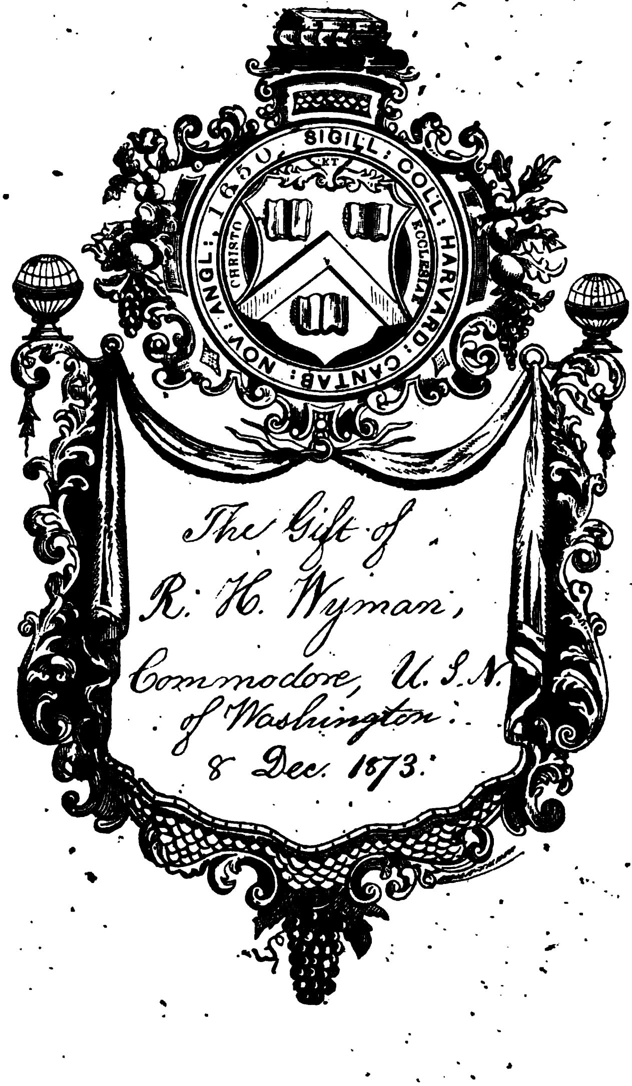

SIGILL: COLL: HARVARD: CANTAB: NOV: ANGL: 1650
CHRISTO ET ECCLESIAE
The Gift of
R. H. Wyman,
Commodore, U. S. N.
of Washington.
8 Dec. 1873.

NAVY DEPARTMENT, BUREAU OF NAVIGATION — WASHINGTON. December 29. 1868.

THE

MAGNETISM OF SHIPS

AND

THE DEVIATIONS OF THE COMPASS,

COMPRISING

THE THREE REPORTS

OF THE

LIVERPOOL COMPASS COMMISSION,

WITH ADDITIONAL PAPERS BY

MR. ARCHIBALD SMITH, F.R.S., &c., AND STAFF CAPTAIN F. J. EVANS, R.N.

REPRINTED BY ORDER OF

THE SECRETARY OF THE NAVY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1869.

1873, Dec. 8.
Gift of Commodore
R. H. Wyman U. S. N.
of Washington.

PREFATORY NOTE.

This volume contains the three Reports of the Liverpool Compass Commission referred to in the Preface to the preceding volume of this publication. It was deemed expedient to include the "Introduction," by Mr. Archibald Smith, to the late Dr. Scoresby's journal of his voyage in the Royal Charter, ("*Journal of a Vöyage to Australia and around the World for Magnetical Research*: By the Rev. W. Scoresby, D.D., F.R.S., &c. London, 1859,") on account of the interest and importance attached to the magnetic history of that vessel. Two papers are likewise added—one by Mr. Archibald Smith, and the other by Staff Captain F. J. Evans. R. N., which have appeared since the first volume was published.

ERRATA.

Page.	Line.	Error.	Correction.
28	2 from top.	London.	Sandon.
44	25 from top.	1.147	0.147
317	3 from top.	L. L. D.	LL. D.

LIVERPOOL COMPASS REPORTS.

PREFACE OR INTRODUCTION.

In 1855 a grant of £100 was made to the Liverpool Compass Committee, by the Board of Trade, on condition that a report of proceedings should be forwarded at the end of the year.

On the recommendation of the Astronomer Royal, a similar grant was made in 1856, and on the same condition.

Both these Reports are printed in the following pages, and below are appended the letters which have been received from the Astronomer Royal on the subject.

LETTER No. 1.

Letter from the Astronomer Royal to the Board of Trade in reference to the Report of the Liverpool Compass Committee for the year 1855.

ROYAL OBSERVATORY, *Greenwich. April* 24, 1856.

SIR: I have the honor to acknowledge your letter of the 19th instant, enclosing the report of the first year's proceedings of the Liverpool Compass Committee, and requesting, for the guidance of the Lords of the Committee of Privy Council for Trade, my opinion on the expediency of increasing the grant made by their Lordships to the Liverpool Committee for assistance in effecting the purposes for which the Committee was constituted. I have carefully read the report, and I submit, for their Lordships' consideration, the following remarks:

I think it appears sufficiently upon the face of the report that the Committee are pursuing their object with vigor and judgment. In engaging a proper person to devote himself to the inquiry, instead of trusting to the irregular attentions of busy commercial men, they have shown a determination to carry out their purpose in a systematic way. In the attention which they have given to the various points of errors of the variations marked on charts, disturbance of the compass by cargoes of iron, influence of the position in which the ship was built, and change in the compass errors as depending on geographic locality, they have taken a comprehensive view of the subject, where probably a limited view would have led them into error.

