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METHODS OF RADIO DIRECTION FINDING AS AN AID TO NAVIGATION:  
THE RELATIVE ADVANTAGES OF LOCATING THE DIRECTION FINDER  
ON SHORE AND ON SHIPBOARD

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Now that the great value of the radio direction finder as an aid to navigation is being generally recognized, considerable importance attaches to the question whether its proper location is on shipboard, in the hands of the navigator, or on shore.

The essential part of a radio direction finding equipment or "radio compass" consists of a coil of wire usually wound on a frame from four to five feet square, so mounted as to be rotatable about a vertical axis. Suitable radio receiving apparatus is connected to this coil for the reception of the radio beacon signals. The construction and operation of the direction finder have been discussed in detail in Bureau of Standards Scientific Paper No. 428, by F. A. Kolster and F. W. Dunmore, to which the reader may refer for further information.\* The present paper is concerned primarily with a comparison of the relative advantages of the location of the direction finder on shore and on shipboard.

The two methods may be briefly described as follows:

1. Direction Finder on Shore. -- This method, usually consists in the use of two or more radio direction finder station installations on shore, each of these compass stations being connected by wire to a controlling transmitting station. A ship's navigator wishing to know his position orders the radio operator to call the control station by radio and make a request for bearings, the signals "Q.T.E." being used for such a request. If the direction finder stations are not busy taking bearings on some other ship, the radio operator on the ship in question is requested to transmit the signal letters "M.O." for a period of one minute, during which time each of the compass stations takes radio bearings. These bearings, if satisfactory, are then transmitted by wire to the control station where they are plotted and checked and retransmitted by radio from the control station to the ship and turned over to the navigator,

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by the radio operator. Should one of the three radio compass stations on shore fail for any reason to obtain a satisfactory bearing the ship is requested to repeat the "M.O." signal until a bearing is obtained. Single stations on shore are also used to furnish bearings only.

At the time that the development of this system was started, it was the only immediately feasible method of direction finding, since very few ships were equipped with direction finders, and in a time of military exigency it was not possible to install such equipment on all ships. Also the method of direction finding on shipboard had not been developed to its present state of efficiency.

2. Direction Finder on Shipboard.--This method, which makes use of the direction finder on shipboard and transmitting radio beacon stations on shore, for instance, at lighthouses, or moored lightvessels, has been developed by the U.S. Bureau of Standards in cooperation with the U.S. Lighthouse Service. The Bureau of Standards, in developing this system of direction finding has so simplified the apparatus that the direction finder is put directly in the hands of the navigating officer on shipboard. At lighthouses or other suitable places on shore, radio transmitting equipment is installed which operates automatically when once set in motion. These transmitting stations are placed in operation during fog, and at stated times given in a published schedule. At present four such beacons are in operation, one on Fire Island Lightvessel, another on Ambrose Channel Lightvessel, a third at Sea Girt Lighthouse, Sea Girt, N.J., and a fourth on San Francisco Lightvessel. When funds are available, further installations are planned for the important lightvessels and lighthouses on the Atlantic and Pacific coasts. These radio beacons operate automatically on a wave length of 1000 meters, each beacon sending a different distinctive characteristic signal at given intervals, the intervals being different for each neighboring beacon. The signals are of a group-dot nature and are as easily recognized by the untrained ear, as the characteristic light flashes at a lighthouse are differentiated by eye. Neighboring beacons are operated on slightly different wave lengths in order to reduce the interference between beacons. The ship's navigator desiring to determine his position, or the line of direction to a lightvessel or lighthouse radio beacon, turns to the radio direction finder which is usually installed in the pilot house, closes a switch and adjusts a single tuning condenser until the desired beacon signal characteristic is heard. The radio compass coil is then rotated to the point of signal extinction, the radio bearing being then read directly with respect to magnetic north on the card of a magnetic compass, which forms part of the direction finder equipment.

