SHIPS' COMPASSES:

INCLUDING THE SUBJECTS OF

BINNACLES AND SWINGING SHIP.

REMARKS AND INSTRUCTIONS COLLATED AND ARRANGED

BY

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The following works are recommended to American officers and others engaged in navigation:

Admiralty Manual for Ascertaining and Applying the Deviations of the Compass, &c., &c., 1863, London.

Practical Information on the Deviation of the Compass, &c., &c., by John Thomas Towson, F. R. G. S., 1869, London.

Magnetism of Ships and Deviations of the Compass. Republished by the Bureau of Navigation, 1867.

Reports of the Liverpool Compass Committee. Republished by the Bureau of Navigation, 1869.

COMPASSES.

So delicate and sensitive an instrument as a well-made compass should be most carefully placed for use on board ship, and guarded very vigilantly from the action of any magnetic substance casually within the reach of its influence on the needle.

It should always be borne in mind that the local attraction of the iron in a vessel affects the compass more or less, by causing the needle to deviate from the position it would have if suspended above the water or earth at a distance from any magnetic influence other than that of the earth itself, (the terrestrial magnetism;) that this deviation is variable; that lightning sometimes causes sudden changes; and that the attraction of iron varies with the circumstances of distance, position, &c.

When the vessel's head is towards the magnetic north or south, local attraction usually acts on the needle nearly in the same direction as terrestrial magnetism, (though not always,) and then compass bearings taken on board that vessel are nearly the same as if no local magnetism were influencing the needle.

And when the vessel lies nearly across or at right angles to the magnetic meridian the deviation is usually the greatest, the vessel's attraction drawing the needle the most out of its correct magnetic position; but in iron ships this does not hold good invariably.

Terrestrial magnetism causes the needle to incline or dip, more or less, and in order to keep it horizontal a sliding weight is attached. This must be shifted when in very different latitudes, as the dip varies. It is one cause of the compass card oscillating when the vessel rolls, because it gives unbalanced momentum to the needle.

Compass needles should be deep vertically, but narrow, in order that the direction of magnetism may coincide with their middle line. The centres, supported on steel or jewelled points, should be of agate or hard metal.

Spare cards should be kept in pairs, the north and south ends together, or connected by small pieces of soft iron called keepers, to preserve their magnetic power.

If correcting magnets are fixed, their actual effect should be often tested by placing the vessel's head to the magnetic north or south, indicated by a compass placed in a position where the vessel's local attraction is not sensible, or by a celestial object, allowing the supposed (if not known) variation of the place.

A point where the vessel's local attraction is not sensible is called *neutral*, if within her influence, as on deck; but if aloft, as in a top, or other high place where there is no iron, this term is inapplicable, as in such a position the needle is affected by terrestrial or general magnetic influence alone, not by that of the vessel. A *neutral point* is somewhat difficult to find and preserve in most vessels, but the nearer to it a compass can be placed, the better it will serve as a *standard*, or for frequent reference. It is necessary not only to guard against iron in or near the compass binnacle, but to prevent the possibility of such a cause of error as far as possible, by binnacles without doors, and by preventing the temporary approach of any magnetic substance within a certain distance.

The standard (azimuth) compass, mounted either on a pedestal, or for special work on a tripod, should be placed on or occupy, when gotten up for use, a neutral point, if possible and convenient, or at least a spot from which bearings can be taken all round, or nearly so, and where the instrument may *always* be placed (as each change of position of course alters the effect of local attraction.)

The advantage of ascertaining a *neutral point* (where the local attraction is scarcely felt in *any* direction of the vessel's head, owing to the counter action of opposing influences,) and a neutral line (in which the vessel's length should lie while taking correct magnetic bearings) is well worth the trouble of experiment.

Generally the centre of magnetic effort exerted by the iron of a vessel is *before* the binnacle, *but it may be abaft it*, if a mass of iron should be very near *but abaft* the compass. Professor Barlow's correcting plate used to be placed so as to counteract the vessel's local attraction, or to double it, and thus show the amount.

Standard compasses to which steering compasses are to be referred are usually, and should always be, of superior make, and so fitted with prismatic reflectors (for reading the graduated arc) and sight vanes as to answer well for observations in azimuth. The best descriptions at present made and in use have a graduated circle of metal on which the sight vanes traverse. This being horizontal, on account of the compass being suspended in gimbals, affords the means of measuring a horizontal angle like a theodolite. Such a circle is, however, more useful on land than afloat, but it may also be used afloat when there is not much motion. A round of horizontal angles may be taken quickly between terrestrial objects which a sextant would not give without reduction. It is moveable without affecting the card, and useful in noting deviation.

Various experiments have been tried with a view to cutting off or considerably diminishing local magnetic influence on a needle, but so far unsuccessfully. Copper bowls,* cases and screens have been variously adopted, to little or no useful purpose.

Whether the needle be in air or in a vacuum is immaterial, it would appear by the investigations made expressly, as the magnetic influence seems to pervade or penetrate through any interposing medium to a certain distance not very different from that of its action when unopposed.

* Iron is sometimes present in mixed metal, which becomes magnetic.

MAGNETIC VARIATIONS.

The variation of the compass should be observed more than once a day if possible, and always by the standard compass, in the same place, noting and entering in the table the direction of the vessel's head by the same standard compass and occupying the same place at the time of making the observation. When the variation is determined by observation of the moon or a star, the sign ☽ or * should be placed after the entry in the log-book. The signs for azimuth (az.) or amplitude (amp.) should also always be noted. The variation of the compass should be ascertained at all places visited when practicable, and the results compared with the variation charts and tables, and differences, if material, noted.

It will be necessary to observe frequently the sun's azimuth and amplitude on the courses steered, and daily to compare the starboard compass with the binnacle compass by which the vessel is steered. Too much care cannot be bestowed upon this subject, for although the deviations may have been accurately determined and tabulated, or the compasses may have been adjusted by magnets before the vessel left port, and that correction be good in the place where ascertained; yet as the vessel changes her position and alters not only the variation, (or declination,) but the dip (or inclination) of the needle and likewise probably the intensity of magnetic action, the relative forces of magnetism alter also, and the corrections cease to be reliable. In few vessels of the British and American navies are adjustments by magnets used, but under all circumstances, the chief reliance for corrections of compasses at sea must be upon azimuths, amplitudes, and pole stars.

The results of no observations, either in port or at sea, for compass corrections that are not made with great care and attention by competent persons, should be used or recorded. Instructions having been issued for placing the standard (azimuth) compass on board ship, by which all observations for determining the error or deviation of that compass, and for applying the deviation when the real course steered is required to be known, the commanders of vessels should not neglect to give their personal attention to these instructions, so that they are properly complied with, and that the errors of the compasses be correctly reported and recorded for future reference. No opportunity, either at sea or in port, should be lost to repeat observations for testing the correctness of compasses, keeping a correct record of them and reporting the results.

Too much attention cannot be given to the subject of compass tests; it is, however, unfortunately, one which has not received the attention due to its great importance, but on the contrary has been often greatly neglected, which has resulted in the loss of life and property. Of the many vessels known to have been lost for want of proper attention to their compasses, some of them are known to have been adjusted by magnets, and others were not; but it is very important that seamen should understand the great uncertainty which attends the adjustment of compasses by such means, and that under no circumstances should they be relied on for long voyages. An instance is known of an iron vessel whose compasses were carefully adjusted and which performed well until after crossing the equator, when they began to be wrong, and increased in error until in 37° south latitude, where they were found to be 4½ points in error. The remedy is simple; azimuths and amplitude frequently, with the vessel's head on the course to be steered.

It has been found that neither compensation nor a table of deviations can be relied on with safety, except in about the same magnetic latitude as that in which the vessel was swung. And even in returning to the same port after a long voyage, if the vessel's head has been kept for a long time in nearly one direction, the magnetic condition of the vessel frequently undergoes so great a change as to render it dangerous to rely on a table of deviations constructed previously to leaving port. It is therefore very necessary that the commander of an iron vessel should be able to form an approximate estimate of the change in the deviation, both previously to his arrival at a distant port, and before approaching land on his return from a distant port, or after a long voyage. The change of deviation in either case is principally in the magnetism arising from induction in vertical iron at the stern, such as the stern-post, rudder-head, &c., which, if compensated by permanent magnets, would result in very serious error if the vessel proceed from middle northern to high southern latitudes, and in the magnetism acquired in building, not permanently retained after launching; hence if the vessel's head can be brought steadily on any two adjacent cardinal points, (as north or south with east or west,) and azimuths observed with the vessel's head on such two points by compass, the change of deviation may be determined; but it must be recollected that when the deviation is determined with the vessel's head either north or south, it is very important that the vessel should be upright; otherwise it will be impossible to determine how much of the change is owing to the retentive magnetism acquired during the voyage, or to the heeling of the vessel. In case it should be impracticable to take an azimuth with the vessel's head exactly on the cardinal point, two or more observations may be taken with the head of the vessel near such point, and the deviation at the point required be determined by means of Napier's graphic method.

A table of errors, however correctly determined, is of no value if the vessel heel over, unless allowance be made for the disturbance occasioned.

It has been found by experiments that the effect produced by heeling is also influenced by the direction in which the vessel was built. The hypothesis appears to be supported that vessels built in the northern hemisphere, with their heads north, are most affected, and that those built with their heads southeast or southwest the least affected, and those with their heads nearly south have a minus vertical pole below the compass; but heeling experiments have hitherto not been sufficiently numerous to establish this hypothesis.

The two principal causes of disturbance of the deviation of the compass are vertical sub-permanent magnetism below the compass, and the change in the inductive magnetism in transverse horizontal iron. But there are other causes that to a smaller degree either increase or reduce the effect caused by them.

