CONCERNING
THE CORRECTION OF THE QUADRANTAL ERROR IN COMPASSES OF LARGE MAGNETIC MOMENTS.

By

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General N. OGLOBLINSKY of the Imperial Russian Navy, joint author with Lieutenant RIDIGER of a "*Manual of Compass Deviations*" (*), a manual well-known and valued and which has been adopted as the standard work on the subject in the Russian Navy, has just published, in the February 1928 number of the "*Revue Maritime*", an article entitled : "Compensated Induction Liquid Magnetic Compass". The question which is discussed in this article is of great interest to navigators.

This question, already dealt with by the authors of the manual cited above, is clearly defined in the first paragraph of the article, and we think it best to reproduce it textually for the information of readers of the Review.

(translated from the french).

" One of the most important advantages, from a practical point of view, which Lord " KELVIN's dry compass offers to navigation, is that the disturbances of the compass, known " by the term "quadrantal error", may be compensated once and for always and for all places.

" This error results from the magnetization induced in the iron of the ship by the hori- " zontal component H of the Earth's magnetic field. By placing, for example, soft iron spheres " in a suitable position near the centre of the compass, the quadrantal error is successfully annulled " by means of the magnetism induced in the correctors by the same component H. In this " operation the two forces exerted on the compass needle :— the one which produces the error, " the other which compensates it, are both proportional to the component H, and that is why " the equilibrium between the two forces, once obtained, will always be maintained for all places " on the globe. But this is the case only if no account is taken of the magnetization induced " by the compass card needles on the soft iron correctors. In Lord KELVIN's compass this last " condition is almost completely realised, because of the small magnetic moment (200 units " C. G. S.) of the system of short needles of its card. It was not, however, applicable to the " other dry compasses of the period, the magnetic moments of the long needles of which reached " 2000 - 5000 C. G. S.

" Likewise this condition is not fulfilled in modern liquid compasses (the cards of which " are immersed in liquid) adopted as standard compasses in nearly all navies ; their cards have " a moment of 2000 - 3500 units C. G. S. but sometimes reach 5000 — 6000 units C. G. S.

(*) Rukovodstvo Po Deviazii Kompassa — Sostavlieno Leitenantani Grafom Th. Th. RIDIGER & N. N. OGLOBLINSKY — S. Petersburg — 1895.

" The effect of the induction of these powerful magnetic systems on the soft iron correctors, " is to cause a deviation of a quadrantal character, and is far greater than that which is pro- " duced in them, at the same time, by the Earth's field: but the field, exerted by the induction " of the magnets on the compass, is constant (as long as the magnetic moment of the needle " does not vary) and, in consequence, in this case, once the quadrantal error has been annulled, " it will not recur, unless the change of locality of the ship is followed by a change of the " component *H*. The navigator is then obliged to reckon with a constantly changing quadrantal " error, which causes much inconvenience in the practice of navigation.

" To avoid these difficulties, the induction of the needles is sometimes diminished by using " soft iron correctors of greater dimensions, but at a greater distance from the compass, which " tends to obstruct the compass and also diminishes the magnetic moment of the card to extreme " limits, at the risk of rendering precarious the proper working of the compass. In France, " before the war, the question of the induction of the needles on the soft iron correctors (sphe- " res) was treated analytically by Mr. DUNOYER and Vice-Admiral PERRIN.

" Formulae for the spheres have been developed by Mr. DUNOYER with the object of " calculating in advance the variations of the indications to which the compass should be " subjected as the ship changes its magnetic latitude. According to Mr. DUNOYER, in order to " annul these variations, it is frequently necessary to alter the position of the soft iron correctors " with the aid of magnetic charts and a special table which should be constructed for each " compass.

" We propose to give here a description of a different method of solving this problem; " a method by which the indications of the liquid compass of large magnetic moment may be " immediately rendered as independent of changes of place as those of Thomson's compass, and " without any calculations.

" The solution consists of compensating the deviation produced by the induction of the " needles, by placing near the centre of the compass correctors of a different shape which " produce, under the influence of the needles, deviations of contrary sign; by combining the " correctors and by placing them at a correct distance from the centre of the compass, the " deviation due to the induction of the needles is annulled.