Disadvantages and advantages of the method of locating the radio direction finder on shore for determining the position of a ship at sea are as follows:

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### A. Disadvantages of Direction Finder on Shore

1. The service rendered by direction finders located on shore is very limited, for at a given harbor entrance only one ship at a time may obtain bearings, it being necessary for the others to wait in turn.

It will readily be seen that this is a handicap, for in time of fog when the radio compass is most useful, many ships need bearings and need them frequently. This congestion involves loss of time, which, especially in the case of large passenger ships, means considerable expense to the shipping companies.

2. A ship's navigator is inclined to put less confidence in bearings obtained by another observer on shore than in those which he may take himself.

The responsibility of the navigation of a ship is very great and should be left entirely in the hands of the navigating officer who should take his own observations and bearings. Just as the responsibility of reading the sextant, pelorus and magnetic compass are in his hands, in a like manner it is logical that the operation of the radio compass should be so handled.

3. Considerable expense is involved in erecting and maintaining radio compass stations on shore. The cost and difficulty of maintaining special trained personnel to operate these stations is also a factor worth noting.

Radio compass stations on shore can not conveniently make use of existing personnel and buildings as is the case when the transmitting station is on shore and the direction finder on shipboard; hence the cost of maintaining such stations is considerably greater. It is also difficult to keep personnel in many of the isolated places where direction finder stations are usually installed.

4. The possibility for personal error is greatly increased: To obtain a single bearing (not a "fix") the information must pass through five stages, as follows:

- (a) The radio bearing must be read from the radio compass scale.
- (b) It must be correctly transmitted by wire to the control station.
- (c) It must be correctly received by the operator at the control station.
- (d) It must also be accurately sent by radio to the ship.
- (e) Finally it must be received correctly by the operator on shipboard and turned over to the navigator.

5. Ships many miles at sea can not make use of this system as they are beyond the range for good direction finder work.

It is only within a range of 100 to 200 miles of the land direction finder stations that a ship may make use of them. When a ship is far at sea they are of little use.

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6. In time of war, a vessel transmitting to the direction finder stations would also be giving her position away to the enemy, who could locate her with their own direction finders installed on shipboard.

7. A neighboring ship, or ship in distress can not be located by another ship by means of this method.

In case a ship is in distress, it is necessary for the land direction finder station to obtain a fix on the ship in distress, transmit the information to a neighboring ship, get a fix on that ship in case its location is uncertain, and then the latter ship may proceed to the one in distress. It will be apparent that this is a rather roundabout method. Furthermore, the location of a ship in distress, if distant from land, is impossible from shore direction finder stations, but the direction of such a ship can be obtained by other ships equipped with direction finders. The location of a neighboring ship in distress is one of the most important applications of the direction finder, and it is important that the quickest and most accurate methods be employed.

8. It is impossible for a vessel to keep constantly in touch with the shore direction finding station and thus keep check on its course after it has once obtained its position. This can be done with direction finder on shipboard as bearings may be taken on beacons whenever desired.

9. Another disadvantage of direction-finding stations on shore is the lack of control of the decrement of the transmitting apparatus on the ships from which the bearings are obtained. A transmitting set emitting a broad wave will transmit a signal from which it is more difficult to obtain an accurate radio bearing.

#### Advantages of Direction Finder on Shore

1. The cost of a direction finder installation on shipboard is eliminated.

This cost is, however, negligible as compared to the value of such an installation even in a single instance where the time saved may result in the saving of many lives.