It is seldom that an iron vessel is swung for a deviation table, except when upright. This table is therefore of little value when the vessel heels either to port or to starboard, since with the vessel's head north or south by compass the deviation is either increased or decreased, in some cases to the amount of two degrees for each degree the vessel heels, while in other cases little or no disturbance is thus occasioned. If practicable, therefore, the vessel should be heeled both to port and to starboard, and the change in the deviation produced by heeling should be either approximately compensated for by a vertical magnet, or a table constructed showing the change in the deviation. In suggesting the use either of the compensation by the vertical magnet or of approximate tables, the mariner is cautioned not to depend upon them within half a point; using such tables he should, if practicable, so shape his course that even a point of error should not place him in danger. It is not to be supposed that many commanders of iron vessels will place implicit confidence in their compasses; it is therefore very desirable that every facility should be afforded them for determining by the bearings of the heavenly bodies the deviations of their compasses. In order to accomplish this object it is absolutely necessary that they should be able to ascertain the variation of the compass at any part of the oceans and navigable seas. The British Admiralty variation charts answer to this necessity. Without a correct or approximately correct variation chart, the most careful observations would not enable the navigator to determine how much of the error of the compass is due to deviation and how much to variation. The navigator must be able to determine the error of his compass by azimuths of any heavenly body in a favorable position. The comparison of the true azimuth with the bearing by compass gives the combined effects of variation and deviation, which is the "*correction*" to be applied to courses steered on the same line of equal variation, with the vessel's head in the same direction as when the azimuth was taken, and the variation chart enables the mariner to separate the two. The heeling of the vessel must enter into these calculations to insure correct results.

The best method of determining the difference between the true and compass bearings is by time azimuths;* it requires but one observer, and is always available, whether the vessel is in port or at sea, when the altitude cannot be observed on account of the horizon not being visible. The only objection to time azimuths has been the difficulty attendant on their

* See Burwood's Tables, giving time azimuths of the sun by inspection.

calculation, and several contrivances have been adopted to reduce this labor. Burwood's tables will, it is presumed, do away with this objection, since the time necessary to calculate the time azimuths of any heavenly body is less than that which is required to work an amplitude. These azimuths, since they only require a few minutes to determine, should be frequently taken whenever the state of the atmosphere will allow. In fine weather, whenever the heel of the vessel changes, or the direction of her head is changed, either night or day, an azimuth should be taken. Night azimuths are not generally observed, except that of the north star, the bearing of which is frequently taken when its altitude is so great as to render the observations liable to great instrumental errors; this practice should therefore be discouraged. The smaller the altitude, the greater the reliance that may be placed on the observed azimuths. When an opportunity presents of taking azimuths of several stars, the lowest that can be observed should be preferred, although it seldom happens that a star can be observed at less than 10° altitude, yet the altitude ought not to exceed 30°. An azimuth of a star can seldom be observed by reflexion, consequently with ordinary azimuth compasses the star should not be higher than the vane. The slit of the sight vane must be the twentieth of an inch wide, otherwise so much of the star's light is shut off from the eye as to render a star invisible.

Extracts from the Third Report of the Liverpool Compass Committee to the Board of Trade, (1857–'60:)

Undoubtedly the best practical corrective for errors of the compass of all kinds is to be found in a competent and careful captain. How to make the captains and future officers of iron ships more competent in this special department of their very varied duties, deserves the most careful attention. A fair knowledge of the elements of magnetism and mechanics may, it is thought, be reasonably required in the commander of an iron ship. The practical mode of correcting the compass is so simple and may be acquired in so short a space of time, that every officer in an iron ship might be expected to show practically that he can perform this operation.

Only those who have made it a subject of inquiry can form a correct idea how large a proportion of the complaints respecting the compasses of iron ships have reference to their sluggishness and want of directive power. Either by celestial observation or by the "inverse" method, the correct direction of the ship's head is usually very approximately ascertained. What is chiefly required is a steering compass which, in all latitudes and in all directions of the ship's head, shall have enough directive power for the wants of the man at the wheel. It is to produce this desirable result that the committee have already recommended the introduction of a vertical compensating bar in the construction of iron ships, and they now recommend the officers of iron ships to master for themselves the mode of properly applying a compensating magnet whenever it may be required at sea.

But not unfrequently the reported compass errors of iron ships arise from purely mechanical causes, which have no connection with the ship's magnetism. They are sometimes due to cracked or holed agates, but more commonly to worn pivots, with needles which have never had or have lost their proper directive power. An opinion prevails with some compass-makers that the steel pivot for the card should not be hardened, and a compass-maker of some note actually refuses to supply any but pivots of soft steel, except by special request. The objects sought are stated to be preservation of the agate cap and steadiness of the card. Lapidaries and gem engravers consider that the soft metal would have the opposite effect; and any steadiness in the card which is due to a blunted pivot must necessarily be at the expense of accuracy.

The number of cases which have come before this committee of deviation arising from blunted and worn pivots is such as to leave no doubt that this is a most prevalent source of error and bad steering. In one case in a screw steamer in active employment, the pivot had not even been examined for about eight months: in another screw steamer the pivot had not been changed or sharpened for nearly 12 months, and in a third case the agate cup in which the pivot rested had been filled up with brick-dust, for the purpose, it was stated, of steadying the card, so that when examined it was found that the vibration from the screw and the grinding of the brick-dust had made a hole completely through the agate. In the last instance he captain had rectified a supposed error of two points by placing the compensating magnet in a position very much nearer the compass card, so near, in fact, as to produce an error of the same extent.

Every person intrusted with the command or the deck of a vessel, or charged with her navigation, should fully acquaint himself with the following subjects:

1. The elementary theory of magnetism, especially the laws of permanent (or sub-permanent) magnetism, and those of inductive magnetism.

2. The commander and navigator should inform themselves, as far as possible, of the magnetic condition of the vessel, arising from the direction of her head whilst building, (especially if an iron vessel,) and the nature of the changes occurring after launching.

3. They should understand how to swing their vessel under all circumstances, either at a compass station, where the true bearings are given from a buoy to different distant points, or by reciprocal bearings from the vessel anchored anywhere to and from the standard compass on board and a compared azimuth compass on shore.

4. They should understand how to record observations in swinging ship, and fill up the table for local deviations, and understand the use of the steering card, Napier's and other graphic methods.

5. They should understand the methods, and be able to employ them, of compensating compasses of iron vessels for both polar and quadrantal deviation.

6. If the compasses have been compensated they should acquaint themselves with the means for correcting from time to time the changes which take place in the remaining deviation.

7. Having a table of errors to correct a course steered, they should be able to shape a course by means of a modification of such table.

8. Having a table of deviations determined by swinging ship, they should, by means of observations made when the vessel's head is on two adjoining cardinal points, be able to modify such table so as to be useful in entering a distant port or in approaching land when returning from a voyage or cruise.

9. They should acquaint themselves with the changes in the deviation caused by the heeling of the vessel, and having the deviation table for a vessel on an even keel or beam, and the changes of deviation by heeling, with the vessel's head on any one point, (except east or west nearly,) to construct an approximate deviation table for the vessel when heeling 10° to starboard and 10° to port, or to compensate for heeling by means of a vertical magnet.

10. They should be able to determine the correction of the compass by azimuths time, or otherwise, of the sun, moon, planets, or stars.

11. Also, to determine the variation of the compass by means of the variation chart or otherwise, and to separate deviation from variation.

12. Also, to record observations in a form suitable for further correction of the compass, or for their guidance under similar circumstances. All that any officer can require on the subject of compass deviation will be found in the British Admiralty Manual for ascertaining and applying the deviations of the compass. The series of papers from the transactions of foreign societies, &c., republished by the Bureau of Navigation; the reports of the Liverpool compass committee, republished by the Bureau of Navigation; and the numerous forms and circulars, all of which are furnished to the vessels of the navy by the bureau, supply all needed information.

The subject of ships' compasses and compass errors is one of too much importance to be neglected by any commander or other officer whose duty it is to navigate or to assist in navigating a vessel. Every effort has been made by the bureau to provide the necessary means for safely navigating the vessels of the navy, and if these means are not intelligently employed, those who fail to avail themselves of them and misfortune follows, they alone will be responsible.

COMPASSES IN THE NAVY.

1. Every vessel of the navy when fitted for sea will be provided with a *standard compass*, (azimuth and all its appliances,) fitted on a pedestal, (if possible,) placed in the best position that can be found with reference to local magnetic influences and the uses to be made of it for taking azimuths and amplitudes, bearings of celestial and terrestrial objects, and as the standard of comparison for the binnacle or steering compasses.

2. An *azimuth compass* with all its appliances, similar in every respect to the one fitted on a pedestal, but with a tripod for use at any part of the vessel or on shore, as circumstances may require.

3. The requisite number of steering or binnacle compasses, by which the vessel is to be steered; but the courses steered and bearings taken by the binnacle compasses are to be referred directly to the standard compass.

4. Boat compasses.

THE STANDARD AZIMUTH COMPASS ON A PEDESTAL.

The azimuth compass, furnished as a *standard compass*, will be of the most approved form, and of the best material and construction. The one now in use in the navy is in all essential points and particulars identical with the azimuth compass adopted by the British admiralty upon the recommendation of a board of scientific gentlemen convened for the purpose of considering the subject of compasses for the use of the British navy.

The bowl of this compass is made of pure copper, sufficiently heavy and thick to diminish the vibration of the card, which has its pivot of suspension at the intersection of the axes of the gimbals.