The results which they have yet produced are not extensive, but this is sufficiently explained by two reasons. First, that some observations already made are useless till they shall have been compared with future observations. Secondly, that it is exceedingly difficult to obtain the opportunity of making observations at all. I have myself seen that a ship-owner, although he knew that the safety of his ship depended on the examination of the compasses, would interrupt that examination at any moment on some insignificant question of loading or of speed.

Repeating the expression of my opinion, that the Liverpool Committee are advancing well in their work, and remarking, also, that the value of general success in the under-taking would not be confined to Liverpool, or to the commercial navy, but would also be felt by every port, and by the military navy, I think that, both for material support and for moral encouragement, the Committee well deserves the powerful aid of the Government. And looking at the amount of the expenses incurred by them, and the amount of aid hitherto granted by Government, I think that that aid may with propriety be increased, or even doubled, if the Lords of the Committee of Privy Council shall so think fit. I return herewith the report. I have, &c

G B. AIRY.

T. H. FARRER, Esq.,
Secretary of the Marine Department of the Board of Trade.

LETTER No. 2.

ROYAL OBSERVATORY,
Greenwich, London, S. E., March 21, 1857.

SIR: I have to acknowledge the receipt of your letter of Marth 14, accompanying the "Report of the proceedings of the Liverpool Compass Committee for the year 1856," and requesting that I would transmit to the Lords of the Committee of Privy Council for Trade any observations which I may have to offer upon it. In reply, I have to say, that I have perused the report, and have the honor to offer the following remarks upon it:

1. This report is by very far the most important document, in reference to the difficult subjects of the magnetim of iron ships, the change of magnetism, the correction of the compass, and the adjustment of the correcting apparatus, that has yet appeared It does more to remove doubt on several important points (I would particularly cite the influence of the position of the ship while building, the occasional rapid change of magnetism in a short time after launching, and the general slow change afterwards) than all the discussions which have previously taken place; and, generally speaking, it explains more completely the difficulties, moral and physical, attending this subject, than all other papers known to me.

2. I think it very desirable that this report should be printed.

3. I remark that, in page 42, the Compass Committee allude to a probable early termination of their labors. It may be well that, at no distant time, their operations should be closed; but I trust that they may be continued sufficiently long to enable the Committee to receive and use the observations to which they allude, as expected from ships now at sea.

4. If (as I understand) some pecuniary aid from the Government is practically neeessary, to enable the Committee to continue their investigations, I think that it ought to be given.

5. I beg leave particularly to invite the attention of the Board of Trade to the remarks on page 42, as to the difficulties attending the action of a quasi-private committee, and as to the advantage of using the authority and organization of the Board of Trade for equivalent inquiries.

6. And, generally, I would submit for consideration, whether it is not proper that a knowledge of the method of correcting the compass and adjusting the correcting apparatus, should not be required in the captains of iron ships. I return herewith the report. I have, &c.

G. B. AIRY.

T. H. FARRER, Esq., &c.

CONTENTS.

THE LIVERPOOL COMPASS REPORTS TO THE BOARD OF TRADE.

THE FIRST REPORT—1855.

	Page.
Report, chiefly confined to description of mode of operations of the Liverpool Compass Committee	1
Evidence sought by distributing list of queries among ship captains and others	1
Deviation of the compass in wooden ships	2
Commanders of wooden ships sometimes led astray by trusting to the variation laid down upon old charts, and neglecting the use of the azimuth compass	2
Change of deviation arising from change of geographical position, as recorded in log-books belonging to iron ships	2
Rev. Dr Scoresby's experimental voyage to Australia in the "Royal Charter," promoted by the Compass Committee	3
Nature of the experiments which are being tried in Liverpool, and appointment of officer to conduct them	3
Expenses attendant on the investigation, and aid requested	4
Description of illustrations and signification of the symbols employed to represent components of ships' magnetism	5
ILLUSTRATIONS.	
No. 1. Deviation curves of elevated, standard, and steering compasses..........to face page	4
No. 2. Exterior lines of no deviation of seven iron ships..........to face page	4
APPENDICES.	
No. 1. List of members of Liverpool Compass Committee	6
Circular letters and letter respecting variation in the Irish Channel	8
No. 2. Circular, with list of queries, &c.	11
No. 3. Tabular form and instructions	13

THE SECOND REPORT—1856.

Object of the report	19
Difficulties attending the Compass Inquiry	19
Introduction of system of fixed magnetic bearings	20
Use of the "dumb-card"	20
Connection between magnetism of a ship and her position when building	21
Examples: Ships built with head towards or near the cardinal points	22
Influence of masses of vertical iron	23
Ships built in positions intermediate to the cardinal points	24
A ship's original magnetism frequently permanent in direction, but undergoing rapid change in amount	24
Evidence of compass adjusters on this head	24
Examples: "Royal Charter," "Panic," "Sarah Palmer," "Astræa," "Nauphante," "Bœotia," "Ionia," &c.	25
Easy mode of testing a change	26
Effect of reduction of ship's magnetism in vessels built with head towards the east	27
Changes in ship's magnetism usually very small after they have made one or two voyages	27
Example: "Great Britain"	27
Effect of vertical and horizontal induction	28
How it may be exhibited	28
Induced magnetism increased and for a time retained under certain conditions	28
Examples: "Royal Charter," "Drogheda," Mediterranean steamers, North American steamers, "Laconia," &c.	29
Case of "New Granada," on the west coast of South America	30