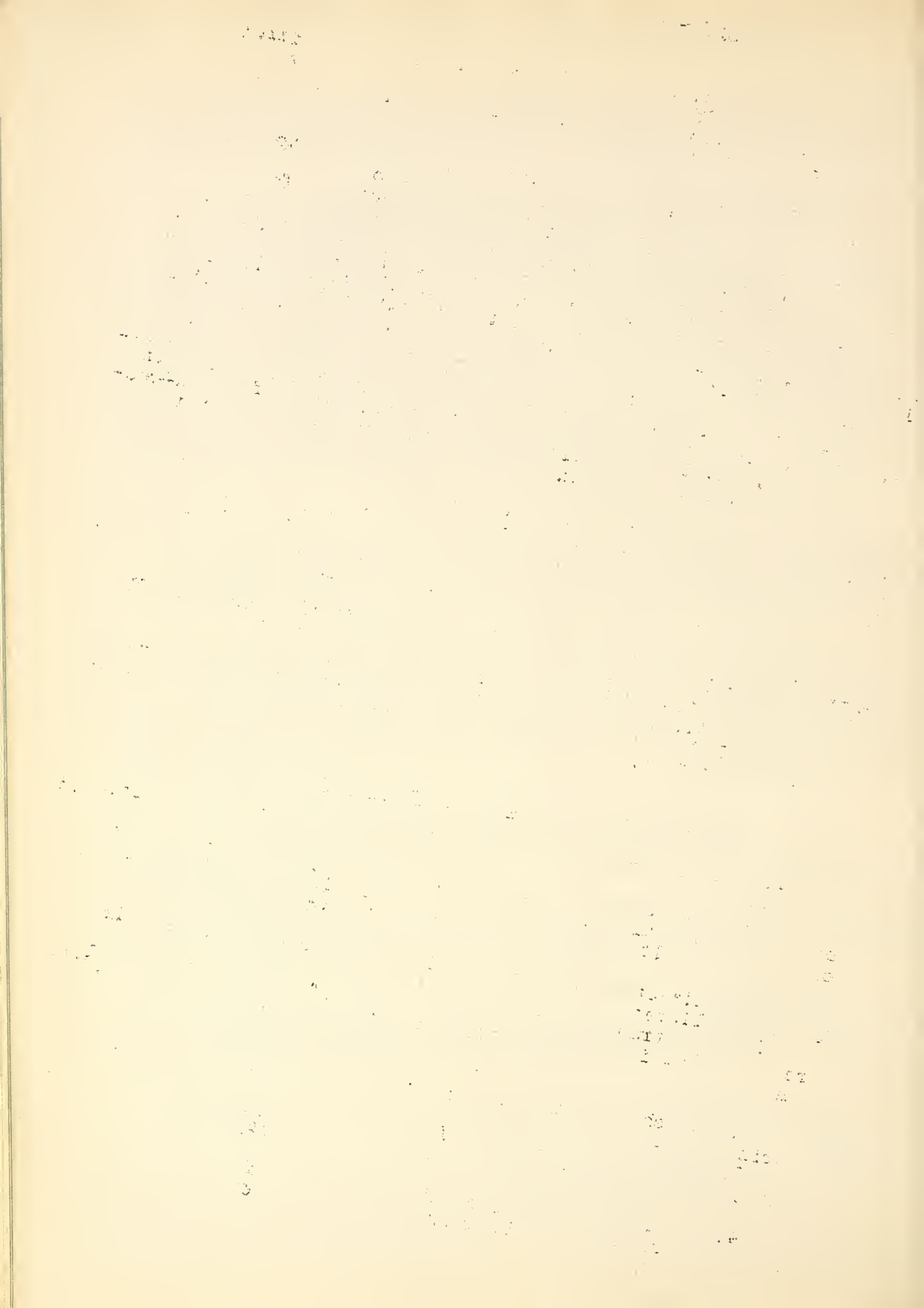
2. A direction finder installed on shore should require but one calibration.

This is true except in cases where power or telephone lines are installed in the neighborhood after a calibration has been made.

3. Any ships with a radio transmitting set may obtain bearings.

This is a most valuable feature at the present time, since most ships have transmitting sets but no direction finder.

4. The radio compass on shore is fixed in position making possible more accurate bearings than can be obtained on a ship in a heavy storm.





For marine navigation an accuracy of two or three degrees is sufficient, since a ship can not hold a course any closer than this. (Many of the larger ships do not roll appreciably except in very heavy weather.)

5. The radio compass bearings on the vessel may be made simultaneously by two or more shore stations and in that manner fix its bearings from the several stations at the same instant.