There are two different and distinct cards used; one card marked A, which has an agate or ruby centre, is to be used at all times except in bad weather or heavy sea, when the motion of the vessel becomes excessive. Four pointed pivots of steel or of native alloy with a spare cap are furnished with and belong to card A. The other compass card, being heavier than the card A, is centred with speculum metal, and marked J. A spare cap and two ruby-pointed pivots of a hemispherical form accompany the card marked J.

The compass needles are thin compound bars made of the best quality clock spring-steel. There are four needles to each card, fixed parallel and equidistant on a light brass frame, to which the card is secured by small brass screws. The length of the central pair is 7.2 inches; that of the external pair is 5.3 inches, and their extremities are respectively 15° and 45° from the north and south points of the card. Four small sliding weights of brass, fixed to the frame that carries the needles, are so adjusted that the card is level when at rest. These slides are moved when necessary to overcome the dip of the needle. Sealing wax is frequently improperly used for this adjustment instead of the slides, thereby greatly adding to the weight of the card. The paper forming the card is cemented to a thin disk of mica, and afterwards printed; by which means its liability to subsequent change of form is diminished.

It being necessary in adjusting and testing the accuracy of compasses to make the north and south lines of the card parallel to the magnetic axis of the system of needles, a centre bouche must be inserted concentric with the edge of the card, so that by loosening the screws which attach the card to the brass frame, the card may be revolved through a sufficient angle to make the proper adjustments.

In addition to the ordinary division of quarter points its margin is graduated to 20′. Provision must also be made for raising the card from the pivot by a screw at the side of the bowl.

The azimuth circle is fitted as a cover to the bowl. It is accurately graduated and reads to minutes by two opposite verniers on the circle which carries the prism and sight-vane. Two colored glasses are attached to the prism to protect the eye of the observer when taking azimuths of the sun, and a black glass mirror is fitted to the sight-vane for observing objects at great altitudes. A plain glass cover is used as a substitute for the azimuth circle when the instrument is used as an ordinary compass for giving courses and taking bearings.

Each azimuth compass is provided with a small magnifying glass, and a spare hair line for the sight vane. As a general rule (and always when it is possible to do so) a permanent pedestal, for supporting the standard compass, will be erected on the midship line of that part of the vessel where it will be least affected by local deviation, and at the same time sufficiently convenient for observing azimuths and bearings. This pedestal will be made of non-magnetic material upon the plan and according to specifications furnished or approved by the Bureau.

It is of primary importance in selecting a position for the standard (pedestal) compass, or for the tripod standard compass, to avoid close proximity to any considerable mass of iron, especially any that is vertical, such as the capstan spindle, iron stanchions, boat davits, &c.

The courses to be steered and bearings taken are to be those shown by the standard compass, which are to be recorded in the log-book. Courses given to the helmsman to steer by the binnacle compasses are to be those corrected by the standard compass. The standard compass, mounted either on a pedestal or tripod, is to be used in its selected position when the vessel is swung for determining the local deviation, and the table of errors arising from local deviation will be applied to that compass, to which all others must be referred.

In case a neutral position is found which is not suited for erecting a pedestal for mounting the standard compass, the position of the legs of the tripod will be carefully marked on the deck, and that compass (its errors for local deviation having been previously ascertained by swinging ship) will be used and referred to as the standard compass. Whenever the standard (azimuth) compass is not being used, when moved, and when guns are fired near it, the card must be lifted from the pivot by turning the milled head at the side of the bowl. The cards of all compasses are always to be placed in the boxes according to their marks, and special care is to be taken to see that no two boxes containing cards are kept in contact with poles of the same name nearest to each other.

The screws attached to the prism and sight-vane of the azimuth compass must not be moved, inasmuch as the adjustment would be altered by doing so.

STEERING COMPASSES.

The steering compasses furnished to vessels of the navy will be dry and liquid, and in either case of the best material, pattern and workmanship. The dry compasses will conform to the British Admiralty pattern, and the liquid compasses to the pattern of the Messrs. Ritchie, of Boston, with such modifications in both as may from time to time be directed by the Bureau.

Boat compasses will be liquid, and fitted with a bracket for hanging them on the back boards of the boats, so that the helmsman may see the compass-card while occupying his seat in the cockswain's box. Boat compasses will be of different sizes, suited to the character and sizes of the boats.

CARE OF THE COMPASSES.

Every compass must be in good order and in perfect adjustment when issued for use on board ship.

Compasses delivered in proper adjustment and in good order will, with ordinary care and attention remain so. Should the bowl not work freely the gimbals must be examined and their bearings rubbed with plumbago. No grease, oil or other fatty matter should be applied to them under any circumstances. The pivots and the caps of the cards must be frequently examined to see that they are clean and in good order. If it should be found that the points or caps are injured they must be replaced immediately. The points of the spare steel pivots must be kept covered with cement to prevent rust and preserve them from injury. The cement used for this purpose can be readily removed by the finger nail.

Special care must be taken to prevent injury to the pivot while screwing it into the bowl; and when in its place the compass-card must be placed upon it gently.

The *sharp-pointed pivots* are to be used only with card A, and the *ruby-pointed pivots* only* with the card J. Careful observance of this direction is of the utmost importance, as neglect of it will insure the speedy destruction of both pivots and caps.

The sliding weights on the under side of the card are to be moved whenever it becomes necessary to counteract the magnetic dip, unti the card rests perfectly horizontal.

COMPASS EXAMINATIONS, TESTS AND ADJUSTMENTS.

To insure the greatest attainable excellence, both of materials and workmanship, in the compasses issued to vessels of the navy, the Bureau has erected a suitable building on the Observatory grounds, where, as far as possible, all new compasses, and all compasses that have undergone repairs, will be carefully examined, tested and accurately adjusted under the direction and supervision of the officer in charge of the Hydrographic Office, before being issued for use. The compass building contains three small stone piers in the line of the magnetic meridian.

The centra pier, which is about six and a half feet distant from each of the other piers, supports a transit theodolite.

On the south pier is suspended, by a thread of untwisted silk, a small tube of magnetized steel, one end of which is closed by a plain circular glass, having a fine scale of equal parts engraved diametrically upon it. In the other end of the tube is fixed a convex lens, the scale being in its focus. This, with the proper apparatus for removing the tension of the suspending thread, and protecting it from the influence of currents of air and other disturbing causes, constitute a magnetic collimator, with which by well-known methods the direction of the magnetic meridian may be readily found. When this has been done, it is only neces-

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*The ruby-pointed pivots are made exclusively for the card marked J, (which has a speculum metal cap,) and are not to be used with any other card.

The steel pivots, and also those pointed with native alloy, (and which have sharp points,) are only to be used with the card marked A, which is fitted with a ruby cap, and a spare agate cap is likewise supplied.

When the card works sluggishly, the pivots and caps are to be examined, and, if necessary, a new cap or pivot is to be screwed in.

sary to measure with the theodolite its angle with the true meridian by reference to the established azimuth, to obtain the magnetic declination at the time of observation.

The north pier is fitted with a sliding top, which may be moved by a screw, so as to bring the pivot of a compass placed upon it into the line indicated by the theodolite. An adjustable combination of lenses fixed by means of a cap to the telescope of the theodolite, and removable at pleasure, gives distinct vision of a compass card placed on the north pier, without disturbing the focal adjustment for infinitely distant objects, required for observations with the collimator.

Openings in the roof, covered by movable shutters, and windows to the north and south, afford facilities for determining the direction of the true meridian by astronomical observations.

The building is constructed wholly of non-magnetic materials and placed at a considerable distance from any structure which might be magnetic.

New compasses, as far as may be found practicable, will be sent to the Hydrographic Office for examination and adjustment before being placed in store for issue.

When vessels return from cruises and are put out of commission, all their compasses will be forwarded to the Hydrographic Office for repair, and before being sent into store for reissue they will be carefully adjusted at the compass building.

No compass will be issued, if it can be avoided, to a cruising vessel until it shall have undergone the necessary examination and adjustment, after repair.

A record of the examinations of all the compasses will be kept, and the reasons for all rejections by trial are to be fully stated on the record.

The examinations, tests and adjustments of all the compasses carefully made, will justify the fullest confidence in the correctness of those sent afloat.

INSTRUCTIONS FOR THE EXAMINATION AND ADJUSTMENT OF COMPASSES.

AZIMUTH COMPASS, (TO BE USED AS STANDARDS,) MOUNTED EITHER ON PEDESTALS OR TRIPODS.

Azimuth compasses will be examined and adjusted as follows:

1. The general finish of the instrument, its packing, and contents of its box, are to be carefully examined.

2. The boxes are to be strong and well made, of mahogany, well oiled, and varnished on the outside. The different parts the boxes contain must be securely fixed or fitted in their places to prevent injury when transported or handled. No iron screws, iron nails, or other magnetic material are to be used in making compass boxes. The lacquer in the bowl and other metal parts must be of a dark color, bright and hard.

The material and workmanship throughout must be of the best quality.

Repaired compasses must have the appearance of new ones.

CONTENTS OF THE BOXES.

The first box will contain the bowl, with its gimbal-ring and plain glass cover.

The second box will contain the azimuth circle, prism and sight vane, fork-spindle, magnifying glass, and spare hair-line.

The third box will contain the card A with cap, spare cap, and four spare pivots.

The fourth box will contain the card J with cap, spare cap, and two spare pivots.

2. *Examination of the bowl and gimbals.*—The bowl must be made of pure copper, painted white inside, with the lubber line plainly marked, corresponding in depth and diameter with the standard gauge. The bowl must be truly cylindrical and perfectly balanced. The cover must go on easily, fit without shaking, and the pins for retaining it be in their proper places.

The glass both of the bottom and the cover must be of sufficient thickness, of good quality, and without cracks, flaws, or veins.