B

Page.
Influence, amount, and direction of ship's magnetism, as determined by experiments with the vibration needle ... 30
Vibration experiments on board the "Royal Charter" before and after her first Australian voyage ... 31
Similar experiments on board the "Great Britain," &c ... 31
Nature of "quadrantal deviation" not understood or compensated by many compass adjusters ... 31
Errors induced by heeling in iron ships ... 32
Several causes for this enumerated ... 32
Evidence of ship captains on this head ... 33
Instances afforded by "Laconia," "Sarah Sands," and "City of Baltimore" ... 33
Elevated or mast compasses, and character of their deviations ... 34
Modes of swinging ships ... 35
Mechanical adjustment of compasses ... 35
Large deviations on change of hemisphere chiefly confined to steering compasses ... 36
Want of directive power in the compass needle frequently more complained of than the amount of the deviations ... 36
Comparison of compensated and standard compasses on board the "Royal Charter" ... 36
Ease with which the steering compass of the "Royal Charter" might have been kept quite correct ... 37
More difficult but successful case with a compass placed further aft ... 37
Utility of soft iron or "chain-box" compensation for "quadrantal deviation" ... 38
Objectionable use of permanent magnets ... 38
The effect of magnets placed very near the compass ... 38
Projection of deviation tables by curves ... 39
They afford an easy mode of changing "compass courses" into "magnetic courses," and the contrary ... 39
A matter not sufficiently understood or attended to by ship captains and compass adjusters ... 39
Miscellaneous operations of the Committee ... 40
Effect of collisions ... 40
Utility of compass records ... 40
How easily collected by Board of Trade ... 40
Close of the operations of the Compass Committee ... 42
Proposed experiments to complete the Compass Investigatton, and the further aid of the Board of Trade solicited ... 42
Arrangement for publishing final report ... 42

ILLUSTRATIONS.

	Page.	Plate.
Magnetic bearings of the Vauxhall chimney, at Liverpool. and description	....	3
Deviation curves of "Astræa," before and after first voyage	....	4
Deviation curves of "Nauphante," before and after partial compensation	....	4
"Lalla Rookh." Table and diagrams to exhibit force and direction of magnetism near her stern	49	5
"Nauphante." Experiments to show changes in her magnetism	49	6
Lines of no deviation	....	7
Steamship "Bœotia." Lines of no deviation before and after her first Mediterranean voyages	....	8
"Sarah Palmer." Lines of no deviation after her fist voyage to Calcutta	....	8
"City of Washington." Lines of no deviation on two occasions	....	9
Steamship "Etna." Deviation curves for five compasses	....	10
Steamship "Great Britain." Lines of no deviation, on five trials, and with head in opposite directions	51	11
Vibration experiments during the same time	52	11
Steamship "Royal Charter." Position of her compasses	53	12
Lines of no deviation	....	12
Diagrams to show effect of error in the shore compass	....	13
Large diagram to show deviation at Melbourne, &c	....	14
Table of magnetic co-efficients, and direction and value of ship's magnetism, as derived from the deviation tables	54	15

		Page.	Plate.
Steamship "Royal Charter."	Comparison of compensated and uncompensated compasses	56	....
	Ship's force, as determined by vibration experiments	56	....
	The same shown graphically	....	16
	The same, in different manner, compared with "Ironside"	....	17-20
	Vibration experiments on return from Australia	57	....
	Vibration experiments with aftermost compass	57	....
	Deviation curves of steering and companion compasses without compensation	....	21
	Deviation curves of Admiralty compass after alteration and repair of ship	....	22
Steamship "Bœotia." Deviation curves at different times, to show change		....	23, 24
Steamships "Ionia" and "St. Andrew." Deviation curves to show change in ship's magnetism		....	25
Diagrams to show nature of "polar" and "quadrantal" deviations, and effect of their combination, and note on possibility of obtaining table of deviations by two observations when quadrantal magnetism is compensated		55	26, 27
"Mexicana," "Sappho." To exhibit imperfect deviation curve and errors in shore compass		....	28
"Prospero," "Great Britain." Deviation curves, to show effect of index error		....	29
"City of Washington." Deviation curves to show change in ship's magnetism		....	30
"Valparaiso." Curve of uncompensated steering compass		....	30

APPENDICES.

		Page.
No. 1.	Copy of letter from the Astronomer Royal, with his estimate of the magnetic changes in "Royal Charter"	44
No. 2.	Board of Trade form, as filled in for the steamship "Calpe"	46
No. 3.	Circular on the accumulation of small compass errors in wooden ships	60
	Use and abuse of magnetic bearings painted on the dock walls at Liverpool	63
No. 4.	Circular and list of subscriptions	66

THE THIRD REPORT—1857-60.

Contents of former reports confirmed	71
Effect of heeling on the compasses of iron ships	72
Observations by merchant captains not apparently in accordance with the Admiralty experiments on the effect of heeling	72
Heeling experiments on board the steamship "City of Baltimore"	72
Similar experiments on board the iron sailing ships "Aphrodita" and "Simla"	75
Similar experiments on board the iron sailing ship "Slieve Donard"	78
Comparison of the results obtained from the two ships which were swung by direction of the Admiralty, and the four ships which have been swung by the Committee	80
General deductions from the experiments on heeling	81
Further experiments desirable	82
Difficulties attending experiments of this kind in Liverpool	83
Amount and direction of the magnetism of the iron ship "Accrington" with ship's head on each point of the compass	83
Attempts to estimate the values of the two components of a ship's polar magnetism	85
Dr. Scoresby's dipping-needle experiments on board the "Royal Charter"	85
Attempt to estimate, from these experiments, the changes in the vertical magnetism of the "Royal Charter"	88
Reports by merchant captains of changes in a ship's magnetic condition at sea	90
Extract from a letter addressed to the owners of the "Harvest Home"	90
Extract from the log of the "Evangeline"	91
Logs generally deficient in details	91
"Inverse process" of navigation described by Dr. Scoresby	91
Logs of the "Advance" and "Astræa" specimens of the best kind of compass logs which have been submitted to the Committee	92
The magnetic theory by which the examination of ships' compass logs has been made	93