6. In time of war it would be possible to limit the furnishing of positions to friendly vessels. But by transmitting the required signals the ship is in danger of disclosing her position to enemy ships equipped with direction finders.

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The disadvantages and advantages of the method of installing the direction finder on shipboard are as follows:

A. Disadvantages of Direction Finder on Shipboard

1. In very rough weather the bearings obtained are perhaps not quite as accurate as those obtained by means of the shore system.

The only error in direction finder bearings caused by a heavy sea is the possible error of a degree or two in reading the magnetic compass. The operation of the radio direction finder itself is but little affected. Bearings taken under such circumstances are, however, sufficiently accurate for navigational purposes.

The effect of this error is less as the beacon is being approached. This is especially true as a lightvessel beacon at a harbor entrance is approached. In other words, the nearer the approach to danger (land) the greater the accuracy.

2. In some cases where wooden ships carry a metallic cargo, it may be necessary to recalibrate with the cargo on board.

If the ship has a metallic hull, which most ships do, a metallic cargo inside this hull should not alter the calibration, since the distortion of the wave front should be practically the same in both cases.

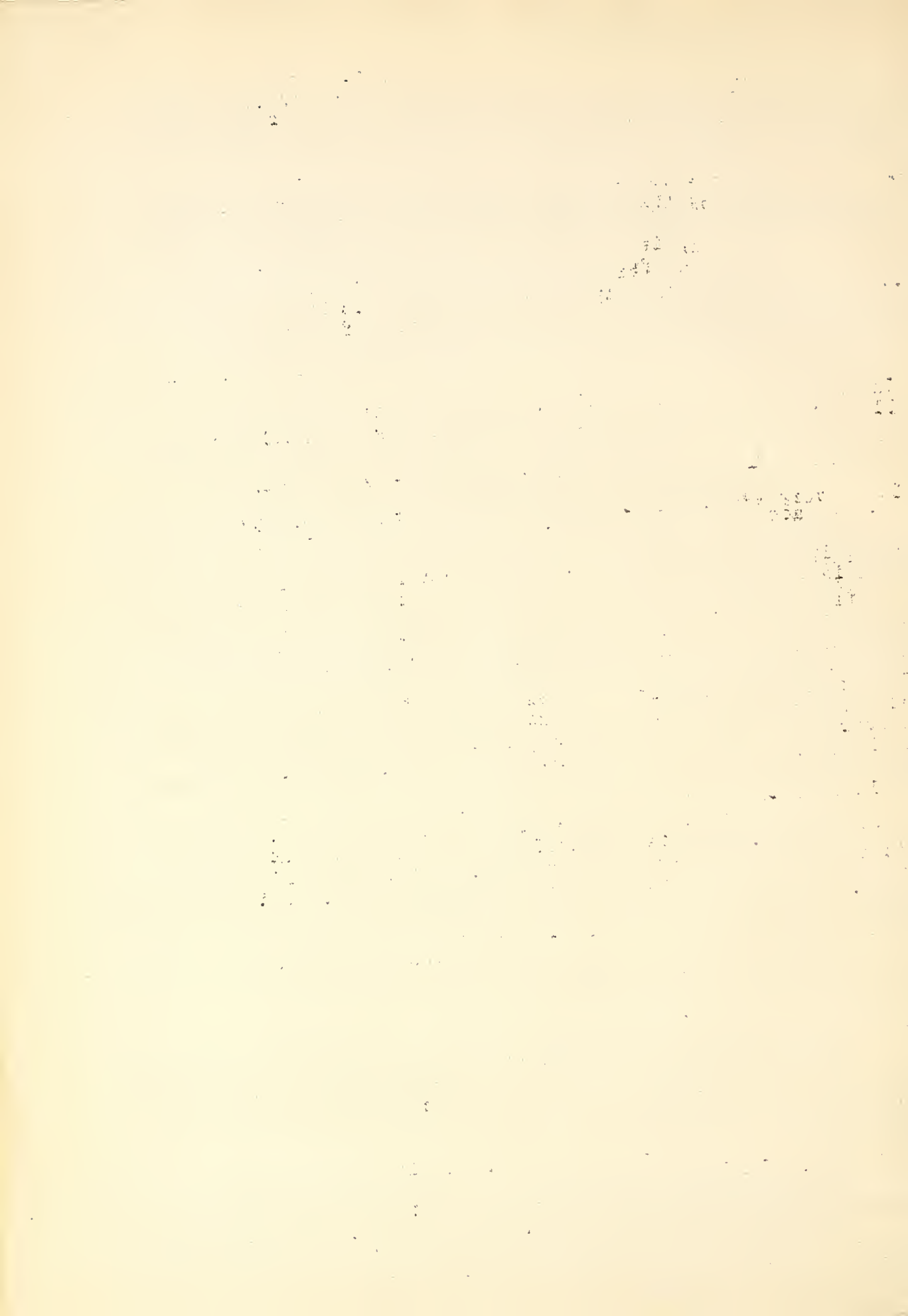
Wooden ships that carry such cargo must swing ship anyway to correct the magnetic compass so a radio compass calibration could be made at same time.