The bowl must work freely in its gimbals, but without too much play, both in the box and the fork, and must turn completely round in the gimbal-ring. The bearings of the gimbal-ring and fork must be secured with small screws, to prevent their working out.

All the bearings and bouches must be of hard bell-metal. The lifter must work smoothly and raise the card horizontally far enough to secure it against the glass cover, or the centre pin if there be one.

The fork must turn smoothly upon the spindle, and be firmly held by the clamp screw.

3. The azimuth circle must go on the bowl easily and fit it closely. The glass must be of good quality. The graduation of the limb and the

verniers must be uniform and distinct when examined with a magnifying-glass.

The movable circle must turn about its axis without shaking, and the hinges of the sight-vane and mirror, and the colored glasses, must work smoothly, but with just friction enough to retain them in any required position. The hair-line must be straight, fine, and perfectly black, and it must be perpendicular to the plane of the circle when the sight-vane is raised.

4. The card A must be correctly centred, flat, circular, and of the diameter indicated by standard gauge. The impression must be clear and distinct. The needles must be straight and their planes perpendicular to that of the card. Their dimensions and the distances between them at both ends must correspond with the indications of the standard gauge. The slides must move easily, with sufficient friction to retain them in their places. Both caps must fit the card, and when either is in place the point of suspension must not be sensibly out of the plane of the card. The agate or ruby centre and the points of the four pivots must appear to be perfect when viewed with a magnifying-glass, and the pivots must fit properly their place in the bowl. The card marked A should weigh not less than 3.8 oz. nor more than 4.2 oz., and when tested for deflection must not deflect less than 25° at the distance of 17 inches.

5. Card J must be examined and tested in the same manner that the card A is. The weight of card J should not exceed 9.1 oz. and not be less than 6.9 oz. It should deflect not less than 30° at the distance of 17 inches.

I. Adjustments of the azimuth compass.

The quality of the metal comprising the compass bowl is tested by bringing the bowl near to the collimator. If the collimator is deviated by the close proximity of the bowl, it will be evidence that the bowl is not made of pure non-magnetic metal.

AZIMUTH CIRCLE.

1. *The axis of the movable circle is to be brought into coincidence with that of the limb.*—Read both verniers, and after turning the circle 180°, read them again. The arc intercepted between them, counting always from the same vernier and in the same direction, should remain the same; but if it does not remain unchanged, the cap on the under side must be removed, and the axis moved by the screws towards the side of the greater arc. If the circle is without screws for making this adjustment, the screws which retain the axis must be loosened, and the axis itself carefully moved in the proper direction. This operation is to be repeated at points 90° distant from the preceding one until the adjustment is satisfactorily completed.

2. *The verniers are to be brought diametrically opposite to each other.*—

Place the zero of one vernier on any one of the divisions, when the zero of the other should coincide with the division 180° distant from the first one; but if it does not, one of the verniers must be moved laterally until they are directly opposite to each other.

3. *The verniers must be fixed at proper distances from the centre of the circle.*—Set the zero of either vernier on any one of the divisions, and note whether the last division of the vernier coincides also with a division of the limb. If the vernier is apparently too long, it must be moved further from the centre of the circle; if apparently too short, it must be moved towards the centre of the circle until its first and last divisions coincide with divisions of the limb. Having adjusted both verniers with reference to the centre of the circle, it will be necessary to re-examine the preceding adjustment and test the accuracy of the graduation at various parts of the limb.

The foregoing adjustments of the azimuth circle not being liable to derangement, unless by violence or bad handling, they should be perfected by the maker before leaving the shop, and their subsequent examinations be merely precautionary.

II. Adjustments of the cards.

The direction of the magnetic meridian for the time having been determined in the usual way, the focusing cap is to be put on the telescope of the theodolite.

The cap when used must be adjusted to give distinct vision of the point examined, and its collimation error eliminated if necessary by reversing the telescope.

A pointed pivot is next to be screwed into the pivot stand on the north pier and brought into the meridian indicated by the theodolite.

Card A is then to be placed on the pivot, and the sliding weights adjusted until it is horizontal. Its north and south points seen through the telescope should now be in the meridian. If they are not, the screws on the face of the card must be loosened and the card revolved on the frame which carries the needles until the adjustment is perfected.

A ruby point is then to be substituted in the pivot stand, and card J adjusted by the same means.

III. Adjustments of the compass.

1. *The pivot must be brought into the centre of the bowl.*—Place the bowl, fitted with card A and the azimuth circle, on the north pier, and when the card is at rest set the zero of one of the verniers in one of the divisions of the limb, and note the bearing indicated by the coincidence of the hair line with the graduation of the card. Turn the circle 180° without disturbing the card, and read the bearing as before. The difference should be 180° from the former, but if it is not, the pivot pin is to be moved by the capstan-headed screws at the bottom towards the side on which the angle is apparently less than 180°. This operation

must be repeated at points 90° apart, until the adjustment is satisfactorily completed.

2. *The index error of the prism is to be corrected.*—With the theodolite determine the magnetic azimuth for the time of some conspicuous distant object. Set one of the verniers at 0°, the sight-vane being over the lubber-line, and by turning the bowl bring the hair-line upon the same object.

The bearing read from the card should agree with that previously found. If it does not, the prism or sight-vane is to be moved in the proper direction until the indicated bearing is correct. This adjustment must be re-examined after deviating the card a few degrees and allowing it to come to rest again.

3. *The following conditions are to be verified.*—The compass remaining in the last-mentioned position, the lubber-line will also indicate the same bearing if it is correctly placed.

The axis of the mirror must be perpendicular to the plane of the sights. This will be the case if an object seen in it through the slit of the prism appears to move in a line parallel to the hair-line as the mirror is moved.

The mirror must also be perpendicular to the plane of the sights. Its position is correct when an object and its reflected image, seen through the sights at the same time, both coincide with the hair-line.

Finally, the bearing of any convenient object is to be observed with the lubber-line successively north, east, south, and west, repeating each reading after deviating the card and allowing it to come to rest again. From any remarkable discrepancy in the results, it may be inferred that the bowl itself is magnetic.

Tripods for mounting azimuth compasses should be examined with reference to their stability, and to see that the fork fits properly.

IV. Steering compasses.

1. Every part of a steering compass must be subjected to the same examinations and tests that corresponding parts of azimuth compasses are subjected to. Every compass box must contain a certificate of the date and place of its last examination, test, and adjustment.

2. When it is not practicable to have compasses tested at the Hydrographic Office before issuing them for use at sea, navigation officers in charge at stations will make such detailed examinations, tests, and adjustments as may be in their power with the available means at their command.

3. Navigating officers attached to vessels in commission are expected and required to give particular attention to the compasses, compass-cards, and all their parts; see that they are kept in good order, that no improper lubricating or cleaning materials are used, and that the cards when packed for storage below are not improperly placed relatively to each other. Compasses should not be handled with their cards resting on the pivots when it can be avoided.

4. The cards of azimuth (standard) compasses should never be allowed to rest on their pivots when they are not in use for observations or bearings. The cards should be invariably lifted from their pivots so soon as the bearing is taken or the observation made.

[Circular No. 9.]

BUREAU OF NAVIGATION, NAVY DEPARTMENT,
Washington, March 7, 1867.

To prevent misunderstanding or misapprehension as to the true intent and meaning of the terms *standard compass* and *azimuth compass*, as they are used in the tables of the book of allowances, it is directed:

1. That every vessel fitting for sea shall be provided with a standard compass, with which all azimuths and amplitudes are to be observed, all important bearings taken, when practicable; and when it is not practicable to take bearings from the standard compass, then the bearings taken with another compass are to be corrected by it; it being intended that all courses steered, and recorded in the log-book, shall be those shown by the standard compass as the regulator of the binnacle compasses.

2. That the standard compass shall in all cases, when possible, be placed upon a permanent pillar or pedestal on the midship line, either on or near the quarter deck, or on the poop deck if there be one, and as far removed as possible from any considerable mass of iron, especially if placed vertically, such as the spindle of the capstan, iron stanchions, iron boat davits, &c., &c.

3. The compass to be placed and used as a standard will be of the most approved form of *azimuth compass*, comprising a graduated circle and all the azimuthal appliances, in addition to a *plain glass cover* for ordinary use. It will be securely and permanently placed on the top of the pillar or pedestal above the hammock nettings and bulwarks, or fitted with rack, pinion, and crank for elevating and lowering it at will. It will be fitted into a conical or other regularly shaped box, constructed of non-magnetic metal, with a light, movable top, to which a door, opening abaft, will be fitted, so that the direction of the vessel's head may be seen and approximate bearings taken at any time.

4. In addition to the standard compass, as above defined, to be placed and fitted as directed in paragraphs 1, 2, and 3, every vessel fitting for sea will be provided with a *portable azimuth compass*, to be placed on a tripod when required to be used. It will be of the most approved pattern, with a graduated circle and all the usual azimuthal appliances.

5. When, from any cause, no suitable position for the standard compass can be found which is free from surrounding material that might cause excessive local deviation, then a position is to be selected, after suitable trial and experiment, for placing the portable azimuth compass, to be used as the regulating and reference compass, in place of the permanent standard compass. Having determined upon the best place for

placing the portable azimuth compass for use, the points occupied by the azimuth tripod legs are to be marked on the deck, so that they may always be placed in the same position when observing azimuths and amplitudes, taking bearings, or determining the difference between it and the binnacle compasses.

6. When the vessel is swung for the purpose of determining the local deviations, the permanent standard compass placed on the pedestal will be used on board; but if no permanent standard is fitted, then the portable azimuth compass will be used; and in the latter case, all bearings and observations will be taken from the position selected as hereinbefore directed.

