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ADJUSTING THE MAGNETIC DEVIATION TABLE FOR MK 2000S COMPASS OUTFIT IN EDUCATIONAL PURPOSES

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Abstract: *In time as a seafarer the orientation on sea it was a great art of sailing. The historical naval events revealed that the direction in azimuth gained by the navigation instruments should be calibrate appropriate in order to confer the safety at sea. In this purposes the International Maritime Organization recommend safety measures such as a standard for magnetic compass to ensure the steering during a voyage. The purpose of this article is to determine the magnetic deviation table of the MK 2000S Compass Outfit from Lilley & Gillie's company after a detachment of equipment from an initial place to a final destination, comparing this fact with a long stationary during which the ship's diametrically plan position has not changed from the magnetic meridian.*
Keywords**:** *navigation instruments, magnetic deviation table, MK 2000S Compass Outfit.*

INTRODUCTION

The magnetic compass it is the oldest instrument for navigation and has been a vital tool for navigators at sea for centuries. The compass allows ships to steer a selected course. By taking bearings of visible object with a compass, the navigator is also able to fix a ship's position on a chart.

It runs on its property of magnetic rose as being the sensitive element of a magnetic compass and gives the North compass direction. The parts of a magnetic compass are:

- sensitive element – magnetic rose;
- azimuth instrument;
- compass box with gimbal system consists of non-magnetic material with the role of ensuring the free movement of magnetic rose and ensure the horizontality of the compass box during the navigation;
- pedestal made of non-magnetic material fixed to the deck;
- the binnacle which covers the magnetic rose, made of copper, and a destination to protect from hits;
- compensating device consists of vertical permanent heeling magnet in the central vertical tube, fore and aft *B* permanent magnets in their trays, athwartship *C* permanent magnets in their trays, vertical soft iron Flinders bar in its external tube and soft iron spheres.

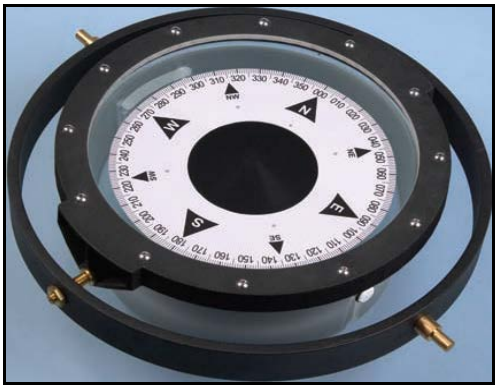

Figure 1 A magnetic rose of MK 2000S Compass Outfit[1]

CARRIAGE REQUIREMENTS FOR NAVIGATIONAL SYSTEMS AND EQUIPMENT

All ships irrespective of size shall have a properly adjusted standard magnetic compass, or other means, independent of any power supply to determine the ship's heading and display the reading at the main steering position and a compass bearing device independent of any power supply to take bearings over an arc of the horizon of 360°.

All ships of 150 gross tonnage and upwards and passenger ships irrespective of size shall, in addition to the requirements be fitted with a spare magnetic compass interchangeable with the magnetic compass.[2]

The compass card shall be graduated in 360 single degrees. A numerical indication shall be provided every ten degrees, starting from North (000°) clockwise to 360°. The cardinal points shall be indicated by the capital letters N, E, S and W. The North point may instead be indicated by a suitable emblem. The directional error of the card, composed of inaccuracies in graduation, eccentricity of the card on its pivot and inaccuracy of orientation of the card on the magnetic system shall not exceed 0.5° on any heading. The card of the steering compass shall clearly be readable both in daylight and artificial light at a distance.

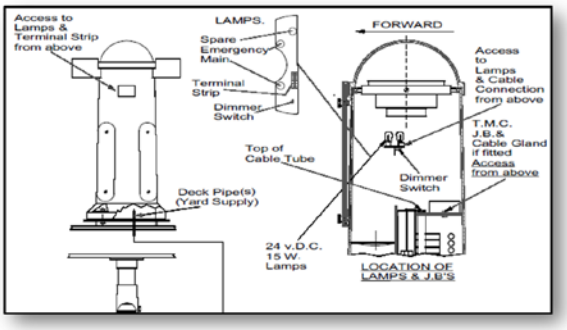

Figure 2 MK 2000S reflector binnacle–cable connection[1]

The magnetic compass equipment shall be installed if practicable and reasonable on the ship's centerline. The main lubber mark shall indicate the ship's heading with an accuracy of ±0.5°. The standard compass shall be installed so that from its position the view is as uninterrupted as possible, for the purpose of taking horizontal and celestial bearings. The steering compass shall be clearly readable by the helmsman at the main steering position.

