic direction finder. Generally found only on larger vessels, the ADF[1] shows the bearing of a vessel at all times, and does not require manual manipulation of the antenna by an operator.

The antenna of an automatic direction finder consists of two loops, mounted at right angles to each other. An electronic circuit rapidly switches the antennas, which produces the same effect as would be achieved by turning the antennas around constantly. The signal obtained by this instrument is presented on a small picture

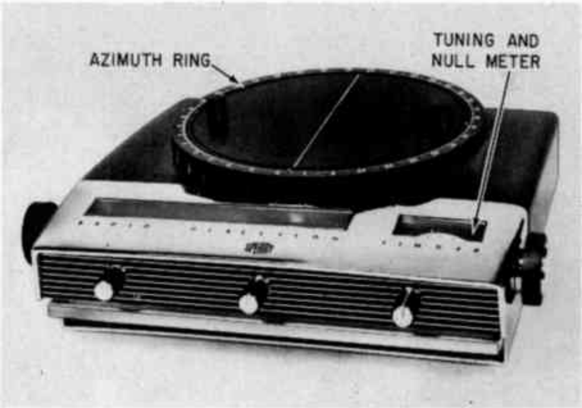


Fig. 708. *All-transistorized small RDF designed for three-band reception. Separate ferrite antenna windings are used for long wave beacon, standard broadcast and marine bands. A sensitivity control adjusts for weak or strong signals from beacons or stations and aids in obtaining the best null when rotating the loop antenna for a bearing.* (Sperry Piedmont Co.)

tube as in a TV set. The picture shown looks like a small propeller. The tips of this propeller indicate the points of the compass on a dial. As soon as a station is tuned in, the electronic pointer appears on the picture tube at the same relative bearing as the transmitting station is to the ship.

A separate whip-type antenna acts as a sensing device. A push-button on the set, when operated, will cause the image on the picture tube to move to one side or the other, giving the true "sense" of the received signal.

[1] Direction finders are either automatic or are manually operated. The automatic type is called ADF; the manually operated radio direction finder is termed RDF.

Installation

Certain precautions must be observed when installing a direction finder on a vessel. A bracket or holder should be placed which will hold the radio lined up with the ship's keel. Facing the instrument, you should be looking along a line that is parallel with a line from the bow to the stern of the boat.

The bearings you take on a radio station will be accurate only if you know the way the ship is pointing at the time the reading is taken. Therefore, the direction finder should either be near the compass, where both can be seen at once, or located so that the navigator can call to the pilot and determine the ship's heading when the reading is taken. Practically, the vessel would be kept on the same heading while the readings were being taken, but the RDF (see Fig. 708) operator should be alert to the possibility that the vessel may yaw and introduce an error in the reading.

While having the direction finder near the compass is desirable from the standpoint of reading the instruments, the radio, particularly the magnet in the speaker, may introduce a serious error in the compass. A compromise location may have to be chosen because of this.

Also, just as metallic objects aboard may affect the compass, they may also affect the radio direction finder. The presence of metal may actually cause wrong readings on the RDF. This cannot ordinarily be compensated for by placing magnets about the ship, as for correcting a compass. Instead, it is customary to prepare a correction card to go with the radio. When the RDF is installed aboard the vessel, tests should be made and the errors noted on the card. This should cover the separate frequencies which are to be used for direction finding.

As long as the direction finder is always kept in the same location, and as long as no large bodies of metal are moved on, off or around the ship, the corrections in readings can always be made from the correction card.

To calibrate a direction finder correctly requires tests when the weather is clear or when the position of the vessel is accurately known. The RDF can then be used to check the vessel's position, to see how it compares with the known location as determined visually. But a direction finder is only as good as the skill of the person who operates it. For this reason, it is recommended that the boat operator gain as much experience as possible in using the device.

Even when, in clear weather, radio direction finding is not nec-

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essary, the operator should use the instrument anyway, checking the results with visible points on shore. He should take readings as he travels, so he can see just what results he is getting. This practice will give him a confidence in himself and the instrument which may avoid a state of panic in an emergency later.

If you own one of the portable transistor RDF's, you can learn something by using it on land the next time you drive your car. You will discover for yourself the errors that the metal in your automobile will cause. You will also note errors in direction caused by hills or other characteristics of the terrain. However, you will still gain some valuable practice in using the instrument.

When direction-finding equipment of the kind that runs off the ship's power is installed aboard a vessel, the same precautions and good workmanship in running the wires should be followed, as with other electrical apparatus. The wiring should be neatly and safely fastened, in a dry location. The wires should be protected from abrasion, and the circuit should be separately and adequately fused.

Using the rdf

To use a radio direction finder, you will also need a chart of the water on which you are traveling, a pair of dividers and a compass, and a "course protractor." (See Fig. 709.) This is a transparent plastic compass rose, to the center of which is fastened one end of a ruler. Such a protractor can be used in plotting a course and in several other operations on a maritime chart. For instance, it can be used to "transfer" the compass rose printed on the chart to any other part of the chart. It can also be used to plot directions from the longitude and latitude lines.

For radio direction finding, the disk is centered on the radio station to which you are tuned. The ruler is pointed along the chart in the direction indicated by the reciprocal of the number of degrees shown at the null point on your direction finder. Within the limits of accuracy, this will tell you that your ship lies somewhere along this line.

The next step is to take another null reading on a different station. Again place the protractor on the radio station, and point the ruler in the reciprocal of the direction indicated by the RDF pointer. If possible, take another reading on a third station. The point on your chart where these lines intersect will be the approximate position of your vessel.

The reciprocal reading is the reading on the opposite side of the compass rose. Thus if the RDF shows the radio station to be on a bearing of 90° (east), the protractor, when centered on the station, should read at 270° (west). If the radio station is east of you, you are west of the station.

