6. The Compass

KNOWLEDGE OF THE LODESTONE and its influence on a piece of iron touched by it is of great antiquity. Its use in a form to indicate directions at sea was a subsequent development. The Chinese, Arabs, Greeks, Etruscans, Finns and Italians have all been credited as originators of the compass. *Encyclopedia Britannica* (14th ed., Vol. 6, p. 176, "Compass") says . . . "the earliest definite mention as yet known of the use of the mariner's compass in the middle ages occurs in a treatise entitled *De utensilibus,* written by Alexander Neckam in the 12th century. He speaks there of a needle carried on board ship which, being placed on a pivot, and allowed to take its own position of repose, shows mariners their course when the polar star is hidden."

The Magnetic Compass of today as used on ships is the Thomson (Lord Kelvin) instrument introduced in 1876 with a few improvements. Kelvin used several magnetic needles in parallel attached under a circular card on which were printed the "points," the whole supported on a pivot for easy rotation. A subsequent improvement was filling the compass bowl with an alcohol mixture and sealing it under the glass cover, a corrugated chamber being provided for expansion of the liquid with increased temperatures. Instead of the flat glass top, a modern development is the "spherical" (really hemispherical) glass cover. Compasses are swung on gimbals to keep them level when the ship rolls or pitches, and mounted in a pedestal called a

binnacle. Through the bowl there is painted a thin black line from front to back. This is known as the lubber's line and the compass must be installed with this line exactly parallel to the ship's keel. The forward tip of the line, visible over the compass card, is the mark by which the helmsman notes the course, on the card, of the ship's head.

Compass cards are marked in two principal ways:

The old point system consists of 32 points around the circle, starting from north as follows:

North	Northeast by East
North by East	East Northeast
North Northeast	East by North
Northeast by North	East
Northeast	etc.

Each point is $11\frac{1}{4}$ degrees from the next. A system of quarter points is added, each being equal to about 2.8 degrees. The older (Merchant Marine) custom and the newer (Navy) custom of naming these quarter points are both somewhat difficult to memorize and of no real use to the student.

The other method of marking is in 360° around the circle clockwise. This system has many advantages aside from the fact that steamers can be steered to 1° while the smallest unit of the point system is about 3°. East is 90°, South is 180°, West is 270° and North is 360° or 0°. This system is all one needs at sea for celestial navigation.

Compass error results from two main causes, Variation and Deviation, now to be discussed.

Variation. The earth may be thought of as a great

magnet whose poles, however, do not exactly correspond to the geographical poles. The north magnetic pole is at about Lat. 70° N., Long. 97° W. and the south magnetic pole at Lat. 73° S., Long. 155° E. (As unlike poles attract and likes repel, the "north" end of the compass needle is really "north-seeking" or south.) As the north magnetic pole is above Hudson Bay and about 1200 miles below the geographical north pole, it will be evident that, in the
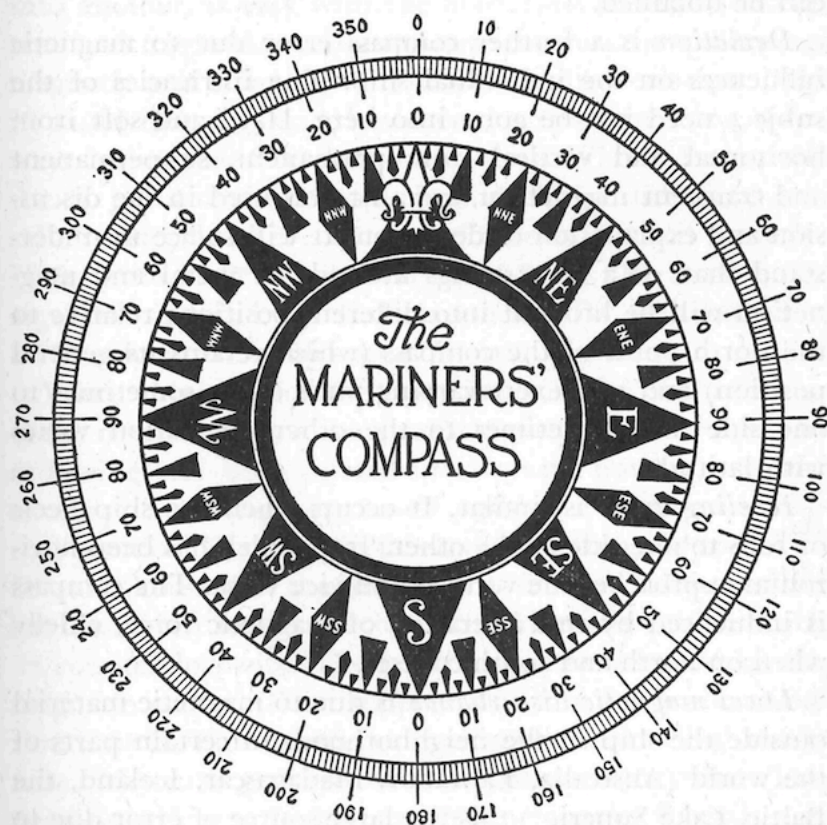
Fɪɢ. 30. Compass Card showing three methods of marking.