7. All the compasses put on board any vessel are to be of the most approved pattern and construction, and fitted with all the latest improvements. For the present the dry compasses of the British admiralty pattern, and the liquid compasses of the Messrs. Ritchie, of Boston, will be used.

It is of the greatest importance that more attention should be given than hitherto, as a general rule, to compasses placed on board vessels of the navy, and particularly to their errors, caused by neglect while in the store-rooms, by being improperly placed when used on deck, and by the greatly increased masses of iron now employed in constructing and fitting vessels of war.

THORNTON A. JENKINS,
Chief of Bureau.

V. Pedestal binnacles.

1. Pedestal binnacles, fitted with a rack and pinion for elevating the standard (azimuth) compasses for use on board of vessels of the navy, will be constructed and fitted upon one uniform plan or model for all vessels, varying only in height to suit the height of the bulwarks, boats, &c., above the deck of each particular vessel. The size and weight of the pillar or support to the compass-box will be regulated by its height.

2. The box, or receptacle, for the compass, when not elevated by the rack and pinion-work, will be of one uniform shape and size for all vessels, to suit the one size standard (azimuth) compass.

3. In determining the height for the compass card, the length of the elevating bar must be taken into consideration. The compass should not be elevated more than necessary above the box, nor higher than it will be convenient and easy for the officer or observer standing on the top of the ladder to read the bearings and handle the attachments with freedom of limb and body. Where the bulwarks of a vessel are sufficiently low, and there are no boats or other obstructions to vision around the horizon except the masts, the compass should be placed permanently without the elevating rack and pinion-work, but in every other respect similar to the pedestal fitted with rack and pinion for high bulwarks, &c.

4. In no case should the elevating bar be longer than just sufficient to

raise the compass to the required height, which should not exceed two or three feet. Stability and steadiness of the compass being essential to correct bearings and azimuths at sea, the shorter the elevating bar the better. All bearings and azimuths should be taken from the same elevation.

5. No unnecessary material, either of wood or metal, nor useless ornamentation, should be allowed in constructing pedestal binnacles.

6. Plans, drawings, and specifications for pedestals will be furnished or approved by the bureau when necessary.

VI. Steering-compass binnacle.

1. Binnacles for the steering compasses on board of vessels of the navy will be constructed and fitted upon one uniform plan or model for all vessels, varying only in weight or lightness, according to the larger or smallei size of the vessel. The box or receptacle for the steering compass will be of one uniform size and shape for all vessels and suited to the reception of steering compasses of the greatest diameter in use or authorized. The compass card of steering compasses should be about three and a half feet above the deck, so that the helmsman may keep his eye upon it without changing his easiest and most natural posture while at the wheel. If the compass be placed too low, the helmsman will have to stoop to steer by it; and if too high, he will have to stand nearer to it than would be convenient to use the wheel advantageously, especially in a heavy sea. No spaces are to be left in the binnacle in which articles other than the parts of the compass are to be kept. Great care is to be taken to prevent the use of any magnetic material in the construction of pedestal and steering-compass binnacles. The purest non-magnetic copper or brass must be selected and tested before being used for constructing binnacles and their necessary appendages.

2. Plans, drawings, and specifications for making steering-compass binnacles will be furnished or approved by the bureau when necessary.

VII. Swinging ship for compass deviation.

For convenience and expedition in swinging vessels of the navy for deviation, compass stations have been established by the Bureau of Navigation at Portsmouth, New Hampshire, Boston, New York, Philadelphia, and at Hampton Roads, Virginia. These stations, although useful in furnishing the true magnetic bearings from the centre buoy of each station to several well-defined distant objects, as shown by the charts, are not essential. Other modes which must be familiar to every one who has taken the trouble to examine into the subject are available, and must necessarily be resorted to elsewhere than at those specially designated places. The forms for recording the observations and their reductions, and for reporting results to the bureau, are in the main the same as or similar to those adopted by the British Admiralty and Board of Trade, and they should be strictly conformed to. Although there are at present but few iron vessels in the navy, and not many in the commercial marine, yet they have greatly increased in the navy within a few years past, and are daily increasing in the merchant service, rendering it of great importance to seafaring men that the means for safely navigating them should be diligently studied. But all vessels have more or less magnetic deviation, and safety and economy of time, the natural result of approximating more nearly to arcs of great circles by the aid of correct compass courses, demand more than ever before, the attention and care of commanding officers.

VIII. Swinging ship for deviation.

[Compiled by Rear-Admiral Fitzroy, F. R. S.]

1. When a ship is ready for sea, with her stores and weights, especially all iron materials on board, in their proper places, she should be swung or turned round so as to bring her head gradually to each point of the compass.

2. If time or circumstances will not admit of a complete swinging, choice should be made of at least four principal points opposite to each other, namely, NE., SE., SW., and NW. Next to these in importance are the intermediate cardinal points, and then the alternate ones.

3. The object being simply to ascertain the error of the compass caused by the ship's effect on it in each ordinary position, observations may be either consecutive or made at intervals, as opportunities offer. The ship's effect or the attraction of the iron in and about the ship varies irregularly in some cases, perhaps many, however uniformly in others, and therefore should be ascertained experimentally when practicable.

4. A good compass should be used as a standard, with which the others should be compared frequently.

5. Where the standard compass should be placed must depend on the peculiar arrangement of a ship. It ought to be over the mid-ship fore and aft line of the quarter deck or poop, high enough for taking bearings over the bulwarks, and always used in the same position.

6. No iron, not permanent, ought to be within fourteen feet of this compass, in any direction; none at all, indeed, within these limits if avoidable.

7. It ought not to be corrected or compensated by magnets, although other compasses may be, if they are adjustable when used in voyages that greatly change the latitude. To be a check on the other compasses it must be independent. The more elevated it is, consistently with use and safety, the better, because less affected by local attraction; but this should not include a height of more than a few feet above the highest bulwarks or hammock nettings. As a compass is raised above the ship's centre of motion, its tendency to oscilliate and injure its centering is increased.

8. Not only is an accurate knowledge of the deviation necessary for keeping a correct account of the ship's course, for making the shortest

track and for detecting currents, but it is indispensible for the safety of some ships, especially those constructed of iron, or which may have much iron near their compasses.

9. This includes errors caused by *list-deviation*—a term used in preference to "incline-deviation," because "list" is a nautical term, and incline is too near inclination (already inconveniently used for dip.) Ships are usually "swung" when upright. Their compasses are "adjusted" similarly. But at sea sailing ships heel, or have a list of from say five to fifteen degrees, and while so listed their deviation is different, sometimes *very* different from that which they would have if upright, with the ship's head in the *same* direction. In one iron ship—the W. S. Lindsay—more than two points of difference were caused by her heeling over under sail, (see Walker on Ships' Magnetism.) The reasons are obvious. When a ship is on "an even keel" (upright) the iron of either side acts on a compass similarly to that of the other. When there is a considerable list, the iron on either side acts differently from that of the other. Tanks and ballast affect the compass differently from guns, shot, and iron in the upper part of the ship; and the sharp iron after bodies or "runs" of vessels (being vertical and very magnetic) have an effect on the compass contrary to that of the iron in the *upper* body of the ship *before* the binnacles.

10. A remedy seems to be to place a ship along her *neutral line*, (that in which she has the least deviation,) then to list or heel her over, as if under sail, and ascertain what difference is caused in the deviation. It appears probable, but it has not been proved, that equal or proportionate differences would be caused by equal lists with the ship's head in other directions.

11. Although ships should be swung carefully and without hurry while in port, the deviation may be obtained with sufficient accuracy when out of harbor. Just before the pilot leaves or before losing sight of the land, every ship ought to test her compasses; and from time to time at sea, as well as in foreign ports, such trials should be repeated.

12. They may be made by taking transit bearings, or even the bearing of only one distant object, while the ship's head is on a *few* points nearly equidistant round the compass. About eight points are sufficient, except in some rare instances of iron vessels or peculiarly arranged steamers. Perhaps, indeed, four bearings will often be sufficient if taken with the ship's head near NE., SE., SW., and NW.

13. The deviation on other points may be inferred by calculation or a diagram.* In the absence of a transit bearing of known direction, the correct or real magnetic bearing may be assumed to be the mean of all the bearings, supposing them taken nearly equidistant. This will, in general, be sufficiently accurate for safety, though not invariably exact.

14. In a calm, or while hove to, such observations may be speedily made, even in a sailing vessel; and they become invaluable, because the ship

* See page 37.

having then all her weights stowed, and being free from influence of land, wharves, other ships, &c., shows her *real* local attraction at that place, which can be relied on more than the results deduced from "swinging ship" in a narrow locality.

15. Ships swung in docks or other confined spaces may be near masses of iron, on the nearest jetties, or other ships perhaps built of iron, or loaded with it, or large anchors or mooring chains under water beneath the hull—besides which the land itself is strongly magnetic in some places, often little suspected.

16. Anchors being weighed, chain cables all in board, boats hoisted up, and everything in its sea place, make more or less change in a ship's magnetism.

17. At sea, the Pole-star, the Southern Cross—any star near the horizon in the east or west; the sun or moon rising or setting, or any distant object not changing its bearing sensibly during a few minutes, may afford the means of testing compasses even better than when in port, yet, obvious as the fact is, attention has not been drawn to the subject sufficiently to make it as familiar to all seaman as it ought to be.

18. Besides these simple means, and transit bearings, or the bearing of two objects in one line, (whose relative bearing is known,) there is the horizontal angle between the direction of the ship's head, or fore and aft line, and any heavenly body on the meridian, or of which the bearing can be obtained by calculation, so commonly available.