This method requires an accurate knowledge of the vessel's heading, so the ship's compass must be constantly consulted while making the readings. Even so, radio direction finding is subject to many inaccuracies. For instance, if you are tuned to a station which

Fig. 709. ***Setup for navigation: a direction finder, chart and course protractor.*** **(Heath Co.)**

transmits from an inland point, where the signal must first travel over land before reaching the water, it is subject to "land effect." This is an error in true bearing which results from the signal's encounter with land masses. This is one of the weaknesses in using broadcast stations for RDF purposes.

There is also a "night effect" with which to contend. Radio waves behave differently at nighttime than they do during the day. This effect is often very pronounced at twilight. It also introduces

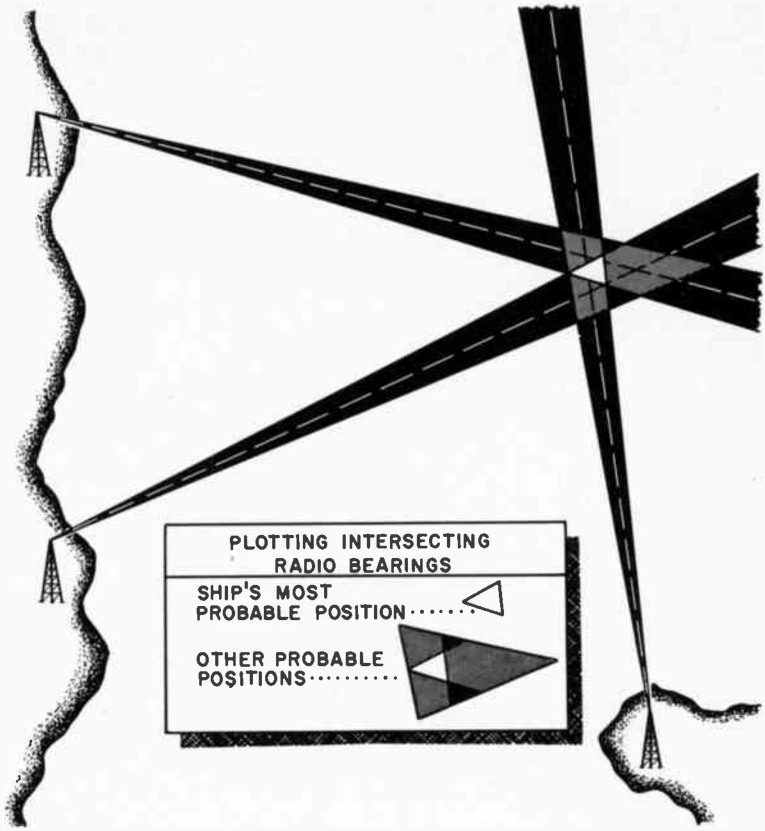

Fig. 710. *Direction finding by means of three shore stations.* (US Navy Hydrographic Office Publication No. 205)

errors in direction finding. Large bodies of metal on shore, such as a large bridge, can affect the accuracy of RDF readings made near them.

Even if all of these inaccuracies are at a minimum, there is still the complication of the chart projection. Because the earth is round, mapmakers have always had a problem of presenting a spherical surface on a flat sheet of paper. Several systems are used, and a map or chart will usually show which system of "projection" has been used.

Mercator's projection

Among the methods used is Mercator's projection which produces a map that has parallel meridians of longitude. This type of map is excellent for some purposes, but radio waves follow Great Circle courses in traveling around the earth. A Great Circle

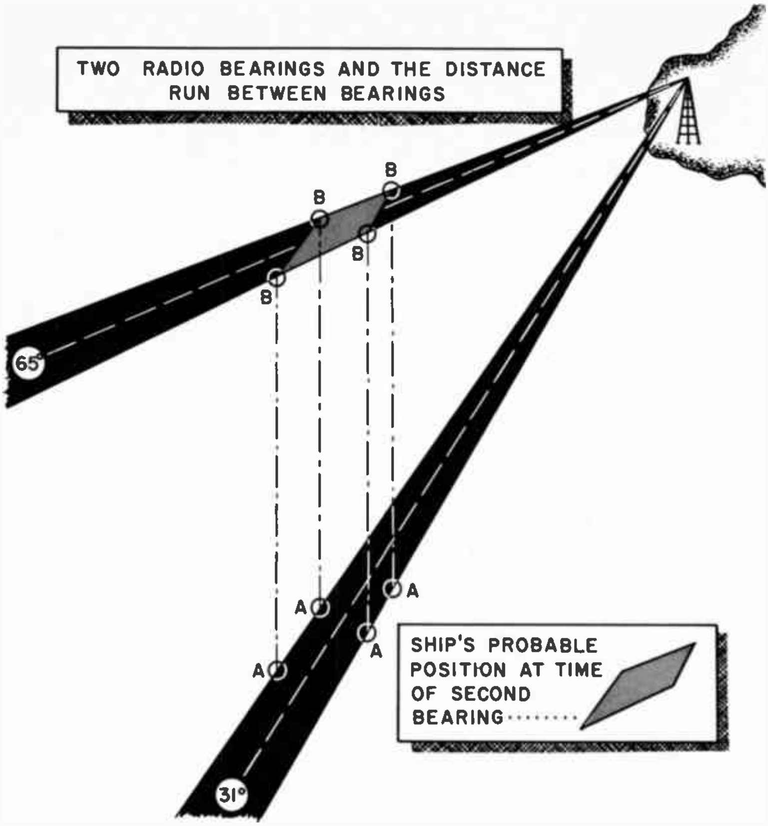

Fig. 711. *Direction finding by means of one shore station.* (US Navy Hydrographic Publication No. 205)

course is the route which would be marked by stretching a string between two points on a globe. Thus while a Mercator's projection map shows Japan to be due west of California, the great circle route followed by ships and by radio waves, takes the shortest route, which is somewhat north of this.

Tables are available to convert radio direction-finder locations to charts using Mercator's projection. Such a table is included in Hydrographic Office *Publication No. 205,* mentioned earlier.