	Page.
Discussion of observations made on board the "Advance," 1855 to 1860	93
Discussion of observations made on board the "Astræa," 1856 to 1859	101
Discussion of observations made on board the "Aphrodita" during her first voyage to Calcutta	106
Similar results as respects standard compasses, obtained from observations made on board the steamers "Adventure" and "Assistance," and the Turkish steam frigate "Faid Gehadd"	109
Almost total absence of records from screw steamers	110
Discussion of observations made on board the steamship "Bœotia" at Liverpool and Malta	110
Discussion of observations made on board the iron ship "Simla," on her first voyage to Calcutta	111
Discussion of observations made on board the iron ship "Slieve Donard"	113
Discussion of observations made on board the iron ship "Swarthmore"	115
The thanks of the Compass Committee due to the captains of these and several other iron ships	119
Partial compensation of the steering compass in its usual position by the introduction of a vertical iron bar while the ship is building	120
Peculiarity in the compensation of the steering compass of ships built head to south	120
Experiments on the compensation of quadrantal deviation	120
Different degrees of accuracy obtained in compensating double and single needle cards, &c.	121
Observations on quadrantal deviation	122
Quadrantal deviation no index to the quality of iron	122
Experiments on the magnetism of different kinds of iron incomplete	123
Changes in the magnetism of iron ships	123
Example of the "Aphrodita"	124
Example of the "Sarah Palmer"	124
Difference in the results, though both were built of good iron	124
Experiments on board the "Great Eastern"	125
Present system of compass correction	126
A careful captain the best compass corrector	127
A knowledge of the elements of magnetism and mechanics should be required of the officers of iron ships	128
A large proportion of compass complaints belong to mechanical causes	128
When should iron ships be swung	129
Utility of swinging ship	129
Occurrence of strandings on the first voyage after steamers have been swung	130
Difficulty of ascertaining which of seven operating causes has put a screw steamer out of her course	131
Conclusion	132

APPENDICES.

Appendix A. Details of the heeling experiments on board the "City of Baltimore"	133
Appendix B. Details of the heeling experiments on board the "Aphrodita"	148
Appendix C. Details of the heeling experiments on board the "Simla"	151
Appendix D. Details of the heeling experiments on board the "Slieve Donard"	159
Appendix E. Details of the heeling experiments on board the "Beann Uamha"	164
Appendix F. Details of the heeling experiments on board the "Gitana"	166
Appendix G. Deviation tables and tables of magnetic co-efficients for the Admiralty heeling experiments, and for those by the Liverpool Compass Committee	169
Appendix H. Particulars of cases in which a vertical iron bar has been introduced for the compensation of the fore-and-aft changing magnetism of iron ships	171
Appendix K. Twelve examples of quadrantal deviation	173
Appendix L. Construction of a deviation table representing that of the standard compass of the "Royal Charter," from given elements, and illustrating the irregularity of the quadrantal deviation in adjacent quadrants	179
Appendix M. Extracts from compass logs of the "Advance," and illustrations of the curves of deviation obtained in different magnetic latitudes	183
The same, for the "Astræa," "Simla," "Aphrodita," and "Slieve Donard"	218
Appendix N. Experiments on board the "Great Eastern"	260
Appendix O. Letters from Mr. Bennett	279

FIRST ADDITIONAL PAPER.

MR. ARCHIBALD SMITH'S INTRODUCTION TO DR. SCORESBY'S JOURNAL OF HIS VOYAGE IN THE ROYAL CHARTER.

[*London.* 1859.]

	Page.
Circumstances which led to this voyage	287
Questions to be solved by it	288
History of the deviation of the compass	288
Results of different investigations	289
Glance at the mathematical theory	292
Mr. Airy's paper of 1839	299
Objections to some of his conclusions	299
Dr. Scoresby's investigations	304
a. The effect of changes in latitude	304
b. The effect of mechanical action	305
Different papers by Dr. Scoresby on this subject	305
His controversy with Mr. Airy	306
Results of Dr. Scoresby's voyage	308
What has been done by different public bodies	314

SECOND ADDITIONAL PAPER.

MR. ARCHIBALD SMITH ON THE LOSS OF THE IRON-BUILT SHIP GLENORCHY.

[*Proceedings of the Roy. Soc.* 1869.]

Circumstances of the loss of the Glenorchy	317
Magnetic character of the ship	318
The attempts to correct the deviation	319
Magnetic constants of the ship	320
The causes of the loss traced	321
Due to a wrong application of the heeling error	323
Conclusions	325

THIRD ADDITIONAL PAPER.

STAFF CAPTAIN EVANS, R. N., ON THE AMOUNT AND CHANGES OF THE POLAR MAGNETISM OF THE IRON-PLATED SHIP NORTHUMBERLAND.

[*Phil. Trans. Roy. Soc. for* 1868.]

Magnetic character of the Northumberland	327
Mr. Hopkins's proposition to "depolarize" that vessel	329
Subsequent examination of the ship	330
Unsatisfactory result of Mr. Hopkins's experiments	338
Conclusions, generally, from this investigation	338
Tables illustrating magnetic observations on "one azimuth"	340

FIRST REPORT

FROM

THE LIVERPOOL COMPASS COMMITTEE

TO

THE BOARD OF TRADE.