" This is done independently of the value of the Earth's magnetic field and of the value " of the magnetic moment of the needles. In consequence, such a compensation will always " remain correct for all places on the globe.

" The method was invented by J. CLAPIER DE COLONGUE, officer holding the rank of " Admiral in the Russian Navy (1901), for the compensation of the induction of the needles of " his dry compass, the card of which, constructed according to THOMSON'S, had a magnetic " moment of 250 — 320 units C. G. S.; in this compass the effect of the induction of the needles " already reached an appreciable value in practice.

" The author of this note has applied this method to liquid compasses, constructed by " himself for the Russian Navy in 1902 and 1910. It is used, in an approved form, for the " compensation of the induction of the needles in two new types of liquid compasses lately " constructed in France by the author."

Soft iron correctors of cylindrical shape, which have the same compensating properties as the system of correctors originally invented by DE COLONGUE and adopted, with slight modifications, by General OGLOBLINSKY in his "induction compensated compass", have been used in the Royal Italian Navy since the end of the year 1912, to compensate the quadrantal error of the standard liquid compass (the card of which has a magnetic moment of 3000-3400 units C. G. S.). In other words, by using cylindrical correctors of the Italian type in lieu of spheres, "the deviation due to the induction exerted by the needles on the correctors may be annulled."

This type of correctors was recommended in 1911 by the author of this note, following some very simple theoretical considerations and experiments.

quoted in two articles published in the "*Rivista Marittima*" 1911 (*) and in the 8th volume of the "*Annali Idrografici*" 1911-12 of the Italian Hydrographic Office. (**)

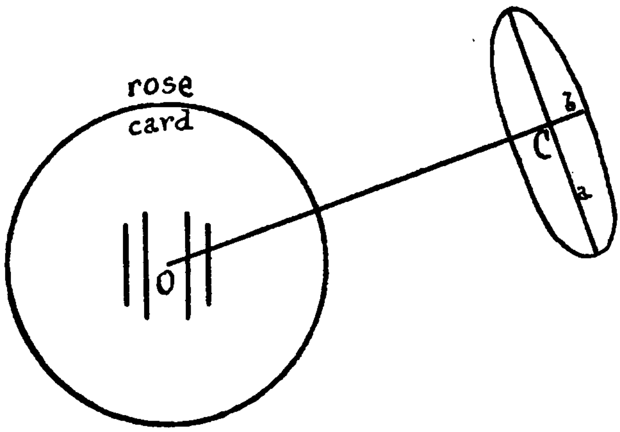

Fig. 1

The conclusion resulting from these treatises is that *the elimination of the effect of the induction on the correctors by the needles may be obtained* if a soft iron compensator of elongated shape is used, for example, an ovoid of revolution of equatorial radius *b* and major axis *a* (axis of revolution), placed perpendicularly to the radius *OC* of the compass (Fig. 1), *for a known quality of soft iron, and a known value of the ratio* $\frac{b}{a}$ *of the lengths of the axes.*

With the object of making this matter clearer and to define a starting point for practical experiments, the author has adopted for this ratio the value $\frac{b}{a} = 0.3$ approx.

The calculation was made with formulae deduced from hypotheses in order to simplify them, and by considering the case of a soft iron corrector (of coefficient of magnetic susceptibility very near 5).

It may be added that the suggested ovoid provides perhaps the most finished solution, but that it may be concluded that the same results could be obtained with a *cylinder* which, of rather different form from the ovoid which has been described, would serve from a magnetic point of view in the same way as the ovoid itself.

At this period also Lieutenant E. MODENA carried out, on his part, at the Hydrographic Institute, Genoa, a series of long, laborious and accurate experiments, the results of which have confirmed the principle which I had advanced.

(*) Tonta: "Come si possa compensare stabilmente la quadrantale di una bussola a grande momento magnetico" – Rivista Marittima — Roma — Ottobre 1911 — pages 27 et seq.