Fig. 710 shows the method by which three readings by a radio direction finder will give the location of a vessel. The black triangle in the center of the intersecting beams from the three stations shows the most probable position of the ship, if the best degree of accuracy has been obtained in making the readings. The width of the beam as shown represents an accuracy of 2°. The shaded areas show other possible positions for the ship if one of the readings is in error by more than 2°.

Fig. 711 shows the method for radio direction finding when only one station can be used. Here a reading (31°) is taken on the one station while the ship is at position A. The vessel is then run on a straight course for a definite distance, and a second reading is made at B (65°). This information can be transferred to the chart, and the ship's position then determined.

Again, as in the previous illustration, an accuracy of 2° is assumed, and the width of the white beam shows the possible error from the center line or true bearing. The lines from A to B show the possibilities which could occur within these limitations. Therefore, the shaded area with the B's at the corners represents the location of the ship within these limits of accuracy.

Radar

Radar is an electronic ranging device which sends out a radio wave of extremely high frequency. In a radar set, it is made to travel in a sharp beam over line-of-sight distances. If this beam strikes any object, a reflected wave results, which echoes back to the radar set (Fig. 712).

The radar receives this reflected wave in a special type of radio receiver, which presents a display on a cathode-ray oscilloscope tube. Although this tube is of the same general kind as television tubes, it does not present an actual picture of the surroundings. Radars are of different types, and give different kinds of presentations. Radar used in the war to spot enemy airplanes showed only a straight line across the face of the tube. A small upward point or "pip" on this line meant that the radar was reflecting from some object. The distance the pip appeared along the line could be converted into the distance from the radar antenna to the reflecting object. Considerable skill was required to interpret properly the pips which appeared.

The radar used by highway patrolmen to check speeders works on the same principle as far as a reflected radio wave is concerned. However, it will reflect only from moving objects. The frequency of the transmitted wave is compared electronically to the received wave; if the reflecting object is moving, this frequency will be different. The difference can be measured in miles per hour. This radar does not use a picture tube. Its only indication is a meter with a pointer which shows the speed of the approaching or receding car.

A type of radar used at airports and on vessels is one that has a rotating antenna which constantly "scans" the territory around it. The result of this scanning is presented on a picture tube which gives a sort of a map of the surroundings. However, this map is how the territory looks to a radio beam, not a light wave; so the picture is not the same as you would see if you were standing at the radar antenna site.

As with other radar, skill must be acquired in interpreting the presentation on the picture tube, if the instrument is to be of full use. Although radar is not of much help if you are in open waters where there is nothing for the instrument to "see," it can be insurance against collision with another vessel under conditions of poor visibility.

It is of perhaps of more use in harbors or channels, on vessels like towboats, whose pilots have to watch clearances of their tow, and be ever alert for canal locks, bridges, jetties and other vessels.

The radar shown in Fig. 712 comes in two sections, antenna and indicator. The antenna unit contains the radar transmitter and receiver and connects to the indicator by a cable. The indicator houses a transistorized power supply that furnishes all the power requirements for the radar. The radar operates from either 12- or 32-volt dc power supplies.

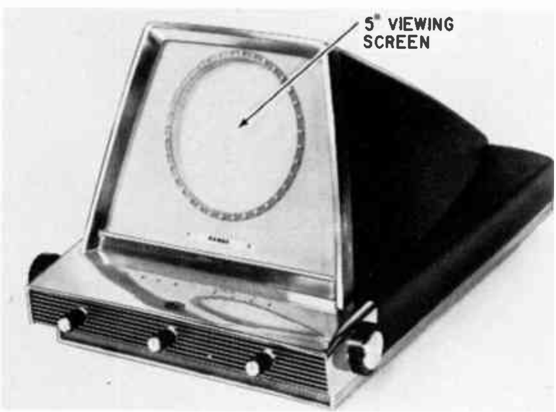

Fig. 712. *Radar unit has cursor and azimuth rings, enabling the pilot to obtain relative bearings of other vessels and objects within range of the radar. This photo shows the indicator only. The antenna unit mounts above deck and contains the radar transmitter and receiver.* (Sperry Piedmont Co.)

Some aids to navigation include radar reflectors—specially made metal areas—in addition to bells and lights, in order that they may be identified on the radar screen.

Inertial systems

The famed trip of the submarine *Nautilus* under the North Pole icecap was accomplished by means of an "inertial-guidance" system. This system was developed for directing an object to a destination without the help of radio or celestial navigation. In a sense, it might be called a highly developed dead-reckoning machine. The equipment contains delicate instruments which are extremely sensitive to any movement of the vessel. These instruments can detect speeding up, slowing down and change of direction.

Thus, if the starting point is known, and the distance and direction traveled are known, and every deviation from the course is known, the present position can be calculated. The human pilot tries to do this by dead reckoning. The inertial system includes an electronic computer which figures things out and makes the necessary corrections to keep the vessel on course. This equipment is not yet in the small-boat class.

epilog

It was stated at the beginning of this book that good manners are one of the essentials of successful marine radio operation. This also applies to your conduct in operating your boat.

Operation of a small boat also requires a lot of specialized knowledge and the observance of practices and rules that you can best learn from your fellow boat owners. If you behave yourself on the radio and at the helm, you will make a host of friends in the select circle of people who own vessels at your marina.

The common interest of being a boat owner brings a fellowship between the operators of the largest yachts and the smallest outboards. This camaraderie can be of immeasurable help to all concerned, and will be of particular benefit to you when you need help or advice.

Boat clubs

In many regions, clubs are being formed among boat owners. Some are patterned after the automobile clubs. These clubs will have a great influence on the future of boating. Their voices will be heard when state laws regulating boats are being enacted. Investigate the clubs in your area. It may be of mutual benefit if you decide to join.

Coast guard auxiliary

Look into the Coast Guard Auxiliary. This organization sponsors educational courses in boat operation which anyone can take. You'll learn important things about handling your boat, which may help you in an emergency. This knowledge might also come in very useful if your state places more stringent licensing laws into effect.