3. Lack of radio beacons.

At the present time (March, 1922) the fact that there are only four radio beacon installations is somewhat of a handicap, but as stated previously, many more beacon installations are planned for by the Lighthouse Service, as soon as funds are available.

4. Interference caused by two or more radio beacons operating simultaneously.

Some interference is experienced between the different beacons where more than one is installed at a harbor entrance and the ship is approximately equidistant from any two. This is overcome to a great extent by giving each beacon a different



time interval of transmission so that they will never get in step, and periods of time will occur when one may be heard operating alone. Also by the use of modern transmitting apparatus, the sharpness of tuning is increased so that a slight difference in operating wave length of the three beacons will make possible the elimination of interference by tuning. Different tone frequencies are of help. Also as a beacon is approached, interference is not objectionable on account of the increased signal strength.

#### B. Advantages of Direction Finder on Shipboard

1. One of the chief advantages of locating the direction finder on board ship with beacons on lightships and lighthouses is that any number of ships may obtain bearings simultaneously, as often as desired, and when desired, without the necessity of waiting in turn. Also the necessity of any transmission other than that of the radio beacons is eliminated, thus reducing the ever-increasing interference problem. This advantage is a valuable one, especially in congested harbor entrances such as New York and other large ports.

2. The navigator, being the operator of the radio direction finder himself, becomes familiar with its accuracy and is thereby able to judge its merits and is consequently made more confident in his own bearings than he would be in those furnished him from shore, which he played no part in obtaining.

3. No extra personnel or houses are required. The radio direction finder as developed by the Bureau of Standards in cooperation with the Lighthouse Service is of such a simple type as to be readily operated by the navigating officer of the ship, who may have no knowledge of radio. The system is easily installed and no knowledge of the International Morse or other telegraph code is needed. The apparatus may need occasional attention, which may be given by a port inspector who could take care of a number of direction finder installations.

The design of the radio beacons is such that they are entirely automatic in operation and are put into service by the lighthouse keeper by merely pressing a button. An occasional inspection of these beacons is necessary which may be made by one man hired for that purpose. The radio direction finder is installed in the pilot or chart house and the beacons on light-vessels and lighthouses, so no extra housing structures are needed.

4. The possibility for error in getting a bearing is greatly reduced as the information is handled but once, the bearing being read directly on the magnetic compass by the navigating officer. It will be noted also that this method is a great time-saver, as the information is obtained directly in contrast to the other method, where it must be handled five times.

5. This method gives the ship the advantage of the use of radio bearings when far at sea, for, by means of long-range radio beacons, bearings may be obtained when many miles out.

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6. This method has strategic military advantages, in that a ship may obtain her own position by means of the signals from the radio beacon stations, without thereby disclosing her position to the enemy.