(**) Tonta: "Sui compensatori allungati e sul compensatore stabile della quadrantale" — Annali Idrografici — 1911-1912 — pages 433 et seq.

These results were published in the "*Rivista Marittima*"(*) 1912. The correctors used for the experiments of Lt. MODENA where of *silicic* iron and of cylindrical shape, and the experiments were carried out with two models of magnetic compass cards having magnetic moments of 3370 and 990 units C. G. S. respectively.

This type of cylindrical corrector was at once adopted for the compensation of liquid compasses in the Royal Navy and the proof to which they have been put during the fifteen years which followed their adoption has fully confirmed thier efficacy as permanent compensators of the quadrantal error.

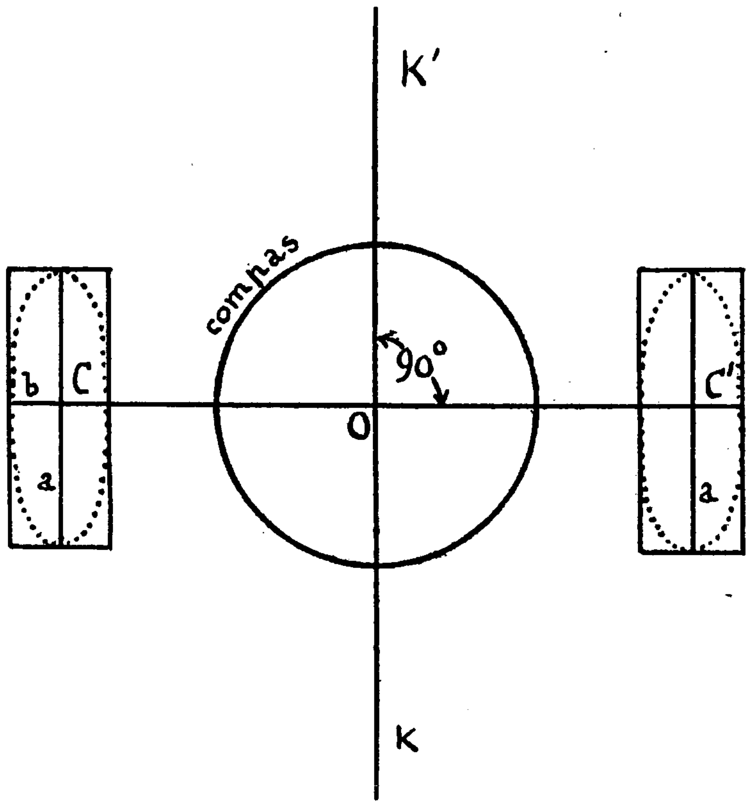

Fig. 2

The cylinders are used *in pairs,* like the spheres and, like these, they are fixed to the binnacle of the compass on two supports opposite each other on the diameter *COC'* of the compass, perpendicular to the plane of symmetry *KOK'* of the soft iron of the ship (Fig. 2). The axis *a* of the cylinders is perpendicular to the diameter *COC'* and is in the horizontal plane which contains the needles of the compass card.

(*) E. MODENA : "Il compensatore stabile della quadrantale" — Rivista Marittima — Maggio 1912 — pages 223 et seq.

There are four different sizes of cylinders. The following are their dimensions expressed in *millimeters* : –

Type	*A*	length a = 390 ;	diameter b =	90
»	*B*	» 300	»	70
»	*C*	» 230	»	55
»	*D*	» 160	»	40

The following is the table of compensation of the quadrantal error, compiled by Lt MODENA as a result of his experiments, and at present used generally in the Royal Navy :—

TABLE
FOR THE COMPENSATION OF THE QUADRANTAL ERROR BY A PAIR OF SILICIC IRON CYLINDRICAL CORRECTORS.