Power squadrons

Perhaps you'll be invited to join one of the United States Power Squadrons. These are groups of serious-minded boat owners. They are influential organizations, and there is considerable prestige in belonging. In addition to other membership benefits, the squadrons conduct extensive training programs, which teach piloting and navigation.

Inquire about these things in your location. You'll find that there is a great deal of fun in store for you once you own a boat. This fun will be increased as you get into the radio field, and begin to equip your vessel with some of the electronic equipment mentioned in this book.

Learning radio

There's a good chance that you will wind up with radio as an alternate hobby to amuse you when the weather is too rugged for boating. Building kits will give you an excellent opportunity to learn something of the way in which electronic apparatus is assembled, plus a greater familiarity with schematic diagrams. Knowing more about the fundamentals of electricity and electronics will give you greater confidence in handling electrical and electronic equipment.

appendix

Appendix I

Coast Guard Radio Stations

The Coast Guard makes scheduled and emergency information voice broadcasts at the radio stations listed below. Scheduled marine information broadcasts may include important notices to mariners, hydrographic information, storm warnings and other urgent marine information.

station	location	frequency (kc)	scheduled time of broadcast (gmt)
NMF	Boston, Mass.	2694	0420 and 1620
NMY	New York, N. Y.	2662	0450 and 1650
NMK	Cape May, N. J.	2662	0550 and 1750
NMX	Baltimore, Md.	2702	1630
NMN	Norfolk, Va.	2702	0520 and 1720
NMN-37	Fort Macon, N. C.	2702	1700
NMB	Charleston, S. C.	2678	0420 and 1620
NMV	Jacksonville Beach, Fla.	2678	0620 and 1820
NMA	Miami, Fla.	2678	0450 and 1650
NOF	St. Petersburg, Fla.	2678	0420 and 1620
NMR	San Juan, P. R.	2678	0300 and 1500
NMG	New Orleans, La.	2686	0550 and 1750
NOY	Galveston, Tex.	2686	0520 and 1720
NMQ	Long Beach, Calif.	2694	0500 and 1700
NMC	San Francisco, Calif.	2662	0430 and 1630

station	location	frequency (kc)	scheduled time of broadcast (gmt)
NMW	Seattle, Wash.	2702	0530 and 1730
NMJ	Ketchikan, Alaska	2678	0600 and 1800
NMO	Honolulu, Hawaii	2686	0930 and 2130

In addition to these, the Coast Guard has over 200 radio stations located at lifeboat stations, light stations, bases and depots. These stations maintain a watch on 2182 kc for distress calls.

Appendix II

Marine Radio Stations Which Broadcast Weather Forecasts

station	*location*	*frequency (kc)*	*local time*
		Pacific	
KFX	Astoria, Ore.	2598	9:15 am and pm
KOE	Eureka, Calif.	2506, 2450	9 am and pm
KQX	Portland, Ore.	2598	9:30 am and pm
KLH	San Francisco, Calif.	2506, 2566, 2450	8:30 am and pm
KOW	Seattle, Wash.	2522	9 am and pm
NMW	Seattle, Wash.	2702	9:30 am and pm
NMQ	Long Beach, Calif.	2694	9 am and pm
KOU	San Pedro, Calif.	2566	8 am and pm
		Gulf	
KQP	Galveston, Tex.	2530	12:30 and 7 pm
NOY	Galveston, Tex.	2686	11:20 am and pm
NMG	New Orleans, La.	2686	11:50 am and pm
WAK	New Orleans, La.	2598	8 am and 11 pm
WSG	Swan Island	2738	11:05 am
WLO	Mobile, Ala.	2572	5 am to 11 pm (odd hours)
WFA	Tampa, Fla.	2550	6 am and pm
		Atlantic	
NMV	Jacksonville, Fla.	2678	1:20 am and pm
WNJ	Jacksonville, Fla.	2566	7 am and pm
WDR	Miami, Fla.	2514	7:15 am and pm
WGB	Norfolk, Va.	2538	12 noon and 6 am and pm
NMN37	Fort Macon, N. C.	2702	12 noon
WJO	Charleston, S. C.	2566	7:15 am and pm
NMX	Baltimore, Md.	2702	11:30 am
NMK	Cape May, N. J.	2662	12:50 am and pm
WAQ	Ocean Gate, N. J.	2558	7:15 am and pm
WEH	Wilmington, Del.	2558	7:30 am and pm
WOX	Staten Island, N. Y.	2522, 2590	7:15 am and pm
WOU	Boston, Mass.	2506	5:20, 11:20 am and pm
	Great Lakes	*(during navigation season)*	
WMI	Lorain, Ohio	2514, 4420.7	12:02 and 6:02 am and pm
WAY	Chicago, Ill.	2514, 4420.7	12:09 and 6:09 am and pm
WLC	Rogers City, Mich.	2514, 4420.7	12:16 and 6:16 am and pm
WBL	Buffalo, N. Y.	4420.7	12:23 and 6:23 am and pm
WAS	Duluth, Minn.	4420.7	12:27 and 6:27 am and pm
WAD	Pt. Wash'ton, Wis.	2514	12:23, 6:23 am and 12:27 pm

Appendix III

Time Zones

The Coast Guard, the Weather Bureau and others keep time by the 24-hour clock, based on Greenwich Mean time. The 24-hour clock uses the hours 1 to 12 for AM time and the hours 13 to 24 for PM. The time is expressed as a four-digit number which represents the hours and the minutes. For instance, 6:37 AM would be called 0637, without using the letters AM. By way of contrast, 6:37 PM would be called 1837, without the designation PM.

12- and 24-hour clocks

A regular clock can be used for 24-hour time by writing in the numbers 13 to 24 on the face of the clock, next to the 1 to 12 digits. Here is a comparison between 12-and 24-hour clocks.