The magnetic compasses shall be installed as far as possible from magnetic material. The minimum distances of the standard compass from any magnetic material which is part of the ship's structure shall be in accordance with the diagram described lower. The minimum desirable distances for the steering compass may be reduced to 65% of the values given by the diagram provided that no distance is less than 1 m. If there is only a steering compass the minimum distances

[1] LILLEY & GILLIE, MK 2000S Compass Outfit, Installation and operators manual

[2] International Maritime Organization, International Convention for the Safety of Life at Sea, Chapter V, Regulation 19, 1974

for the standard compass shall be applied as far as practicable.

of 1.4 m.

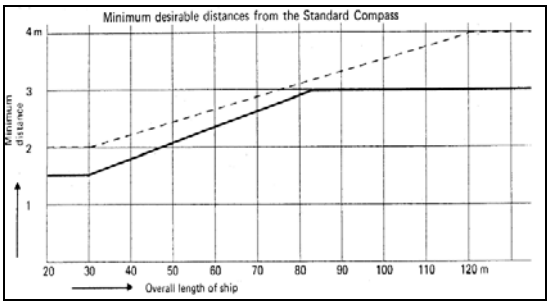

Figure 3 Diagram of minimum desirable distances from the standard compass[1]

In figure 3 is describe the distance between the fixed magnetic material represented by the uninterrupted line and the parts of the fixed magnetic material such as top edges of walls, bulkheads, extremities of frames, girders, stanchions, beams, pillars and similar steel parts[3].

MK 2000S COMPASS OUTFIT AND SIMRAD GC80 COMPACT GYROCOMPASS SYSTEM CONFIGURATION

The MK 2000S Compass Outfit and SIMRAD GC80 Compact gyrocompass are the systems installed in one of the laboratory in Naval Academy "Mircea cel Bătrân" to train the students to undertake practical exercises in the use of compasses for normal day-to-day watchkeeping.

The intention in this objective is that the students should be able to deal descriptively with the deviation produced on various headings by a magnet or soft iron rod in a given position, relative to the compass, in an otherwise non-magnetic vessel.

Also the importance of the gyrocompass it is given by the regular and frequent checking of the gyrocompass against magnetic compasses, of repeaters against the master gyro and of gyrocompass error.

The compass corrections is basic knowledge for a watchkeeping officer. According to watchkeeping duties it is important to obtain the compass error at every watch and at every large alteration of course. The compass can be checked by transit bearing, bearing to a distant object or azimuth of celestial body. The comparison of compasses, for instance of gyrocompass against magnetic compasses, should be a normal checking procedure[4].

In order to perform a deviation table, one of the procedure requires a multiple comparison between the headings of the two compass. Further is presented the two systems configuration of the devices.

MK 2000S Compass Outfit

The MK 2000S Magnetic Compass Outfit is configured as in the following features[5]:

- Material- reinforced glassfibre binnacle;
- Correction-a full set of compensating magnets for *B*, *C* and *H* plus adequate quadrantal corrector and flinders plate;
- Periscope-telescopic with a maximum vertical length of two meters;
- Fixings-rubber base gasket and four S/S M20x90mouting, bolts, nuts and washers;
- Lighting-two 24vdc 15w lamps and one spare fitted within the binnacle;
- Power supplies-the FW9862 Control Unit includes a transformer and has AC mains and 24vdc inputs with 24vdc outputs;
- Compass-Lilley & Gillie 'SR4', class A;
- Azimuth mirror-The FW9011 Azimuth Reading Device.

Also to provide readings of the magnetic compass is installed a GS 720 transmitting compass system as a heading data display.