7. A leading bearing may be obtained on lightvessel radio beacons stationed at harbor entrances, thus enabling the ship to approach the harbor entrances without the necessity of a "fix" or 3-Point bearing. Leading bearings may also be given by radio beacons located on shore.

8. In special cases the radio direction finder may be used by the ship's radio operator as a means of eliminating an interfering station when it is desired to receive an urgent message.

9. By means of low-power beacon signals sent from ships at intervals during fog, vessels equipped with direction finders will be able to keep clear of all other ships sending these beacon signals, thereby avoiding collision.

10. With the direction finder on shipboard, the navigator may keep in almost constant touch with the radio beacon, re-checking the bearings as often as desired, and thus eliminate any possible chance of errors of any but negligible magnitude. Furthermore, in using a leading bearing, no matter how faulty the adjustment of the magnetic compass may be, it will result in no error in the ship's course if the radio bearing is taken and the ship navigated from the same compass.

11. Paramount among the advantages to be gained by using the direction finder on shipboard instead of ashore will be the value of such an installation in times of disasters at sea. By means of a few radio signals from a ship in distress, a second ship equipped with a radio direction finder may obtain a leading bearing to the vessel in distress and thereby proceed immediately and directly to the rescue, either in fog or clear weather. When the scene of disaster is reached, if lifeboats are adrift in the fog and full of survivors from the wreck, they may be located and picked up by means of beacon signals from low-powered hand-operated radio transmitting sets installed on the lifeboats. No knowledge of the code is necessary. The importance of the use of the direction finder for this purpose will be apparent when it is realized that many instances have occurred where lifeboats adrift in the fog in the open ocean were not located until it was too late to save those aboard, and cases are on record where boats full of survivors were never found.

A striking example of the need and advantage of installing the direction finder on shipboard is shown by the following incident:

At about 9:15 on the night of August 6, the steamship "Alaska," from Portland to San Francisco, carrying 136 passengers and a crew of 84, struck Blunts Reef, off Cape Mendocino in northern California, in a heavy fog and sank in about 30 minutes. Throughout this time the "Alaska" sent out distress signals and the steamship "Anyox" reached the scene of the wreck from a

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distance of about 10 miles at about 11:15 p.m., and with the assistance of other boats which came later rescued many persons. Forty-two lives were lost. The "Anyox" had a barge in tow, which made it extremely difficult for her to stop or start or maneuver around in the fog. The steamship "Wahkeena" was only about fourteen miles from the "Alaska" at the time that the first distress signal was transmitted and responded promptly, but did not reach the scene of the disaster until 7:30 a.m., the next day. For two hours prior to the grounding of the "Alaska" its radio operator had been trying to obtain radio bearings by transmitting to the radio compass station on shore, at Eureka, California, but had been unable to get in communication with that station. The failure to obtain radio bearings was due in part to the fact that a large number of ships were endeavoring to obtain radio bearings at the same time. The "Wahkeena" did not rescue any persons. Neither the "Alaska," the "Anyox," nor the "Wahkeena" was equipped with a radio compass.

If the steamship "Alaska" had been provided with a radio compass, and radio beacon transmitting stations had been established on the lightships and on shore, the radio operator on the "Alaska" could have determined her position at frequent intervals, and the wreck would probably never have occurred. If the "Anyox" had been provided with a simple radio compass, it could probably have reached the "Alaska" before it sank, instead of requiring two hours. If the "Wahkeena" had been equipped with a very simple type of radio compass, her radio operator could have very promptly determined the direction of the "Alaska," so that the "Wahkeena" could have reached the "Alaska" in about an hour. The installation of radio compass equipment could thus have in all probability saved many lives and valuable property. The provision of radio compass equipment on board ship is obviously of particular importance in cases in which there are uncharted currents, since in such cases the setting of a course by dead reckoning in a fog may be disastrous.

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From the above considerations and as a result of experience with both systems of direction finding, it is believed that the place for the direction finder, like the magnetic compass and other navigating instruments, is on shipboard in the hands of the navigating officer.

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