12 hour	*24 hour*	*12 hour*	*24 hour*
12:00 (midnight)	2400 (midnight)	12:00 (noon)	1200 (noon)
1:00 am	0100	1:00 pm	1300
2:00 am	0200	2:00 pm	1400
3:00 am	0300	3:00 pm	1500
4:00 am	0400	4:00 pm	1600
5:00 am	0500	5:00 pm	1700
6:00 am	0600	6:00 pm	1800
7:00 am	0700	7:00 pm	1900
8:00 am	0800	8:00 pm	2000
9:00 am	0900	9:00 pm	2100
10:00 am	1000	10:00 pm	2200
11:00 am	1100	11:00 pm	2300

The 24-hour method of keeping time may be used with local standard time or with Greenwich time. The latter compares with the standard time zones in the United States as follows:

Eastern Standard Time is 5 hours slower than Greenwich Time.
Central Standard Time is 6 hours slower than Greenwich Time.
Mountain Standard Time is 7 Hours slower than Greenwich Time.
Pacific Standard Time is 8 Hours slower than Greenwich Time.

Allowance should be made for daylight saving time when it is in effect.

Appendix IV

Phonetic Alphabet

To avoid misunderstanding when spelling out words or giving call letters by voice on radio circuits, a phonetic alphabet is used. A variety of such phonetic alphabets have been developed in the past. Amateur radio operators frequently chose words to match their call letters which pleased their fancy. The armed services used a system in World War II which is still widely used because of the large number of men who learned it while they were in the service.

Because people who spoke other tongues had difficulty in pronouncing these words, a new phonetic alphabet was developed. The old, the new and the official pronunciation of the new are shown below:

letter	*old word*	*new word*	*pronunciation*
A	ABLE	ALFA	AL'FAH
B	BAKER	BRAVO	BRAH'VOH'
C	CHARLIE	CHARLIE	CHAR'LEE
D	DOG	DELTA	DELL'TAH
E	EASY	ECHO	ECK'OH
F	FOX	FOXTROT	FOKS'TROT
G	GEORGE	GOLF	GOLF
H	HOW	HOTEL	HOH'TELL
I	ITEM	INDIA	IN'DEEAH
J	JIG	JULIETT	JEW'LEE ETT'
K	KING	KILO	KEY'LOH
L	LOVE	LIMA	LEE'MAH
M	MIKE	MIKE	MIKE
N	NAN	NOVEMBER	NO VEM'BER
O	OBOE	OSCAR	OSS'CAH
P	PETER	PAPA	PAH PAH'
Q	QUEEN	QUEBEC	KEH BECK'
R	ROGER	ROMEO	ROW' ME OH
S	SUGAR	SIERRA	SEE' AIR RAH
T	TARE	TANGO	TAN'GO
U	UNCLE	UNIFORM	YOU'NEE FORM
V	VICTOR	VICTOR	VIK-TAH
W	WILLIAM	WHISKEY	WISS' KEY
X	X-RAY	X-RAY	ECKS-RAY
Y	YOKE	YANKEE	YANG' KEE
Z	ZEBRA	ZULU	ZOO' LOO

Appendix V

Marine Radio Frequencies

In addition to separate frequencies assigned to specific stations for ship-to-shore use, the following ship-to-ship frequencies are used:

2003 kc exclusively in the Great Lakes Area
2638 kc in all areas
2738 kc in all areas except the Great Lakes and Gulf of Mexico
2830 kc in the Gulf of Mexico
2182 kc for calling and distress

In the 152–162-mc band, the following frequencies are assigned:
156.3 mc is the intership working frequency
156.8 mc is the international calling and safety frequency
A separate ship-to-shore frequency may also be assigned

Calls from one vessel to another are established by originating the call on the calling frequency, then switching to a ship-to-ship frequency to carry on the conversation. This permits all radio operators to monitor the distress frequency.

Appendix VI

Sources of Material of Interest to Boat Owners

Nautical charts

Charts of navigable coasts, harbors and some inland waters, showing depths, tides, obstructions, lighthouses, beacons, buoys, etc., are available from the US Coast and Geodetic Survey. A booklet describing the symbols used on these charts is also available.

The US Navy Hydrographic Office publishes about 6,000 charts covering the navigable waters of the world and will be pleased to quote by letter the charts of any particular region. Charts can be purchased from the Hydrographic Office or from the agents listed in Appendix No. 8.

Other government agencies which supply maritime charts and publications are:

US Coast Guard—Light lists, United States coasts and possessions. For sale by the Superintendent of Documents, Government Printing Office, Washington 25, D.C., and from Coast Guard sales agents.

US Coast and Geodetic Survey—Department of Commerce. Tide tables, United States and foreign waters; current tables, coast pilots (United States coasts and possessions); United States inside route pilots; coast and harbor charts of the United States and possessions and aeronautical charts of the United States. For sale by Coast and Geodetic Survey sales agents.

US Geological Survey, Department of Interior. Topographic and geological maps of the United States and possessions.

Mississippi River Commission (Secretary, Vicksburg, Miss.). Charts of the Mississippi River from its source to the delta.

US Naval Observatory, Navy Department. *Nautical Almanac*, $2; *American Ephemeris and Nautical Almanac*, $4.50; *American Air Almanac*, printed for 4-month periods of each year, beginning with January, $2. For sale by the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Officer in Charge, Marine Inspection, US Coast Guard. Rules of the road; pilot rules.

US Engineer Office, Louisville, Ky. Charts of the Ohio River.

US Lake Survey Office, Detroit, Mich., and US Engineer Office, Buffalo, N. Y. Charts of Lake Champlain, Oneida Lake, New York canals, the St. Lawrence River above St. Regis and Cornwall, and charts of the Great Lakes (but not harbor charts of Canada nor charts of Georgian Bay).

US Weather Bureau, Department of Commerce. A chart showing the principal types of clouds is sold by the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Price 5¢, in booklet form 35 cents.

US Army Map Service, Washington 25, D. C. Maps of Ohio River. US Engineer Office, Omaha, Neb.—Maps of Missouri River.

US Engineers Office, St. Louis, Mo. Maps of Illinois and Mississippi Rivers.

US Engineer Office, Chicago, Ill. Maps of Illinois Waterway (Lakes to Gulf).