19. A comparatively neutral position may exist in every ship; which should be ascertained, if practicable, as a place from which correct magnetic bearings may be obtained; and which, therefore, so far as magnetism is concerned, is the best place for a standard compass. Besides this, it can hardly be too much urged on seamen to ascertain any neutral *line* of position from time to time; for though varying with difference of stowage as well as with changes of geographical locality, it varies with the deviation, of which the alterations should be continually watched. These important neutral lines are lines of bearing, or rhumbs, in either one of which, when a ship's length is placed, there is little or no error in the compass bearings, caused by deviation.

20. A bearing of any object taken with the ship's length along such a line will be nearly correct, and when compared with a bearing of the same object, from the same spot, with the ship's length not along such a rhumb, but with her head directed to any other point of the compass, will show the amount of deviation in that position; and similarly of other points.

21. Having thus a familiar acquaintance with a ship's usual neutral lines, the deviation on any course, or the correct variation of the compass, or the actual course a ship is steering, can be readily checked at any time of night or day, when an object is in sight sufficiently far off and stationary to admit of its bearing being unaffected by parallax, or a slight change in the relative position of the ship. Of course, the more distant

the object of which a bearing is taken the better, provided it is distinctly defined.*

22. An azimuth circle, a bearing-plate, or a dumb-card, is useful in referring bearings to the direction of a ship's head; such graduated circles, showing the angle between an object and the direction of a ship's head, are very useful.

23. In correcting for deviation, as errors occur, in practice, occasioned by temporary incorrectness of thought, rather than from want of acquaintance with the subject, a few brief notes may be given here, with a view to diminish the risk of mistake.

24. Two graduated circles of horn, paper, or card, of different sizes, (say two spare compass cards,) are useful to assist the mind occasionally.

25. One placed over the other, and turned a little on its centre, will show how local attraction or deviation should be allowed for; and if similarly placed on a chart (or true meridian) will show which way the difference between the magnetic bearing of any point and the true (or the bearing by the world) should be allowed.

26. A ship's magnetism drawing one end of the needle towards the centre of such attraction increases or diminishes the total error of the magnetic bearing, according as the deviation and variation act in the same or contrary directions.

27. When the north end of the needle is drawn to the right of the true north (by the world,) the variation is called east or easterly, and if to the left, west or westerly.

28. So likewise the deviation is called easterly, or east, when the needle on board a ship is drawn to the right of its correct magnetic position (if influenced by the *earth's* general magnetism *alone*,) and vice versâ, as above.

29. Hence the apparent bearing, or course, should be corrected, first, for deviation, and, secondly, for variation, in order to get the true course, or bearing, by the world.

30. But in "*shaping*" a course, or obtaining the apparent magnetic bearing from the true bearing by a chart (or the world,) the *reverse* is the common (though inexact) rule, thus: Apply the correct variation reversely, or with a contrary sign, and then the deviation also reversely, and the result will be the apparent magnetic bearing (approximately.)

31. *Examples.*—The correct variation being 12° E., the deviation 7° W. and the true bearing N. 45° E., the apparent compass bearing will be N. 40° E. approximately.

* It should not be overlooked in making observations for compass deviations by the method of direct bearings, that, unless the object observed be sufficiently distant, the parallax may be such as to materially modify the results, where the deviation is small, as it commonly is in wooden ships.—T. A. J.

2. Apparent compass bearing,	N. 40° E., or N. E. ½ N.
Deviation............	7 W.
	33
Variation............	12 E.
True bearing.........	N. 45 E.

3. True bearing..............	W. 2° 48′ N.
Variation...........	8 30 E.
	W. 5 42 S.
Deviation............	11 10 E.
Apparent compass bearing,	W. 16 52 E.
	or S. 73 8 W., or W. by S. ½ S.

32. This rule is not strictly correct even in ordinary cases, though sufficiently so for the common purposes of navigation in the more frequented latitudes. Should the deviation be large, or vary rapidly, not even a second approximation will give a precisely accurate result, but recourse must be had to a graphical or a tabular method.*

33 It may be observed that *apparent* magnetic bearings being different from most of the correct magnetic bearings of any object "set" from a ship—those points on which a ship's head is steadied, in "swinging" for deviation, are not generally the *real* magnetic points of the compass; some are to the right, and others to the left of the correct lines of magnetic bearing, therefore the angles between the bearings observed differ more or less from the truth, according to the greater or less deviation.

34. By this cause—by inertia of the compass needle on its centre—perhaps by the casual approach of iron, even on the person of the observer himself, while bearings are taken—some of the irregularities observable in tables or diagrams of deviations are effected; and it should always be borne in mind that the "list" or "heeling," or inclination, of a ship, alters the amount of deviation *while* so inclined or "careened."

35. The actual process of swinging a ship may be thus briefly described: In an open port or a roadstead, the ship is swung or turned gradually, so as to bring her head from point to point of the compass, and so to check her swinging as to prevent any continued movement of the card. When steady, with her head on any one point, the bearing of some distant object is observed with the standard compass, and noted. The ship's head is then gradually turned to the next point, and when steadied there, the bearing of the same object is again set, and recorded; and so on, point after point.

* Such as that of Mr. Archibald Smith, Mr. Napier, or Captain Ryder.

36. The object selected should be at such a distance from the ship, that the space through which she is turned shall cause no sensible difference in its bearing. If at single anchor in a tideway, a mark at not less than five miles distance will answer; but if moored a less distance will suffice.

37. The *real* or correct magnetic bearing of the selected object from the ship, or, in other words, the bearing which it would have from on board if the compass were not disturbed by the local attraction of the ship, must be found. This may generally be obtained by taking the mean of all the observed bearings; but a surer result will be obtained from a good chart, or by applying the known variation to an observed true bearing by azimuth or amplitude. Carrying the standard compass to a place on the adjacent shore, from which the ship and the distant object, of which bearings are observed exactly in line with the observer's eye, is open to some objection. In all cases, when a compass is landed, great care must be taken that the place where it is used is not on a trap or granite formation, nor exposed to the influence of masses of iron, or of anchors buried near, or of any collection of iron articles, tanks, chains, &c., in neighboring storehouses.

38. If, however, this method be used, the bearing of the object from that spot ought to be the same as its *real* magnetic bearing from the ship by the same compass. The differences between this real magnetic bearing and the bearings observed with the standard compass on board, when the ship's head was on each of the several points, will be the error at each of those points caused by local attraction or magnetism—the *deviations* of the standard compass.

39. As all bearings should be corrected by the deviation which is due to the direction of the ship's head at the moment they are taken, the seaman will perceive the necessity of stating that direction, whenever he records any bearings, and noting whether they are entered as observed, or corrected.

40. When in a confined place, such as a harbor or basin, should there be no suitable object visible from the ship, sufficiently distant, the deviations may be ascertained by reciprocal or back bearings. A careful observer should go on shore with a second compass, and place its stand in some open and unobjectionable spot, where it may be distinctly seen from the standard compass on board. Then, at signals, the mutual bearings of those two compasses are to be observed when the ship's head is steady on each of the required points.

41. The compass on shore should not be more distant from the ship than is consistent with distinct visibility of each compass from the other. The observations should be made simultaneously, and, to guard against any mistake, such as might be occasioned by a signal being misinterpreted, the time at which each bearing is taken should be noted, both on shore and on board, by compared watches.

42. The standard compass should be carried on shore, and compared there with the other compass employed, by means of the bearing of some

distant object; and any difference should be recorded. This comparison of the two compasses may advantageously be made after, as well as previously to the observations; and in all cases when compasses are compared, the caps, pivots, &c., should be carefully examined.

43. It has been found convenient for the observer on shore to chalk each observation upon a black board, so that it may be read at once by the observer afloat, and if there should be any apparent inconsistency, the observation can be immediately repeated, by which the necessity for again swinging the ship may be prevented.

44. From the observations made, a deviation table should be constructed. A form for it is given on page 35.

45. By comparing the 1st and 3d columns of this table the seaman may also find approximately what course he will have to steer by the standard compass in order to make good any given real magnetic course; but to determine it more nearly he must employ the deviation due to the partly corrected course instead of that belonging to the first course. The assistance of a diagram, under certain circumstances, has been already recommended.

46. Tables and diagrams show also the lines of least deviation, or positions in which a ship must be placed, in order that her local attraction may produce the smallest effect on the direction of the needle of the standard compass. In most wood-built ships these positions are not far from north and south, and nearly opposite to each other; but in some vessels, especially those that carry steam engines, they differ very materially, even to nearly east and west.

47. When the lines or rhumbs of least deviation in any vessel have been determined for a compass *always used in the same spot*, they may be regarded as constants, provided that no alteration is made in the amount or distribution of iron in the ship, or any great change in her geographical position. With this proviso, therefore, an azimuth or amplitude observed at sea, when the ship is upright and her head on (or towards) either of the points of no deviation, will give the correct magnetic variation; but, with her head on any other point, the variation observed must be corrected for the deviation due to that point, and allowance made for "list deviation."

48. In some steamships exceptions to this general law have been found; so that it cannot be too earnestly recommended to prove frequently by actual observation whether any change has taken place in the deviation, when none has occurred in the latitude of the ship, or in the disposition of her iron.

49. When circumstances permit, it is desirable to determine the variation by observation of the sun's azimuth or amplitude, while on the course which the ship is actually steering; for by these means the two corrections, namely, for deviation and variation combined, will be obtained by one observation, and with less uncertainty than if separately observed and applied.