1855.

To the Right Honorable the President and
the Lords of the Committee of Privy Council for Trade:

The Liverpool Compass Committee, in presenting a report of proceedings to my Lords of the Committee of Privy Council for Trade, in compliance with the terms of their letter of January 31, 1855, (No. 652,) addressed to the Local Marine Board of this port, will confine the present communication to a statement of the means which have been adopted, during the past year, to collect information relating to the deviation of the compass in wooden and iron ships, with some particulars of the experiments which have been undertaken to ascertain what changes take place in iron ships from lapse of time, change of geographical position, or other circumstances; but refrain from attempting, at the present stage of the inquiry, to call attention to any deductions which may be made from them. Investigations and experiments which are now in progress, and require some months for their satisfactory completion, will afford more extended data for this purpose, and may perhaps modify to a considerable extent any practical results which could now be obtained.

Evidence respecting reported deviations is sought for by the distribution of a carefully arranged list of questions (see Appendix No. 2) among captains and others who have given attention to the subject; and by placing on board all iron ships and steamers which leave the port, and on board the majority of wooden ships, sailing on long voyages, a tabular form, with instructions, (see Appendix, No. 3,) intended to receive entries of compass observations made at sea; and adapted to afford information respecting such changes as arise from heeling, alteration of magnetic position, cargo, concussion, straining, or other circumstances, supposed to affect, through their action upon the compass, the safety of the ship.

One thousand of the "list of queries," and three hundred of the "tabular forms," have already been issued, and another edition of five hundred of the former is now ready for distribution.

Only a limited number of returns have to this time been made, and it is feared that comparatively few captains are able or willing to give that continuous and systematic attention to the subject which the committee desire. There are some, however, commanding both wooden and iron ships, who enter most cordially into the investigation, and from these much valuable information is expected.

Though a considerable portion of iron is now used in the different kinds of steering apparatus, and in the general construction of wooden ships, it is extremely seldom that any attempt is made to ascertain the amount of deviation which it produces, though cases are known to the committee in which it has exceeded two points. It is equally unusual to take the precaution of swinging the ship, even when cargoes of iron amounting to 600 and 1,000 tons are taken on board. The prevalent opinion is, that compass errors arising from this source are very small. Evidence appears to show that, from three to seven degrees is not an unusual deviation on board ships which have no iron in their cargo; but from the rare use of the azimuth compass, or any exact mode of ascertaining the true direction of the ship's head, and from the uncertainty which exists when strict compass courses are attempted, as to what portion of the observed error is due to currents, imperfect steerage, lee-way, or wrong allowance for variation, it is generally very difficult for the captain to state with precision what his errors of deviation really are, or in what position of his ship they reach a maximum.

If a change of a quarter of a point in the variation of the compass in the Irish Channel was unnoticed by the mariner, (see Appendix, No. 3,) it may be expected that errors may arise from a similar source in other places, and from dependence upon old charts. In Admiralty charts now on sale in this port, the variation is probably in error to the amount of seven degrees. The charts alluded to are those for St. Helena.

In an instance which was brought under the notice of the Compass Committee, of a ship, supposed to have large compass errors arising from a cargo of iron, on her voyage to the St. Lawrence, an examination of the azimuths, which the captain was so careful as to take, proved that the deductions which he made for variation, in reliance on his chart, had, on the average, increased his deviations from five to twelve degrees. Errors from this source are much more likely to affect the safety of wooden than that of iron ships. The case quoted, while it supports the opinion that an iron cargo seldom produces an error to the extent of a point, affords, with others in the hands of the committee, a strong argument for the increased safety which would result from the more general use of the azimuth compass.

In addition to the information derived from the return of "tabular forms," evidence is also sought from compass observations which are entered in the log-books of iron vessels. Interesting facts relating to the changes which take place in the southern hemisphere have been obtained in this way. These tend to show the great importance which attaches to this part of the compass inquiry, and led the members of the committee to promote to the utmost the projected voyage of the Rev. Dr. Scoresby to Australia, for the purpose of investigating this branch of the subject. They feel great pleasure in having been of assistance in carrying this project into effect, and in being allowed to associate with their own, the investigations which Dr. Scoresby is now proceeding with on board the "Royal Charter." It is anticipated that the observations which will be made on the magnetic condition of this vessel during her voyage out and home, will give that precise and accurate information which is at present so much wanted.

In what may be termed the home inquiry, and which seeks to record those magnetic changes occurring at the time or shortly after the launch of iron ships, and any permanent changes which may afterwards occur, the committee believe that satisfactory progress is being made in spite of local difficulties and circumstances that frequently compel them to make only those experiments which the exigencies of commerce will allow, rather than those which would most rapidly advance the ends they have in view. Examples are appended of some of these records.

The diagrams in illustration No. 1, are of use in connexion with the calculated elements of the disturbance of each compass as ascertained by the method of Mr. Archibald Smith, and afford data for comparison with the results to be obtained by re-swinging the ship at a future time. An inspection will also show that they have an interesting bearing upon the discovery of the best position for standard and steering compasses on board iron ships—a subject, it is feared, which is not sufficiently attended to by the shipowner or the naval constructor. Elevation without reference to position will not insure small errors, as a compass on board the Etna, (S. S.,) about thirty feet from the deck, has a maximum error of fourteen degrees.

The very exact mode of registering the magnetic condition of a ship, by counting the vibrations of a suitable needle in each position of the ship's head while she is being swung, as employed by the Astronomer Royal on board the Rainbow and Ironsides, is also used by the committee when circumstances will permit.