SIMRAD GC80 COMPACT GYROCOMPASS

The SIMRAD GC80 compact gyrocompass is configures as in the following features[6]:

- master compass with sensitive element
  - settling time within 3 hours;
  - settle point error less than ±0.1°;
  - roll and pitch error less than ±0.4°;
  - gimbal freedom;
  - range of speed correction:0-50 knots/latitude 0°-+70°;
- compact control unit;
- power supply unit;

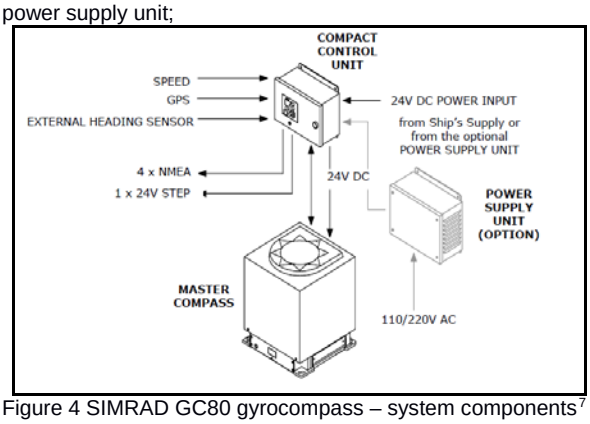

Figure 4 SIMRAD GC80 gyrocompass – system components[7]

PRACTICAL PROCEDURE FOR MAGNETIC COMPASS ADJUSTMENT

A magnetic compass requires a properly adjusted compass in vessels of 82.5 meters or above to have residual deviations of no more than 3° and after the vessel's second adjustment after construction not to exceed 5° in any latitude in which the ship may operate. The device requires to be adjusted in the following situations[8]:

1. no less often than intervals of two years;
2. after dry-docking;
3. after significant structural work;
4. when they are first installed;
5. if they become unreliable;
6. when repairs or structural alterations have been made to the ship that could affect its permanent and/or induced magnetism;
7. if the recorded deviations are excessive or when the compass shows physical defects;
8. at any other time deemed necessary by the Master for the safety of navigation.

[3] International Maritime Organization, International Convention for the Safety of Life at Sea, 1974

[4] Model course – Officer in charge of navigational watch, Course 7.03, Sub-committee on Standards of Training and Watchkeeping, 2013

[5] http://lilleyandgillie.co.uk//

[6] http://www.simrad-yachting.com/

[7] SIMRAD GC80 Compact Gyrocompass, Instruction manual

[8] ISO 25862:2009(E) "International Standard Organization-requirements regarding construction and performance of marine magnetic compasses for navigation and steering purposes, binnacles and azimuth reading devices"

The primary object of adjusting compasses is to reduce deviations; that is, to minimize the difference between the magnetic and compass headings. There are two methods for accomplishing this:

Method 1 We have to place the ship on the desired magnetic heading and correct the compass so that it reads the same as this magnetic heading.

Method 2 We have to place the ship on the desired compass heading and determine the corresponding magnetic heading of the ship. Correct the compass so that it reads the same as this known magnetic heading.

Regarding the first method, placing the ship on the desired magnetic heading, we can establish five methods:

- Method 1 – we have to bring the ship onto a magnetic heading by referencing a gyrocompass;
- Method 2 – we have to place the ship on a magnetic heading by aligning the vanes of an azimuth circle with the sun over the topside compass;
- Method 3 – we have to use a distant object with the azimuth circle when placing the ship on magnetic headings;
- Method 4 – we have to use a pelorus to place the ship on a magnetic heading using the sun's azimuth in much the same manner as with the azimuth circle;
- Method 5 – we have to use a distant object in conjunction with the pelorus, as with the azimuth circle, in order to place the ship on magnetic heading[9].

The MK 2000S Magnetic Compass Outfit was installed 3 years ago and recently it was moved from an initial place to another final destination without uninstalled, case that can be framed in the 1, 5 and 6 situations from ISO 25862 describe above.

Becoming an unreliable device the author decided to perform an adjusting magnetic deviation table for MK 2000S Magnetic Compass be using the procedure that uses the heading comparison of the magnetic compass and the gyrocompass.

Also regarding to this initial situation, it can be fitted in educational purposes as the teacher can simulate a similar case and as the student to gain abilities to determine a deviation table.

Algorithm for adjusting the magnetic deviation table[10]:

I. prepare the observation sheet for turning to starboard side and port side;
II. update the value of the magnetic declination for the year in course;
III. determine the value of the gyro correction;
IV. adjust the speed for the turning with a small helm angle;
V. wait until the rotation speed of the magnetic compass becomes uniform;
VI. at each cross of 10° on the magnetic rose, an observer writes down the compass course and the second observer writes down the gyro course;
VII. perform the calculations in order to determine the magnetic courses and the graphic of the magnetic deviation.