50. Experience has shown that the deviation varies most in places distant from each other in *latitude;* so that in the southern hemisphere it sometimes becomes westerly on the points at which it was easterly in the northern hemisphere, and easterly where it was westerly. It is indispensable, therefore, when a ship changes her geographical position *considerably*, and especially when she has passed from one hemisphere into the other, that an early opportunity should be taken of forming new tables by again swinging the ship and ascertaining the actual deviation. The new tables will of course be for local use only, and should be superseded by others resulting from subsequent change of place and later observations.

51. It should be remembered that the deviations may be at any time examined at sea, and their correspondence with the table ascertained, by a few careful azimuths with the ship's head successively on different points. If the deviations thus found should agree with the tabular deviations, the table will be employed with additional confidence; but if they differ *considerably*, the new results must be further verified by the repetition of similar observations. In any cursory examination the points of most importance to determine will be those of least deviation, of greatest deviation, and then a few of those intermediate.

52. It is the more necessary to insist on often making these observations, because in some ships the magnetism of a portion of the iron is nearly *permanent*, ("sub-permanent," rather than "retentive,") while that of the remainder is *induced* (caused by change of position or circumstances) and variable, and it is found that the changes of deviation, when passing from one magnetic latitude to the other, do not follow the same laws, in all places, in both hemispheres.

53. In iron-built ships, it is desirable that the standard compass should be raised much higher than usual above the deck; but in other respects the remarks here given apply to iron as well as to timber-built vessels. Compasses should be vigilantly watched to see that they are traversing freely, to remedy any defect in their movements, or inconvenience in their positions, and to verify their deviations as frequently as practicable. Fixed or adjustable magnets must be employed, in some cases, for neutralizing great deviations, but the mariner can have no absolutely safe guide, when changing his latitude materially, except actual and very frequent astronomical observations.

54. To iron vessels it would afford some security against sudden and unaccountable changes in their magnetism if a compass were placed high above the deck, out of the influence of iron about the mast, and so as to be readily consulted—were it not for the great oscillation caused by rolling, and the increased action on the centring. It would be a satisfactory experiment, within every one's power, to try at what height above the usual level of the standard compass the greatest deviation diminishes to less than a degree under varying conditions.

55. In steam vessels fitted with telescope funnels, the deviation is

altered by the state of the funnel; therefore, it is necessary that on the principal points of the compass, the deviation should be ascertained with the funnel down as well as with it up.

56. The corrections found for the standard compass belong to that compass alone, and to that compass only while it is in one place. They furnish no guide to the effects of iron on a compass placed in any other part of the ship. It is essential, therefore, that the ship's course should be directed, or set, by one compass, and that all courses and bearings inserted in the log should be those shown by that compass alone; the other compasses being regarded solely as approximate guides. When the ship has been placed on her proper course, the helmsman will notice the point shown to which *he* has to attend; and a comparison of compasses should be frequently made by the officer of the watch, especially whenever alteration occurs in the course. When a ship is by the wind, the apparent course should, in like manner, be referred to one compass, by direct and frequent comparison; and the course indicated is that which should be inserted in the log, and used for the ship's track in navigating.

57. In vessels where a single compass is made to traverse, so as to be in front of the helmsman on each tack, it should be compared afresh at every change, because the effect of local attraction is altered by change of place. In ships which have two permanently fixed binnacle compasses, the comparison with another used as a standard ought likewise to be frequently repeated, both when the helmsman changes sides and when the course is changed, for there will usually be some small difference in the deviations of these two compasses; and they are sometimes so near each other as to attract mutually, thus inducing a complication of error, for which the only safe practical remedy is *direct comparison* with the standard or best compass, with known bearings, or with true bearings of heavenly bodies.

58. While ascertaining the deviations of this compass at any time, it is useful to note and record the corresponding directions of her head by other compasses. An occasional change of magnetism, owing to whatever cause, in a compass needle, may thus be detected and remedied.

59. In conclusion, no one can be too vigilant or too much on his guard, in his observations of the mariner's compass, so liable as it is to be affected by unsuspected causes; altered by a stroke of lightning, or injured in its centring; and yet, although so uncertain a guide, requiring such incessant examination and vigilant comparison, it is the instrument most necessary for navigation.

TABLE I.

Form for registering the observations for determining the effect of local attraction on standard compass.—Real (or correct) magnetic bearing of steeple from ship, N. 83° 0′ E., distant eight miles.

Ship's head by standard compass.	Bearing of steeple by standard compass.	Deviation of standard compass.
	° ′	° ′
North	N. 83 11 E.	0 11 W.
N. by E	N. 82 7 E.	0 53 E.
N. N. E	N. 81 20 E.	1 40 E.
N. E. by N	N. 80 23 E.	2 37 E.
N. E	N. 79 23 E.	3 37 E.
N. E. by E	N. 78 33 E.	4 27 E.
E. N. E	N. 77 38 E.	5 22 E.
E. by N	N. 77 10 E.	5 50 E.
East	N. 77 38 E.	5 22 E.
E. by S	N. 78 3 E.	4 57 E.
E. S. E	N. 78 26 E.	4 34 E.
S. E. by E	N. 79 10 E.	3 50 E.
S. E.	N. 79 51 E.	3 9 E.
S. E. by S	N. 80 30 E.	2 30 E.
S. S. E	N. 81 18 E.	1 42 E.
S. by E	N. 82 9 E.	0 51 E.
South	N. 82 52 E.	0 8 E.
S. by W	N. 83 55 E.	0 55 W.
S. S. W	N. 84 38 E.	1 38 W.
S. W. by S	N. 85 24 E.	2 24 W.
S. W	N. 86 8 E.	3 8 W.
S. W. by W	N. 86 50 E.	3 50 W.
W. S. W	N. 87 39 E.	4 39 W.
W. by S	N. 88 17 E.	5 17 W.
West	N. 88 55 E.	5 55 W.
W. by N	N. 88 35 E.	5 35 W.
W. N. W	N. 88 8 E.	5 8 W.
N. W. by W	N. 87 39 E.	4 39 W.
N. W	N. 86 56 E.	3 56 W.
N. W. by N	N. 86 9 E.	3 9 W.
N. N. W	N. 85 31 E.	2 31 W.
N. by W	N. 84 35 E.	1 35 W.
North	N. 83 11 E.	0 11 W.

N. B.—The nearest degree is quite sufficient, in ordinary practice.

TABLE II.

Form for registering observations for determining the effect of local magnetism on standard compass.

The standard compass and another were compared on shore, by taking the bearing of a distant object with each of them. They were placed at least 10 feet apart, to prevent their having any influence on each other. The bearings, by the mean of several repetitions, were—

By the standard compass	N. 55° 0′ E.
By the other, or shore compass	N. 55° 30′ E.
Difference to be applied to the bearings by shore compass	30′

The standard compass was replaced on board, and mutual bearings were simultaneously observed when the ship's head was successively on each of the 32 points as follows:

Time.	Ship's head by the standard compass.	Bearing of shore compass from standard compass.	Bearing of standard compass from shore compass.		Deviation of the standard compass.
			Observed.	Corrected for the 30′ difference for the compass.	
h. m.		° ′	° ′	° ′	° ′
9 10	North.	S. 36 11 W.	N. 36 30 E.	N. 36 0 E.	0 11 W.
9 14	N. by E.	S. 34 7 W.	N. 35 30 E.	N. 35 0 E.	0 53 E.
9 17	N.N.E.	S. 32 20 W.	N. 34 30 E.	N. 34 0 E.	1 40 E.
9 21	N.E. by N.	S. 30 23 W.	N. 33 30 E.	N. 33 0 E.	2 37 E.

And in like manner at all the points of the compass.

N. B.—The nearest degree is usually sufficient (without minutes.)

TABLE III.

Form for tabulating results; or deviation table.

1. Ship's head, or course by the standard compass.	2. Deviation of the standard compass.	3. Real or correct magnetic course steered.	4. In points.
	° ′	° ′	
North.	0 11 W.	N. 0 11 W.	North.
N. by E.	0 53 E.	N. 12 8 E.	N. by E.
N. N. E.	1 40 E.	N. 24 10 E.	N. N. E. ¼ E.
N. E. by N.	2 37 E.	N. 36 22 E.	N. E. ¾ N.
N. E.	3 37 E.	N. 48 37 E.	N. E. ¼ E.
N. E. by E.	4 27 F.	N. 60 42 E.	N. E. by E. ¾ E.
E. N. E.	5 22 E.	N. 72 52 E.	E. by N. ½ N.
E. by N.	5 50 E.	N. 84 35 E.	E. ½ N.
East.	5 22 E.	S. 84 38 E.	E. ½ S.
E. by S.	4 57 E.	S. 73 48 E.	E. by S. ½ S.
E. S. E.	4 34 E.	S. 62 56 E.	S. E. by E. ½ E.
S. E. by E.	3 50 E.	S. 52 25 E.	S. E. ¾ E.
S. E.	3 9 E.	S. 41 51 E.	S. E. ¾ S.
S. E. by S.	2 30 E.	S. 31 15 E.	S. S. E. ¾ E.
S. S. E.	1 42 E.	S. 20 48 E.	S. by E ¾ E.
S. by E.	0 51 E.	S. 10 24 E.	S. by E.
South.	0 8 E.	S. 0 8 W.	South.
S. by W.	0 55 W.	S. 10 20 W.	S. by W.
S. S. W.	1 38 W.	S. 20 52 W.	S. by W. ¾ W.
S. W. by S.	2 24 W.	S. 31 21 W.	S. S. W. ¾ W.
S. W.	3 8 W.	S. 41 52 W.	S. W. ¾ S.
S. W. by W.	3 50 W.	S. 52 25 W.	S. W. ¾ W.
W. S. W.	4 39 W.	S. 62 51 W.	S. W. by W. ½ W.
W. by S.	5 17 W.	S. 73 28 W.	W. by S. ½ S.
West.	5 55 W.	S. 84 5 W.	W. ½ S.
W. by N.	5 35 W.	N. 84 20 W.	W. ½ N.
W. N. W.	5 8 W.	N. 72 38 W.	W. by N. ½ N.
N. W. by W.	4 39 W.	N. 60 54 W.	N. W. by W. ½ W.
N. W.	3 56 W.	N. 48 56 W.	N. W. ¼ W.
N. W. by N.	3 9 W.	N. 36 54 W.	N. W. ¼ N.
N. N. W.	2 31 W.	N. 25 1 W.	N. N. W. ¼ W.
N. by W.	1 35 W.	N. 12 50 W.	N. by W.
North.	0 11 W.	N. 0 11 W.	North.