The diagrams No. 2 illustrate another method by which a ship's magnetic condition is ascertained, and her characteristic magnetic features delineated. These were constructed from observations made on the outside of the ships while they were in graving-dock, and laying nearly north and south. As most iron ships are placed in graving-dock on the completion of a voyage, for cleaning and painting, there is almost a certainty of finding the same ship in precisely the same position at a future time, and of then ascertaining, by a repetition of the experiments, whether her magnetic lines are permanent or liable to change. The ships represented were all on the blocks, with their heads in exactly the same direction, when the experiments were made. The diverse directions of the resulting magnetic lines appear to countenance Dr. Scoresby's supposition that they depend upon the position of the ship when building. As two of the ships have been twice to Australia, and have made other voyages, there seems reason to suppose that these lines have great permanence also. The inquiries of the committee will probably decide these points during the next twelve months.

This report will exhibit to your Lordships, a brief view of the proceedings of the committee during the past year. It only remains to add, that the demands which the inquiry made upon the time of the members were so great, that it became necessary to engage an assistant to devote the whole of his attention to the subject. A competent secretary, (Mr. W. W. Rundell, formerly of the Royal Cornwall Polytechnic Society,) has been engaged, at £200 per annum, to whom, for the last nine months has been entrusted the details of the experimental investigations, and the keeping the necessary records of proceedings. Suitable office accommodation, with the other expenses of the committee for apparatus, printing, &c, brings the annual expenditure to about £400. These facts are stated in connexion with the remainder of the report, to show that the members of the committee are actively prosecuting the investigation which has been placed in their hands; and will, it is hoped, give them additional claims to the support and encouragement of your honorable board. The results to be obtained from these inquiries are not limited to Liverpool, but possess national proportions, and it is respectfully urged should receive adequate national support. The Compass Committee, therefore, in presenting this report, venture to solicit from the Lords of the Committee of the Council for Trade, increased assistance towards the expenses of the present year.

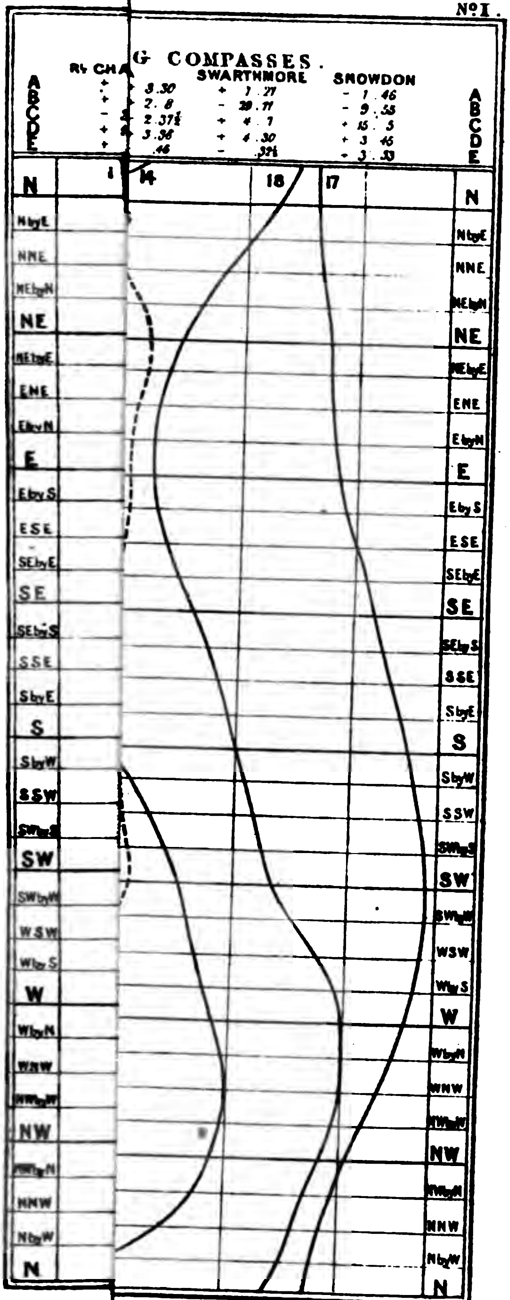
THOS. BROCKLEBANK,

Chairman Liverpool Compass Committee.

40 Tower Buildings East,

February 5, 1856.

No. I.



J. Bien, photo lith

DESCRIPTION OF ILLUSTRATIONS.

DIAGRAMS No. 1.—Seventeen deviation curves. When the curve is to the right of the vertical line, easterly deviations are indicated; when to the left of the line, westerly deviations.

Elevated Compasses.

1.	Elevated	Compass of	Royal Charter,	42 feet above deck.			
2.	"	"	Etna,	about	30	feet	above the deck.
3.	"	"	Persia,	"	40	"	"
4.	"	"	Emeu,	"	40	"	"
5.	"	"	Oronies,	"	25	"	"
6.	"	"	Otter,	"	25	"	"

Standard Compassss.

7.	Standard	compass of	Orontes,	about	5	feet	above the deck.
8.	"	"	Etna,	"	13	"	"
9.	"	"	Sarah Palmer,	"	7	"	"
10.	"	"	Royal Charter,	"	4	feet 6 inches	above deck.
11.	"	"	Swarthmore,	"	4	6 "	"

Steering Compasses.

12 and 13. Steering compass of the Fuzilier, (12,) when at Liverpool, in June, 1855; (13) when in the southern hemisphere, lat. 33¼ S., long. 84 W., in November, 1855.

14. Steering compass of "Lota."

15. Compass placed by request about four feet in front of the binnacle when she was swung.

16. Steering compass of Swarthmore.

17. " " Snowdon.