In order to find the magnetic deviation we will use the following expressions:

$$TH = GH + GE \quad (1)$$
$$MH = TH - var \quad (2)$$
$$\delta = MH - CH \quad (3)$$

where TH - represents the true heading, Dg - gyro heading, GE - gyro error, CH - compass heading, MH - magnetic heading, var – variation and δ - magnetic deviation.

For this adjusting we used the magnetic variation for the actual year and the result from the magnetic rose on the chart are:

d_{2000} = +4°07'
var (14*5') = +1°10'
d_{2014} = +5°17'

where d_{2000} – represents the annually change value in 2000 with a variation of 5' to E, d_{2014} –represents the annually change value for 2014 with the variation of the 14 years.

Following the steps described in the algorithm above we could determine the magnetic deviation table.

Compass heading (CH)	Magnetic deviation (δ_c)
000°	+32.4°
010°	+32°
020°	+30.2°
030°	+26.4°
040°	+22.2°
050°	+18.2°
060°	+15.2°
070°	+14°
080°	+11.8°
090°	+9°
100°	+6.4°
110°	+3.8°
120°	+1.2°
130°	-1.4°
140°	-5.2°
150°	-7.6°
160°	-9.8°
170°	-10.3°
180°	-9.8°
190°	-8.6°
200°	-6.8°
210°	-5.1°
220°	-3°
230°	-0.6°
240°	+2°
250°	+5.2°
260°	+8.1°
270°	+10.8°
280°	+13.1°
290°	+13.1°
300°	+19°
310°	+22.4°
320°	+26°
330°	+28.5°
340°	+31.2°
350°	+32.2°

Table 1 Magnetic deviation table

Analyzing the values obtained from this procedure we can established that the MK 2000S Compass Outfit has residual deviations more than 3° and needs an adjustment and correction on the *B, C permanent magnets and vertical soft iron Flinders.*

[9] Bowditch Nathaniel, The American Practical Navigator, 2011

[10] Boșneagu Romeo, Navigație maritimă, Ed. Hidrografică, 2011,

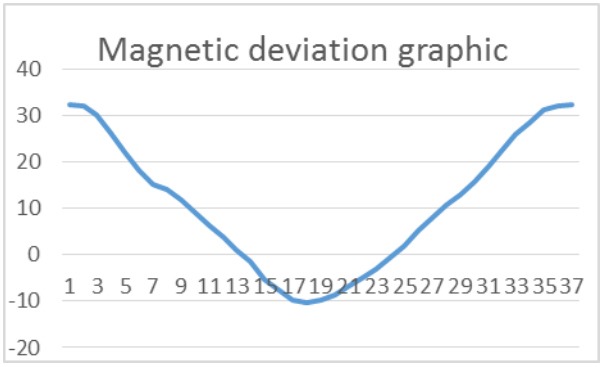

Figure 5 The magnetic deviation graphic of the MK 2000S Compass Outfit

In this situation the author propose adjusting the magnetic deviation by determining the total deviation curve and the specific coefficients, the coefficient of constant deviation, the coefficient of semicircular sine deviation, the coefficient of semicircular cosine deviation, the coefficient of quadrantal sine deviation and the coefficient of quadrantal cosine deviation.

CONCLUSIONS

The latest naval accidents reports revealed that using an equipment without a proper calibration can conduct to vital errors.

In this article it was presented a simple case of moving the equipment from a place to another and we found out that can cause a simple error, an error which in the end bring out to be a magnetic field deviation from his permanent magnets.

Also by this case, it can be used by the civilian students in the Naval Academy “Mircea cel Bătrân” to practice the adjusting magnetic deviation table or to analyze a magnetic deviation graphic at the specialized disciplines to gain capabilities for their first voyage as an officer.

REFERENCES

[1] International Maritime Organization, International Convention for the Safety of Life at Sea, Chapter V, Regulation 19, 1974

[2] International Convention for the Safety of Life at Sea (SOLAS), 1986

[3] Model course – Officer in charge of navigational watch, Course 7.03, Sub-committee on Standards of Training and Watchkeeping, 2013

[4] LILLEY & GILLIE, MK 2000S Compass Outfit, Installation and operators manual

[5] SIMRAD GC80 Compact Gyrocompass, Instruction manual

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[5] http://www.simrad-yachting.com/

[6 ISO 25862:2009(E) “International Standard Organization-requirements regarding construction and performance of marine magnetic compasses for navigation and steering purposes, binnacles and azimuth reading devices”

[7] Boșneagu Romeo, Navigație maritimă, Ed. Hidrografică, 2011.