Atlantic Ocean, the compass will point west of true north and, in the Pacific, east of true north. The amount of this divergence from true is called variation. As long ago as 1700, Halley constructed charts showing lines of equal variation over the earth. Today we obtain the variation from our charts for any locality. There is also a slow change which is noted on the chart as so much per year and, by figuring from the date of the chart, the present amount can be obtained.

Deviation is a further compass error due to magnetic influences on the individual ship. The intricacies of the subject need not be gone into here. Hard and soft iron, horizontal and vertical iron, permanent; subpermanent and transient magnetism, are all terms used in the discussion and explanation of deviation. It will suffice to understand that, as a ship swings around, its metal and magnetism will be brought into different positions relative to the north point of the compass (which retains its general position) and will exert varying pulls on it, sometimes to one side and sometimes to the other. Deviation varies with latitude.

Heeling error is similar. It occurs when the ship heels or rolls to one side or the other. Iron which has been horizontal approaches the vertical and vice versa. The compass is influenced by this alteration of magnetic force, chiefly when on north and south courses.

Local magnetic disturbance is due to magnetic material outside the ship in the neighborhood. In certain parts of the world (Australia, Labrador, Madagascar, Iceland, the Baltic, Lake Superior) this is a large source of error due to mineral deposits in the ocean or lake bed. Minor causes

are present at docks due to other vessels, metal, etc.

Correction of much of the error which develops with the ship on different headings or due to heeling is done by placing magnets and iron in certain positions near the compass. This is called compass adjusting and should only be done by a thoroughly trained worker. Nothing is done about local magnetic disturbance.

Conversion of true, magnetic, or compass courses, one into another, is easy with the 360° card system. Between true and magnetic, we must know the variation. Between magnetic and compass, we must know the deviation. Bear in mind that a course, however described in these three ways, is the same direction on the earth. When a force pulls the N. point of the compass in a clockwise direction, it is called easterly and if counterclockwise, it is called westerly. If deviation is 5° W. and variation 7° E., the error is the algebraic sum or 2° E. If deviation is 6° W. and variation 2° W., the error is, of course, 8° W.

When thinking for the first time of these disturbances of the compass card, it is a good scheme to think of the card as having just been rotated in a certain way to a certain extent and to imagine yourself pushing it back to its original position. Say you are heading on a compass course of 20° and know that the deviation is 5° E. This means the card has been forced 5° clockwise. Mentally push it back 5° counterclockwise. The heading will now be 25° or the magnetic course. Then suppose you also know the variation is 6° E. This means the card has been forced 6° clockwise. Mentally push it back 6° counterclockwise. The heading will now be 31° or the true course. In each case we have *added*.