The letters A. B, C, D, E, with the figures opposite to them, represent the values of the magnetic disturbances for each compass, computed by the method of Mr. Archibald Smith, M. A.

A—A constant error, generally arising from wrong position of the "lubber line," or index error of the compass card.

B—Fore and aft disturbance. When the sign + is affixed, the north end of the needle is drawn towards the bow; when the — sign is given, the north end is attracted towards the stern.

C—Transverse disturbance.

+ C shows that the N. end of the needle is drawn to starboard.

— C shows that the N. end of the needle is drawn to port.

D—Difference between effect of the fore and aft and the transverse horizontal induction.

+ D shows preponderance of the fore and aft iron which is entirely before or aft of the compass and transvere iron extending from side to side of the vessel, &c.

— D shows preponderance of the transverse iron which is entirely on one side of the compass, and of fore and aft iron which is below, or which extends from stem to stern, &c.

+ produces east deviation when the ship's head is towards the N.E. and S.W. quadrants of the compass, and west deviation in the S.E. and N.W. quadrants.

— D has the contrary effect.

E—Like D, represents a quadrantal disturbance; but shows a maximum at the cardinal points, instead of on the 4-point rhumbs, like D. It is generally very small.

DIAGRAMS No. 2.—Magnetic portraits of seven vessels, taken while in graving-dock, and intended for comparison with future sketches to be taken of the same vessels.

APPENDIX No. 1.

LIST OF MEMBERS OF THE LIVERPOOL COMPASS COMMITTEE.

Chairman.

THOMAS BROCKLEBANK, Esq., merchant and shipowner.

Deputy Chairman.

J. P. PALMER, Esq, shipowner, and member of Local Marine Board.

Treasurer.

THOMAS COURT, Esq., secretary of Underwriters' Association.

Honorary Secretaries.

JOHN GRANTHAM, Esq., naval architect and consulting engineer.
JOHN T. TOWSON, Esq., secretary of Local Marine Board.

Appointed by the Shipowners' Association.

WILLIAM MANN, Esq., chairman of the Shipowners' Association, and vice chairman of Local Marine Board.

S. R. GRAVES, Esq., vice chairman of Shipowners' Association, and member of Local Marine Board.

F. A. CLINT, Esq.

T. M. BLYTH, Esq.

T. H. HOLDERNESS, Esq.

R. CARLYLE, Esq.

Appointed by the Underwriters' Association.

J. P. PALMER, Esq., member of Local Marine Board.

S. MARTIN, Esq.

L. H. MACINTYRE, Esq., shipowner.

JOHN AIKEN, Esq., merchant.

JAMES BEAZLEY, Esq., shipowner, and member of Local Marine Board.

THOMAS BROCKLEBANK, Esq., shipowner, and member of Local Marine Board.

Appointed by the Steamship Association.

R. LAMONT, Esq., chairman of the Liverpool Steamship Association.

J. W. FAIRCLOUGH, Esq., managing owner of Levant Steamers.

WILLIAM INMAN, Esq., managing owner of Liverpool and Philadelphia Steamship Company.

WILLIAM HADFIELD, Esq., secretary of Brazilian Steamship Company.

B. J. THOMSON, Esq., secretary of Steamship Association.

Appointed by the Literary and Philosophical Society.

JOSEPH BROOKS YATES, Esq., F.S.A., &c.
SWINTON BOULT, Esq., secretary Liverpool and London Fire and Life Insurance Company.
JOHN HARTNUP, Esq., F.R.A.S., Liverpool Observatory.
DAVID P. THOMSON, M.D., honorary secretary of the Literary and Philosophical Society.
J. B. EDWARDS, Ph.D., F.C.S.
G. HAMILTON, Esq.
J. T. TOWSON, Esq., examiner of masters and mates.
NORMAN MACLEOD, Esq., examiner of masters and mates.
JOHN JONES, Esq., shipowner.
JAMES NEWLANDS, Esq., borough engineer.

Appointed by the Polytechnic Society.

W. RENNIE, Esq., ship builder.
W. C. MILLER, Esq., ship builder.
C. GRAYSON, Esq., ship builder.
R. GETTY, Esq., ship builder.
J. JONES, Esq., iron ship builder.
E. JONES, Esq., engineer.
M. SCOTT, Esq., engineer.
JOHN GRANTHAM, Esq., naval architect and consulting engineer.
A. KING, Esq., engineer.
H. DAWSON, Esq.
C. F. SALT, Esq., secretary of Polytechnic Society.
J. ABRAHAM, Esq.

Added to their number by the General Committee.

Commander BEVIS, R. N., H. M. agent for transports.
THOMAS COURT, Esq., secretary of Underwriters' Association.
EDWARD HEATH, Esq., president of the Chamber of Commerce.
JOHN LAIRD, Esq., iron ship builder.
JOSEPH MONDELL, Esq., shipowner, and member of Local Marine Board.
W. POTTER, Esq., chairman of Underwriters' Association.
Captain SCHOMBERG, R. N., Chief Emigration Agent.

Secretary.

Mr. W. W. RUNDELL.

The Compass Committee has been appointed to investigate the causes of the deviation of the compass in wooden and iron ships, and to ascertain the best means of correcting errors arising from this source, especially in iron ships.

It is intended to prosecute this inquiry:

1st. By conducting experiments on board vessels which may be placed at the disposal of the committee, particularly on board such as are new.

2d. By furnishing shipmasters with lists of inquiries and other documents to be filled up during their voyages.

3d. By making extracts from log-books, taking evidence, and corresponding with such persons as may feel interested in, or may be able to give information connected with, the investigations of the committee.