D TO BE COMPENSATED.	DISTANCE FROM THE CENTRE OF THE CORRECTOR TO THE CENTRE OF THE CARD.			
	Type A 390 × 90	Type B 300 × 70	Type C 230 × 55	Type D 160 × 40
	centimetres.	centimetres.	centimetres.	centimetres.
2°	—	—	—	22.0
2.5	—	—	23.5	20.0
3	—	—	22.3	18.5
3.5	—	—	21.2	17.5
4	—	28.0	20.4	16.0
4.5	—	26.5	19.6	15.5
5	—	25.5	—	—
5.5	—	24.6	—	—
6	—	23.8	—	—
6.5	—	23.0	—	—
7	28.2	22.4	—	—
7.5	27.6	21.8	—	—
8	27.0	21.2	—	—
8.5	26.4	20.6	—	—
9	25.7	20.1	—	—
9.5	25.1	19.7	—	—
10	24.6	19.3	—	—
10.5	24.1	19.0	—	—

It must here be noted that the values of the ratio $\frac{b}{a}$, relative to the four types of correctors, are not the same as the theoretical value (= 0.3) cited above. Further, this ratio is different for the various types and it is evident that it has a tendency to increase in proportion as the dimensions increase. It varies between 0.23 and 0.25 approx. It should be noted, however, that the difference is not very great and also that the theoretical value refers to a compensator of ellipsoidal instead of cylindrical shape and moreover, that it was determined for a particular value of magnetic susceptibility which is probably not that of *silicic iron.*

On the other hand the experiments of Lt MODENA have demonstrated that the effect of the induction of the needles on the correctors is *practically* eliminated not only for a particular value of $\frac{b}{a}$ but also for the near values. In other words, as long as the value of $\frac{b}{a}$ is included between determined limits, the effects of the induction are nil or scarcely perceptible and, in consequence, negligible.

It must also be remembered that our theory is based, for simplification, on hypotheses which in practice are only satisfied somewhat approximately.

These considerations might therefore also prove that the compensating properties of the cylindrical correctors (or ellipsoids) depend not only on the values of the ratio $\frac{b}{a}$ of the axes, but also on the absolute values of these axes.

It is well also to point out that the elimination of the effects of induction was observed between fixed limits of distances from the correctors to the needles, and that it does not seem right to state definitely that elimination is also produced at greater or lesser distances than those used in the experiments. On the contrary, MODENA's experiments seem to justify the hypothesis that the perfect elimination of the induction is produced only for a particular distance, and that for distances near to it, and within wide enough limits, a sufficiently accurate elimination of the induction is still produced. It must be stated that this fact detracts nothing from the practical value of the method. (*)

The phenomenon of the induction of the needles on the correctors is extremely complex, given the dimensions of the correctors and the short distance at which they are from the compass card and, therefore, it becomes very difficult — and perhaps impossible — to foretell by theory, in a complete manner, what the effects of induction are. The theory is therefore limited to foretelling the phenomenon in its general outlines, so that it is necessary to rely on experiments, from which alone definite conclusions can be drawn. Several years of trial on board ships have confirmed the results of the laboratory experiments, and therefore it might be affirmed that the Italian method solves in a perfect manner and, in fact, in the simplest way, the problem of the compensation of the quadrantal error of compasses of large magnetic moment.

(*) In his article General OGLOBLINSKY infers that, with the system of compensation which he applies to his compass, "*the deviation resulting from the induction of the needles on the correctors*" may be "*reduced to a few minutes of arc, once and for all and for all places*". We do not pretend to assert that such an approximation "a few minutes of arc" may always be obtained with the types of correctors used in the Italian Navy. An approximation of this order may perhaps be obtained but we, after long experience acquired in the course of our career as navigator, believe that, for the accuracy required in nautical measurements, such an approximation is illusory and practically useless; the approximation to half a degree in the annulment of the deviation produced by the induction of the needles on the correctors is quite sufficient.

We speak of compasses in general although, in reality, our cylindrical correctors have been submitted to experiments with systems of needles of a particular type; virtually, however, the differences between the various types of systems of needles are small and, consequently, at least for cards of magnetic moment below 3000 or 4000 units C. G. S., (which are the moments most generally used, as those of the English Chetwynd compass, or the German Bamberg compass, etc.) they are suitable to be used with no matter what other type of compass. Thus the table of compensation to which we have previously alluded can still be said to possess a general character, as does the well-known table for the compensation of the Thomson compass, by spheres.