Only one rule need be memorized and it is this: *From compass toward true add easterly errors.*

This means that from compass to magnetic we add easterly deviation and from magnetic to true we add easterly variation. Similarly we subtract westerly errors. From true toward compass we do just the opposite: subtract easterly and add westerly. Any one of these can be quickly thought out if we start from the one rule and make the necessary reversals. Examples are shown in Table 7.

TABLE 7
COMPASS ERRORS

Compass	Deviation	Magnetic	Variation	True
64	1 E	65	3 E	68
64	2 W	62	1 W	61
64	3 E	67	4 W	63
64	4 W	60	6 E	66

Methods of determining Deviation.

1. By bearings (azimuth) of the sun. This is the usual method when at sea. Polaris and other stars may also be used.

2. By comparison with a gyro compass.

3. By reciprocal bearings.

4. By bearings of a distant object.

5. By ranges.

The first will be discussed later on in this book under Azimuth. The student is referred to Dutton, Chapter II, for methods 2, 3, and 4. Method 5 which is probably the simplest and most convenient for small craft not at sea, may be briefly outlined as follows:

a. Find some pair of objects in line, one nearer and one farther, easily visible and shown on the chart, and determine the magnetic bearing of the line joining them, from the water where you are located, by means of the "compass rose" on the chart.

b. Send your boat across this line heading first 0°, then 15° and every 15° around the circle, noting the bearing of the range at each separate heading.

c. Make a table showing the above and add a column showing deviation on each heading, as in Table 8.

TABLE 8
FINDING DEVIATION

Ship's Head by Compass	Range by Compass	Range Magnetic	Deviation
0°	60°	64°	4° E
15°	58°	64°	6° E
30°	61°	64°	3° E
45° etc.	65°	64°	1° W

This table of deviations for each compass heading is not sufficient for our needs. It does not tell us, what we are more anxious to know, what compass course to steer in order to make a given magnetic course. We want a table arranged the other way around beginning with equal divisions of magnetic and showing the proper compass course for each.

The Napier Diagram is the means by which the above is accomplished. Details will not be given here but the student is referred to Bowditch or Dutton for a full

explanation. The diagram is basically a series of equilateral triangles each side of a base line. Deviation values for each 15° compass course are plotted and a curve drawn, from which it is easy to obtain the proper compass course for any desired magnetic.

Having constructed the curve as above, a table is made giving the desired compass course for each 15° of magnetic, as in Table 9.

TABLE 9
FOR MAGNETIC—STEER COMPASS

For Magnetic	Steer Compass
15	28
30	41
45	55
60	70
75	84
90, etc.	99

For values between these 15° magnetic intervals it is easy to interpolate. However, for more easily visualizing interpolation, there are two methods by which the table may be diagramed.

First, a double vertical scale may be drawn like two parallel thermometer scales and lines then drawn across from the magnetic to the compass scale indicating equivalent values.

Second, a double compass diagram may be had, with one scale outside the other, the inner representing magnetic and the outer representing compass. Lines again connecting equivalents make the process of conversion and interpolation especially easy.

The Gyro Compass obtains its directive force from the force of the earth's rotation. A full description is given in Bowditch. The essential feature is an electrically driven wheel spinning at 6,000 r. p. m. whose axis seeks to remain in the plane of its meridian. The attachments and mechanical details result in a compass which has the following advantages over the magnetic compass:

a. It is unaffected by the ship's magnetic field. (No deviation.)

b. It seeks the true instead of the magnetic meridian. (No variation.)

c. Its directive force is much greater.

d. It may be located in a safe and central portion of the ship and repeater compasses directed electrically from it may be located anywhere.

The disadvantages are:

a. It is a complex and delicate mechanism.

b. It requires a constant source of electrical power.

c. It requires intelligent and expert care.

d. It is expensive ($2,000 up).