Application for any of this material should be made to the authority named.

Aeronautical charts

Primarily for the use of aircraft, these charts cover large areas. They may be of interest to boat owners on inland waters because aircraft beacons are shown. Published by the US Coast and Geodetic Survey.

US Civil Aeronautics Administration. *Airman's Guide, Flight Information Manual, Federal Airways Manual of Operations*, civil aeronautics bulletins and civil air regulations. For sale by the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Radio facility charts

Similar to above, but shows radio information for aircraft only. Does not show topographic features of the land. US Coast and Geodetic Survey.

Radio navigational aids (H. O. Pub. No. 205)

A book of aids to navigation throughout the world. Lists direction-finder stations, radio beacons, time signals, navigational warnings, distress signals, medical advice and quarantine, long-range navigational aids, and radio regulations for territorial waters. Published by US Navy Hydrographic Office. Price $5. This is a loose-leaf book which can be kept up to date as changes occur.

Rules of the FCC

Part 8—*Stations on Shipboard in the Maritime Services.* 35¢
Part 13—*Commercial Radio Operators.* 15¢
Part 14—*Public Fixed Stations and Stations of the Maritime Service in Alaska.* 10¢

The above may be purchased from the Superintendent of Documents, Washington, 25, D.C.

Special Study Guide and Reference Material for Examination for Radiotelephone Third-Class Operator Permit for Operation of Ship Stations is free on request from any field examination office of FCC or from the commission's office at Washington 25, D.C.

Lists of radio stations

Coast Guard—(See Appendix No. I)
Miscellaneous Common Carriers
Official Registry of Common Carrier Radio Systems is published by Communication Engineering Book Co., Monterey, Mass. $3.
VHF maritime radio stations
Official Registry of Radio Systems in the Industrial Services is published by Communication Engineering Book Co., Monterey, Mass. $5.
Telephone company maritime stations—(See Appendix No. VII)
List of Coast and Ship Stations
Alphabetical List of Call Signs

These last two volumes are published by International Telecommunications Union, Geneva, Switzerland. They are also available in the United States from some dealers in maritime charts. Price is about $7.50 per volume.

Coastal warning facilities charts

These charts, prepared by the Weather Bureau for sections of the coastline, show the locations where visual storm warnings are displayed. Also listed are telephone-company and Coast Guard shore stations which broadcast weather information. The station call letters, geographical locations, frequency and times of broadcast are given.

The reverse side of the charts lists AM and FM radio stations, TV stations and air-navigation radio stations which broadcast weather information. Call letters, frequency and antenna locations are given.

Charts are available for the following coastal forecast areas:

Canadian border to Eureka, Calif.; Cape Hatteras to Brunswick, Ga.; eastern Florida; Eastport, Me., to Montauk Point, N. Y.; Eureka to Point Conception, Calif.; Great Lakes (Huron, Erie, Ontario, Superior and Michigan); Manasquan, N. J., to Cape Hatteras and Chesapeake Bay; Montauk Point, N. Y., to Manasquan, N. J.; Morgan City, La., to Apalachicola, Fla.; Morgan City, La., to Brownsville, Tex.; Point Conception, Calif., to Mexican border.

These charts can be purchased for 5¢ each from the Superintendent of Documents, Washington 25, D.C.

Marine radio telephony

A handbook of correct operating procedures for marine radio. Contains a plain-language digest of FCC marine radio rules. Send 60¢ to Radio Technical Commission for Marine Services, c/o Federal Communications Commission, Washington 25, D. C. Ask for *Ship Telephony Education Program SC-34.*

Digest of State Boating Laws

A summary of the laws relating to registration and operation of boats. Free upon request to Outboard Boating Club of America, 307 No. Michigan Ave., Chicago 1, Ill.

Harbor Craft Crewman's Handbook. Department of the Army *Technical Manual TM 55-501.*

A handy book to have if you are new to boats. Tells you everything from shipboard courtesies to how to tie knots. Contains a lot of useful information on safe piloting and navigation, handling a fire, getting off a sand bar, rules of the road and visual communications.

Obtainable from the Superintendent of Documents, Washington 25, D. C. Price $1.50.

Appendix VII

Bell System Coastal Harbor Stations

Pacific

station	*location*	*transmitting frequencies* *coast*	*ship*
KOW	Seattle, Wash.	2522 kc	2126 kc
KOW	Seattle, Wash.	2482	2430
KFX	Astoria, Ore.	2598	2206
KQX	Portland, Ore.	2598	2206
KOE	Eureka, Calif.	2506	2406
KOE	Eureka, Calif.	2450	2003

station	location	transmitting frequencies coast	ship
KLH	San Francisco, Calif.	2506	2406
KLH	San Francisco, Calif.	2450	2003
KOU	San Pedro, Calif.	2566	2009
	Gulf		
KQP	Galveston, Tex.	2530	2134
KQP	Galveston, Tex.	2450	2366
WAK	New Orleans, La.	2598	2206
WAK	New Orleans, La.	2482	2382
WAK	New Orleans, La.	2558	2166
WFA	Tampa, Fla.	2550	2158
	Atlantic		
WOU	Boston, Mass.	2506	2406
WOU	Boston, Mass.	2450	2366
WOX	Staten Island, N. Y.	2522	2126
WOX	Staten Island, N. Y.	2590	2198
WAQ	Ocean Gate, N. J.	2558	2166
WEH	Wilmington, Del.	2558	2166
WGB	Norfolk, Va.	2538	2142
WJO	Charleston, S. C.	2566	2390
WNJ	Jacksonville, Fla.	2566	2390
WDR	Miami, Fla.	2514	2118
WDR	Miami, Fla.	2490	2031.5
	Great Lakes		
WAY	Chicago, Ill.	2182	2182
WAY	Chicago, Ill.	2514	2118
WAY	Chicago, Ill.	2550	2158
WAY	Chicago, Ill.	2582	2206
WAY	Chicago, Ill.	4420.7	4115.3
WAY	Chicago, Ill.	4434.5	4129.1
WAY	Chicago, Ill.	8797.3	8248.1
WFR, WFS, WFV	Detroit, Mich.	2182	2182
WFR, WFS, WFV	Detroit, Mich.	2514	2118
WFR, WFS, WFV	Detroit, Mich.	2550	2158
WFR, WFS, WFV	Detroit, Mich.	2582	2206
	Mississippi River		
WAY	Chicago, Ill.	2782	2782
WAY	Chicago, Ill.	4067	4067
WAY	Chicago, Ill.	4372.4	4372.4
WAY	Chicago, Ill.	6240	6240
WAY	Chicago, Ill.	6455	6455
WAY	Chicago, Ill.	8205.5	8205.5
WCT	San Juan, P. R.	2530	2134