To obtain the real or correct magnetic course of the vessel from the course shown by the standard compass, look in the 1st column of the above table for the apparent course; the 2d column gives the deviation when her head is on that point; and in the 3d column (the deviation having been applied) is the real magnetic course.

To correct any bearings taken by the standard compass, the table is to be entered with the direction of the ship's head at the time, in the 1st column, and corresponding, in the 2d column will be found the amount of deviation to be applied.

To obtain the standard compass course from the correct magnetic course, look in the third column for the correct or real magnetic, and opposite, in the first column, will be the standard compass course to be steered.

Table for converting points of the compass, and their fractional parts, into degrees, &c.

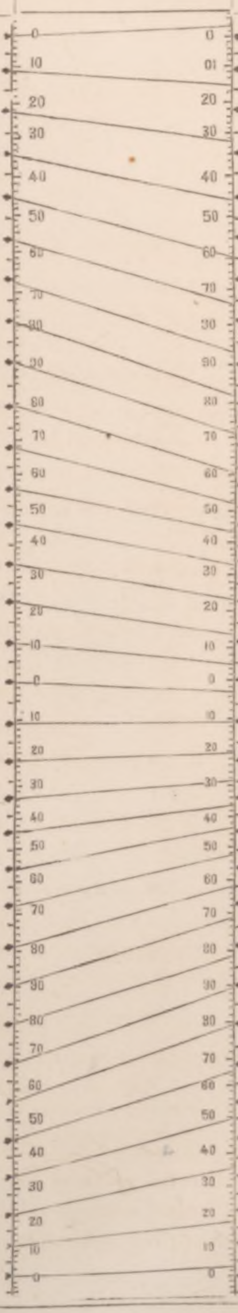
Points.		No.	Degrees, &c.			No.	Points.	
			°	'	"			
NORTH		**0**	0	0	0	**0**	SOUTH.	
		⅛	1	24	22	⅛		
		¼	2	48	45	¼		
		⅜	4	13	7	⅜		
N. ½ E.	N. ½ W.	½	5	37	30	½	S. ½ W.	S ½ E.
		⅝	7	1	52	⅝		
		¾	8	26	15	¾		
		⅞	9	50	37	⅞		
N. by E.	N. by W.	**1**	11	15	0	**1**	S. by W.	S. by E.
		⅛	12	39	22	⅛		
		¼	14	3	45	¼		
		⅜	15	28	7	⅜		
N. by E. ½ E.	N. by W. ½ W.	½	16	52	30	½	S. by W. ½ W.	S. by E. ½ E.
		⅝	18	16	52	⅝		
		¾	19	41	15	¾		
		⅞	21	5	37	⅞		
N. N. E.	N. N. W.	**2**	22	30	0	**2**	S. S. W.	S. S. E.
		⅛	23	54	22	⅛		
		¼	25	18	45	¼		
		⅜	26	43	7	⅜		
N. N. E. ½ E.	N. N. W. ½ W.	½	28	7	30	½	S. S. W. ½ W.	S. S. E. ½ E.
		⅝	29	31	52	⅝		
		¾	30	56	15	¾		
		⅞	32	20	37	⅞		
N. E. by N.	N. W. by N.	**3**	33	45	0	**3**	S. W. by S.	S. E. by S.
		⅛	35	9	22	⅛		
		¼	36	33	45	¼		
		⅜	37	58	7	⅜		
N. E. ½ N.	N. W. ½ N.	½	39	22	30	½	S. W. ½ S.	S. E. ½ S.
		⅝	40	46	52	⅝		
		¾	42	11	15	¾		
		⅞	43	35	37	⅞		
N. E.	N. W.	**4**	45	0	0	**4**	S. W.	S. E.
		⅛	46	24	22	⅛		
		¼	47	48	45	¼		
		⅜	49	13	7	⅜		
N. E. ½ E.	N. W. ½ W.	½	50	37	30	½	S. W. ½ W.	S. E. ½ E.
		⅝	52	1	52	⅝		
		¾	53	26	15	¾		
		⅞	54	50	37	⅞		
N. E. by E.	N. W. by W.	**5**	56	15	0	**5**	S. W. by W.	S. E. by E.
		⅛	57	39	22	⅛		
		¼	59	3	45	¼		
		⅜	60	28	7	⅜		
N. E. by ½ E.	N. W. by W. ½ W.	½	61	52	30	½	S. W. by W. ½ W.	S. E. by E. ½ E.
		⅝	63	16	52	⅝		
		¾	64	41	15	¾		
		⅞	66	5	37	⅞		
E. N. E.	W. N. W.	**6**	67	30	0	**6**	W. S. W.	E. S. E.
		⅛	68	54	22	⅛		
		¼	70	18	45	¼		
		⅜	71	43	7	⅜		
E. by N. ½ N.	W. by N. ½ N.	½	73	7	30	½	W. by S. ½ S.	E. by S. ½ S.
		⅝	74	31	52	⅝		
		¾	75	56	15	¾		
		⅞	77	20	37	⅞		
E. by N.	W. by N.	**7**	78	45	0	**7**	W. by S.	E. by S.
		⅛	80	9	22	⅛		
		¼	81	33	45	¼		
		⅜	82	58	7	⅜		
E. ½ N.	W. ½ N.	½	84	22	30	½	W. ½ S.	E. ½ S.
		⅝	85	46	52	⅝		
		¾	87	11	15	¾		
		⅞	88	35	37	⅞		
EAST	WEST	**8**	90	0	0	**8**	WEST	EAST.

The following are diagrams for correcting deviation of the compass by the straight-line method of Archibald Smith, esq., M.A., F.R.S., late Fellow of Trinity College, Cambridge, which, it is hoped, will be found to remove most of the difficulty of applying tabular correction for deviation:

Her Majesty's ship St. Trident; place, Greenhithe.

Standard compass courses.	Westerly deviation.	Easterly deviation.	Correct magnetic courses.
NORTH	3° 0′	....	N. 3 W.
N. by E....	....	3° 45′	N. 15 E.
N. N. E.....	....	9 15	N. 31 ¾ E.
N. E. by N .	....	12 30	N. 46 ¼ E.
N. E...	....	16 0	N. 61 E.
N. E. by E .	....	17 45	N. 74 E.
E. N. E.....	....	19 30	N. 87 E.
E. by N	....	19 0	S. 82 ¼ E.
EAST.......	....	18 45	S. 71 ¼ E.
E. by S.....	....	17 15	S. 61 ½ E.
E. S. E.	....	16 0	S. 51 ½ E.
S. E. by E..	....	14 0	S. 42 ¼ E.
S. E........	....	12 30	S. 32 ½ E.
S. E. by S ..	....	11 30	S. 22 ¼ E.
S. S. E.	....	9 15	S. 13 ¼ E.
S. by E	....	6 0	S. 5 ¼ E.
SOUTH.....	....	2 30	S. 2 ½ W.
S. by W....	0 0	0 0	S. 11 ¼ W.
S. S. W	2 30	....	S. 20 W.
S. W. by S..	5 45	....	S. 28 W.
S. W.......	9 0	....	S. 36 W.
S. W. by W.	11 45	....	S. 44 ½ W.
W. S. W ...	14 30	....	S. 53 W.
W. by S....	16 45	....	S. 62 W.
WEST	19 0	....	S. 71 W.
W. by N....	20 15	....	S. 81 W.
W. N. W. ..	21 45	....	N. 89 ¼ W.
N. W. by W.	22 15	....	N. 78 ½ W.
N. W.......	20 0	....	N. 65 W.
N. W. by N.	16 30	....	N. 50 ¼ W.
N. N. W....	13 00	....	N. 35 ½ W.
N. by W. ..	7 30	....	N. 18 ¾ W.
NORTH.....	3 0	....	N. 3 W.

Date, September 8, 1852.



Standard compass courses.	Correct magnetic courses.
NORTH ..	NORTH.
N. by E...	N. by E.
N. N. E ...	N. N. E.
N. E. by N.	N. E. by N.
N. E	N. E.
N. E. by E.	N. E. by E.
E. N. E ...	E. N. E.
E. by N ..	E. by N.
EAST	EAST.
E. by S...	E. by S.
E. S. E ...	E. S. E.
S. E. by E.	S. E. by E.
S. E.	S. E.
S. E. by S.	S. E by S.
S. S. E....	S. S. E.
S. by E...	S. by E.
SOUTH ...	SOUTH.
S. by W..	S. by W.
S. S. W ..	S. S. W.
S. W. by S.	S. W. by S.
S. W......	S. W.
S. W. by W.	S. W. by W.
W. S. W ..	W. S. W.
W. by S ..	W. by S.
WEST	WEST.
W. by N..	W. by N.
W. N. W..	W. N. W.
N. W. by W.	N. W. by W.
N. W	N. W.
N. W. by N.	N. W. by N.
N. N. W ..	N. N. W.
N. by W..	N. by W.
NORTH...	NORTH.