An Azimuth Circle is a ring formed to fit flat over a compass bowl and which can be turned to any desired position. It is graduated from 0° to 360° clockwise. Sighting vanes permit the observer to take bearings of terrestrial objects by turning the circle until the object is in line with the vanes while a reflecting prism throws the compass card into view at the same time. An adjustable dark glass reflector brings celestial bodies into view and a concave mirror and reflecting prism make it easy to take the bearing of the sun.

The Pelorus is a "dumb compass" or card without magnetic needles which can be turned to any desired position, and set. A lubber's line as in the compass marks the direction of the ship's head. Sighting vanes are provided. Peloruses are placed so that views can be had in all directions which is seldom possible with the ship's compass. The card is set to correspond with the heading of the ship by compass and then bearings are taken with it which are the same as compass bearings.

TABLE 10

COMPASS POINTS AND QUARTER POINTS SHOWING EQUIVALENT VALUE IN DEGREES

North to East	East to South	South to West	West to North	Points	D. M. S.
North	East	South	West	0	0° 0′ 00″
N¼E	E¼S	S¼W	W¼N	¼	2° 48′ 45″
N½E	E½S	S½W	W½N	½	5° 37′ 30″
N¾E	E¾S	S¾W	W¾N	¾	8° 26′ 15″
N by E	E by S	S by W	W by N	1	11° 15′ 00″
N by E¼E	ESE¾E	S by W¼W	WNW¾W	1¼	14° 3′ 45″
N by E½E	ESE½E	S by W½W	WNW½W	1½	16° 52′ 30″
N by E¾E	ESE¼E	S by W¾W	WNW¼W	1¾	19° 41′ 15″
NNE	ESE	SSW	WNW	2	22° 30′ 00″
NNE¼E	SE by E¾E	SSW¼W	NW by W¾W	2¼	25° 18′ 45″
NNE½E	SE by E½E	SSW½W	NW by W½W	2½	28° 7′ 30″
NNE¾E	SE by E¼E	SSW¾W	NW by W¼W	2¾	30° 56′ 15″
NE by N	SE by E	SW by S	NW by W	3	33° 45′ 00″
NE¾N	SE¾E	SW¾S	NW¾W	3¼	36° 33′ 45″
NE½N	SE½E	SW½S	NW½W	3½	39° 22′ 30″
NE¼N	SE¼E	SW¼S	NW¼W	3¾	42° 11′ 15″
NE	SE	SW	NW	4	45° 00′ 00″
NE¼E	SE¼S	SW¼W	NW¼N	4¼	47° 48′ 45″
NE½E	SE½S	SW½W	NW½N	4½	50° 37′ 30″
NE¾E	SE¾S	SW¾W	NW¾N	4¾	53° 26′ 15″
NE by E	SE by S	SW by W	NW by N	5	56° 15′ 00″
NE by E¼E	SSE¾E	SW by W¼W	NNW¾W	5¼	59° 3′ 45″
NE by E½E	SSE½E	SW by W½W	NNW½W	5½	61° 52′ 30″
NE by E¾E	SSE¼E	SW by W¾W	NNW¼W	5¾	64° 41′ 15″
ENE	SSE	WSW	NNW	6	67° 30′ 00″
ENE¼E	S by E¾E	WSW¼W	N by W¾W	6¼	70° 18′ 45″
ENE½E	S by E½E	WSW½W	N by W½W	6½	73° 7′ 30″
ENE¾E	S by E¼E	WSW¾W	N by W¼W	6¾	75° 56′ 15″
E by N	S by E	W by S	N by W	7	78° 45′ 00″
E¾N	S¾E	W¾S	N¾W	7¼	81° 33′ 45″
E½N	S½E	W½S	N½W	7½	84° 22′ 30″
E¼N	S¼E	W¼S	N¼W	7¾	87° 11′ 15″
				8	90° 00′ 00″