Appendix VIII

Agents for the Sale of Hydrographic Office Charts and Publications

The following agents sell charts and publications of the US Navy Hydrographic Office. Those marked "*" also sell US Coast and Geodetic Survey publications. Those marked "†" also sell US Coast Guard publications.

ALABAMA	
Mobile	*†Mobile Ship Chandlery Co., Dauphin and Commerce Sts., PO Box 149 (Zone 2)
CALIFORNIA	
North Hollywood	*†Pan American Navigation Service, Ventura Blvd.
San Diego	*†Arey-Jones Co., 933 4th St. (Zone 12)
	*†Nuttall-Styris Co., 825 Columbia St.
San Francisco	*†George E. Butler Co., 356 California St. (Zone 4)
	*†San Francisco Instrument Co., 510 Battery St. (Zone 11)
	*†C. J. Hendry Co., 27 Main St. (Zone 5)
San Pedro	*†Marine Hardware Co., 304 South Beacon St.
	*†Southwest Instrument Co.,235 West 7th St.
	*†C. J. Hendry Co., 111-121 South Front St.
	*†Globe Nautical Instrument Co., Inc., 121 West 7th St.
CONNECTICUT	
Essex	*†Essex Paint & Marine Co.
FLORIDA	
Fort Lauderdale	*†Herold Boat Co., 1112 East Las Olas Blvd.
Jacksonville	*†The Nautical Supply Co., 15 North Newman St. (Zone 2)
Miami	*†The Hopkins-Carter Hardware Co., 135 South Miami Ave. (Zone 32)
	*†Florida Precision Instrument Co., 1221 Biscayne Blvd. (Zone 32)
	Aviation International Corporation, PO Box 151, International Airport
Pensacola	*†McKenzie Oerting Supply Co., 601-603 South Palafox St.
Tampa	*†Poston Marine Supply Company, 1012 East Cass St., PO Box 425 (Zone 1)
West Palm Beach	* Hopkins Marine Hardware Co., 207 6th St.

GEORGIA		
	Savannah	*†Southern Morine Supply Co., Inc., 202 West Bay St.
LOUISIANA		
	New Orleans	*†Baker, Lyman & Co., Inc., 308 Magazine St. (Zone 12)
MAINE		
	Portland	*†The Harris Co., 188 Commercial St. (Zone 6)
	Eastport	S. L. Wadsworth & Son, Central Wharf
MARYLAND		
	Annapolis	*†Weems System of Navigation, 227 Prince George St.
		* Aeronautical Services, Inc., 229 Prince George St.
	Baltimore	*†Wilfrid O. White & Sons, Inc., 406 Water St. (Zone 2)
		*†Keefer and Baltimore Nautical Supplies, Inc., 43 South Gay St. (Zone 2)
MASSACHUSETTS		
	Boston	*†James Bliss & Co., Inc., 342 Atlantic Ave. (Zone 10)
		Weems Hughes Plath Navigation, Inc., 286 Summer St. (Zone 10)
	Gloucester	*†George K. Rogers Co., 150 Main St.
	Marblehead	*†Fred L. Woods, Jr., 76 Washington St.
NEW JERSEY		
	Hoboken	Martin S. Kahn, 68 Hudson St., Suite 312
NEW YORK		
	New York	*†American Map Co., 11 West 46th St. (Zone 17)
		*†C. S. Hammond & Co., 1 East 43rd St. (Zone 17)
		Rand McNally & Company, 7 West 48th St. (Zone 20)
		*†T. S. & J. D. Negus, 69 Pearl St. (Zone 4)
		*†Wilfrid O. White & Sons, Inc., 40 Water St. (Zone 4)
NORTH CAROLINA		
	Morehead City	Machine & Supply Co., Inc., Electronics Div., PO Box 335
OREGON		
	Portland	*†Frank H. Parks, 213 SW Washington St. (Zone 4)

PENNSYLVANIA		
	Philadelphia	*†Riggs & Brother, 310 Market St. (Zone 6)
		*†Victor Auguste Gustin, 105 South Second St. (Zone 6)
RHODE ISLAND		
	Wickford	Wickford Shipyard
SOUTH CAROLINA		
	Charleston	*†Capt. Chester H. Taylor, 123-125 East Bay St. (Zone 3)
TEXAS		
	Galveston	*†R. H. John, Inc., 2218 Market St.
	Houston	*†Texas Nautical Co., Cotton Exchange Bldg. (Zone 2)
VIRGINIA		
	Newport News	*†E. Smola Co., 134 25th St.
	Norfolk	*†Henry Eagleton Co., 430 Boush St. (Zone 10)
		*†E. Smola Co., 402 East City Hall Ave.
		*†W. T. Brownley, 123 Randolph St. (Zone 10)
WASHINGTON		
	Seattle	*†Max Kuner Co., 1324 Second Ave. (Zone 1)
		Metsker Maps, 1020 Third Ave.
		*†Northwest Instrument Co., 2313 Third Ave. (Zone 1)
	Tacoma	*†Metsker Maps, 111 South 10th St. (Zone 2)
ALASKA		
	Ketchikan	*†Ketchikan Instrument Co., PO Box 1852
PUERTO RICO		
	San Juan	†Puerto Rico Drydock & Marine Terminals, Inc., P.O. Box 2209 (Zone 10)
VIRGIN ISLANDS		
	Saint Thomas	* E. L. Simmons, Charlotte Amalie