We hope that other navies will submit it to trials (*). These trials are simple and inexpensive; the construction of the cylinders presents no difficulty The silicic iron of which the correctors are composed, is obtained by fusion and is composed of 4.5 % silica, the remainder being iron in which the amount of carbon does not exceed 3.5 % (**). The correctors are solid. The use of silicated iron in lieu of ordinary soft-cast iron was suggested by the fact that this alloy behaves from a magnetic point of view like pure soft cast iron, and its power of retention of residual magnetism is not so strong (and negligible for feeble fields). This condition is particularly necessary for correctors of elongated shape which, as is known, are because of this shape more subject to retain permanently the induced magnetism than spherical correctors.

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In Italy, experiments were made with *compensators of cylindrical shape* and for that reason, knowing the good results obtained, cylindrical compensators without other modification were used for the standard compasses of the Italian Navy. However. for considerations which it is needless to give here, there is every reason to maintain that it is better to use *compensators of ellipsoidal shape* or, more precisely, ovoids of revolution (as those which are represented by a dotted line in Fig. 2).

According to our theoretical conclusions, and taking into account the results of the Italian experiments, it may be assumed that a *practically* perfect stability of compensation of the quadrantal error may be obtained by the use of silicated iron ellipsoids, the equatorial axis b of which should

(*) The Portuguese Navy has perhaps tried it, for the Italian method is described in a printed series of lectures on nautical magnetism by Commander FONTOURA DA COSTA (Desvios da agulha magnetica — Escola Naval — Lisboa — 1925 p. 72 and following.)

(**) Composition of the alloy :

Carbon	3.50 %
Silicum	4.75 %
Manganese	0.60 %
Sulphur	0.80 %
Phosphorus ...	1.00 %
Point of fusion	1380° cent.

be approximately the quarter of the axis of revolution a $\left(\frac{b}{a} = 0.25 \right.$ approximately).

As the compensators are made by moulding cast-iron, their construction does not present greater difficulties than that of cylindrical compensators.

We believe that, among the numerous improvements which the compass constructors are working at to-day, aiming at perfection and also often carried out with a view to commercial competition, the one which concerns the compensation of the quadrantal error by means of ellipsoids, advocated by us, has a great importance and is, perhaps, *indispensable.*

We are of the opinion that *the use of spheres for the compensation of the compass of large magnetic moment,* constitutes a grave error and that, in consequence, it should be abandoned. (*)

The use of spheres is justified (and represents also a finished solution) in the sole case of a compass of feeble magnetic moment, such as that of Thomson's dry card for which, and *for which alone,* they were originally designed by the inventor.

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(*) We refer to the use of *spheres only,* and not to the use ot a mixed system of spheres and bar magnets such as is used by DE COLONGUE and OGLOBLINSKY in the compass of the Russian Navy and which represents a good solution of the problem. Nevertheless, this system has, in our opinion, the disadvantage of being more complex and, moreover, the *placing* of the compensators requires intricate operations. The placing of the ellispoïdal compensators (or cylinders) is, on the contrary, as easy as that of the spheres of Thomson's Compass. It should, however, be remembered that the mixed system of spheres and bar magnets, in spite of its greater complexity, constitutes a very good solution preferable, perhaps, to that which is obtained with a simple pair of elongated compensators (ellipsoids or cylinders) when *the quadrantal error to be compensated is very large.* We have demonstrated this in our previous articles cited above in a footnote ("*Rivista Marittima*" - October 1911 - p. 30 and following; "*Annali Idrografici*" 1911-12 - pp. 446-447).

It should be noted, however. that large quadrantal errors (for example over 10°) constitute exceptional cases in standard compasses, seeing that it is *nearly always* possible to place these compasses at a point in the ship where the value of the error does not exceed 10°.

In the course of our researches we have been led to the conclusion that there is an advantage in particular cases (*i. e.* when the quadrantal error is very large) in a mixed system of slightly elongated ellipsoids and bar magnets which, (this statement being subject to correction) closely resembles the system adopted by General OGLOBLINSKY in his new compass (*See example. Rev. Mar.* February 1928 - p. 153.)