Appendix IX

FCC Field Offices

ALABAMA
419 US Courthouse & Customhouse
Mobile 10

ALASKA
53 US Post Office & Courthouse
Anchorage
6 Shattuck Building
Juneau

CALIFORNIA
539 US Post Office & Courthouse
Temple & Spring Sts.
Los Angeles 12
15-C US Customhouse
Union & F Sts.
San Diego 1
326 US Post Office & Courthouse
San Pedro
323-A Customhouse
555 Battery St.
San Francisco 26

COLORADO
521 New Customhouse
Denver 2

DISTRICT OF COLUMBIA
Briggs Building
22nd & E St., N. W.
Washington 25

FLORIDA
312 Federal Building
Miami 1
409 Postoffice Building
Tampa 2

GEORGIA
718 Atlanta National Building
50 Whitehall St., S. W.
Atlanta 3
214 Postoffice Building
Savannah

HAWAII
502 Federal Building
Honolulu 1

ILLINOIS
826 US Courthouse
219 South Clark St.
Chicago 4

LOUISIANA
608 Federal Building
600 South St.
New Orleans 12

MARYLAND
400 McCawley Building
400 East Lombard St.
Baltimore 2

MASSACHUSETTS
1600 Customhouse
Boston 9

MICHIGAN
1029 New Federal Building
Detroit 26

MINNESOTA
208 Uptown Postoffice &
Federal Courts Building
5th & Washington Sts.
St. Paul 2

MISSOURI
3100 Federal Office Building
911 Walnut St.
Kansas City 6E

NEW YORK
748 Federal Building
641 Washington St.
New York 14
328 Postoffice Building
Buffalo 3

OREGON
433 New US Courthouse
620 Southwest Main St.
Portland 5

PENNSYLVANIA
1005 New US Customhouse
Philadelphia 6

PUERTO RICO
322 Federal Building
San Juan

TEXAS
324 US Appraisers Building
7300 Wingate St.
Houston 11
329 Postoffice Building
300 Willow St.
Beaumont
500 US Terminal Annex Building
Houston & Jackson Sts.
Dallas 22

VIRGINIA
402 Federal Building
Norfolk 10

WASHINGTON
802 Federal Office Building
First Ave. & Marion
Seattle 4

Appendix X

Rules to Remember

YOUR RADIO CAN MEAN YOUR SAFE ARRIVAL—USE IT WITH RESPECT

(Important points of proper usage recommended by the Radio Technical Commission for Marine Services, Washington, D. C.)

PRIORITY CALLS

BE SURE TO GIVE NAME AND POSITION OF VESSEL

emergency situations	*code words*
Distress	Mayday—Mayday—Mayday
Urgent message concerning safety of vessel or crew	Pan—Pan—Pan
Safety or weather information	Security—Security—Security

1. Maintain your watch	Listen to 2182 kc when not in communication with another station. (Rule 8.223)
2. Listen before you talk	Avoid interference with calls in progress. (Rule 8.181)
3. Identify your vessel	Give your call sign and vessel's name at beginning and end of each communication. (Rule 8.364)
4. Make calls correctly	Call other vessels on 2182 kc then switch to intership channel. (Rule 8.366) Call commercial shore stations on an appropriate working channel. (Rule 8.366)

5. Use channels properly	2182 kc for emergencies and brief calls and replies. (Rule 8.353) Intership for safety, navigation or operational and business needs of vessels. (Rule 8.358)
6. Watch your language	Use of profane or obscene language is a criminal offense.
7. Be brief all the time	Limit calls to 30 seconds; conversations to 5 minutes. (Rule 8.366)
8. Keep an accurate log	Enter all transmissions made and distress calls heard. (Rule 8.368)
9. Have documents handy	Ship station license; operator license or permit; Part 8 of the FCC Rules; log book. (Rule 8.367)
10. Have equipment checked	Periodic checks insure safety and good operation.

Appendix XI

WWV Schedules

The National Bureau of Standards operates two radio stations, WWV at Washington, D. C., and WWVH on the island of Maui, Hawaii. These stations broadcast radio frequency and musical-pitch standards in addition to precise time signals. WWV broadcasts on 2.5, 5, 10, 15, 20 and 25 mc; WWVH on 5, 10 and 15 mc only.

The following services are offered by station WWV:

(1) Standard radio frequencies. The broadcast frequencies given above are accurate to better than 1 part in 50,000,000. They can be used as marking points in calibrating radio transmitters or receivers.

(2) Time announcements. Precisely 1 minute before each hour an audio tone is interrupted. The tone is resumed precisely on the hour and each 5 minutes thereafter. The start of the tone, therefore, marks the hour and each 5-minute interval thereafter. Universal time (GMT) is announced in telegraph code each 5 minutes. A voice announcement of Eastern standard time is given following each telegraphic code announcement.

(3) Standard-time intervals. A pulse .005 second long is trans-

mitted every second. This can be heard as a faint tick. It marks the seconds to an accuracy of 1 microsecond.

(4) Standard audio frequencies. Two standard audio frequencies, 600 and 440 cycles, are given by WWV. The 440-cycle frequency is the standard musical pitch for A above middle C. The 600-cycle frequency is sent for 4 minutes, starting on the hour. The tone is interrupted for 1 minute, then 440 cycles is sent for 4 minutes. The tones alternate in this manner continuously.

(5) Radio propagation disturbances. An additional service of the Bureau of Standards is a forecast of radio propagation conditions over the North Atlantic. These are broadcast in a special code over WWV at 19.5 and 49.5 minutes past each hour. The code consists of a letter—N for normal, U for unsettled, and W for disturbed, which describes the present radio reception condition. This is followed by a number which indicates the forecast of future reception. The numbers run from 1 (impossible) to 9 (excellent). The numbers and letters are given in Morse code.

The first four of the above services are also furnished by WWVH in Hawaii.

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