4th. By inviting the co-operation of shipowners in requesting their captains to collect facts, and to take observations, whenever it is possible, with the ship's head on such points of the compass as will suffice for forming deviation tables.

Captains of vessels and others requiring copies of the forms, &c., printed by the committee, or who may wish to make inquiries or give information relative to compass deviations, are requested to call on the secretary, at his office, 40 Tower Buildings East.

COMPASS COMMITTEE,
Liverpool, July, 1855.

SIR: We beg to enclose a list of the members of the Liverpool Compass Committee, with a short statement of the object for which they were appointed, and the means by which they hope to carry to a successful issue the important investigation with which they are entrusted. It is forwarded with the view of pointing out to you the manner in which the shipowners and merchants of the port may afford very valuable assistance to the committee, and of explaining to you the arrangements which have been already decided upon.

Although the labors of the committee will embrace investigations on the magnetic deviation in both wood and iron ships, their chief attention will be directed to the latter. As an essential part of the inquiry, it is necessary to obtain, for future reference and consideration, trustworthy records of their magnetic condition, so as to ascertain the nature and amount of any changes to which it may be liable from differences of latitude and position, from lapse of time, and from the various accidents to which all ships are exposed. In order to prosecute this subject with the attention it demands, the committee have engaged the services of Mr. Rundell, a gentleman of scientific acquirements, as secretary, part of whose duty will be to obtain and record the desired information on board such vessels as may be placed at the disposal of the committee for the purpose; and (when he is invited by the owners or masters) to attend on board ships while they are being swung, to advise and co-operate with the captain and compass adjuster, and to make such additional observations as each particular case may seem to require. The secretary will also, when it is desired, furnish these vessels with a calculated table of deviations for each point of the compass.

To collect evidence, the committee have prepared a list of queries for general distribution among persons conversant with the subject, and a tabular form to be supplied to shipmasters, for registering the observations which they are requested to make during their voyages; specimens of these are enclosed.

As the records of the proceedings of the committee, and of such evidence and information as they may collect during this inquiry, will be for the public benefit, and will be constantly open to the shipowners and merchants of Liverpool, it is hoped that they will assist, as far as possible, by prompting their captains to make and record the required observations while their ships are at sea or in foreign ports; and by affording the committee, and their representative, Mr. Rundell, every facility for ascertaining the magnetic condition of the same vessels while they are in port here.

Soliciting your attention and active co-operation with the committee,

We are, sir, your obedient servants,

JOHN GRANTHAM,
JOHN THOMAS TOWSON,
Hon. Secretaries.

Letter respecting Change of Variation in the Irish Channel.

COMPASS COMMITTEE, 40 TOWER BUILDINGS, EAST,
Liverpool, November 6, 1855.

SIR: I am directed by the Liverpool Compass Committee to inform you, that by careful experiments made here on the 15th and 16th of October, and also at the Magnetic Observatory, Trinity College, Dublin, at the same time, it was ascertained that the correct "variation" at that date was:

For Liverpool.. 24° 22′ west.
For Dublin.. 25° 54′ west.

The mean of these, or 25° 8′, (rather less than 2¼ points of the compass,) is therefore the proper correction to be made for variation for ships navigating between the south of Ireland and Holyhead. As the usual practice with shipmasters is to allow 2½ points, it will be perceived that their ships, in sailing from the Tuskar to Holyhead, or the reverse, will tend to the right of their course, and thus be brought into danger in thick or foggy weather.

The rate of change in the "variation" for the Irish Sea, during ten years, is found to be 6′ per year. No note to this effect is inserted on any charts of the channel; and those charts professing to be corrected to the year 1853, still give the variation as it was many years since, when they were first engraved.

It is thought by the Compass Committee that a notice of the above exhibited in the Underwriters' rooms may tend to prevent accident.

I have the honor to be, sir, your obedient servant,

W. W. Rundell,
Secretary.

Thomas Court, Esq.,
Secretary Underwriters' Association, Liverpool.

Note.—This letter was printed as a large broadside, by order of the Board of Trade, and circulated throughout the kingdom, to the various custom-houses, &c.

APPENDIX No. 2.

LIVERPOOL COMPASS COMMITTEE.

Chairman.

THOMAS BROCKLEBANK, Esq., merchant and shipowner.

Deputy Chairman.

J. PALMER PALMER, Esq., shipowner and underwriter.

Treasurer.

THOMAS COURT, Esq., Secretary of Underwriters' Association.

Honorary Members.

G. B. AIRY, Esq., F.R.S., Astronomer Royal.
F. J. EVANS, Esq., R.N., Superintendent of Compass Observatory, Woolwich.
Rear-Admiral FITZROY, F.R.S., Meteorological Department, Board of Trade.
Major General SABINE, R.A., V.P.R.S., &c.
Rev. W. SCORESBY, D.D., F.R.S., &c.
ARCHIBALD SMITH, Esq., M.A., F.R.S., &c.
J. ABRAHAM, Esq.
JOHN AIKIN, Esq., merchant and underwriter.
JAMES BEAZLEY, Esq., shipowner and underwriter.
Commander BEVIS, R.N., H.M. agent for transports.
T. M. BLYTH, Esq., merchant and shipowner.
SWINTON BOULT, Esq., Secretary of the Liverpool and London Life and Fire Insurance Company.
R. CARLYLE, Esq., shipowner.
F. A. CLINT, Esq., shipowner.
H. DAWSON, Esq.
J. B. EDWARDS, Esq., Ph.D., F.C.S.
J. W. FAIRCLOUGH, Esq., shipowner.
R. GETTY, Esq., ship builder.
S. R. GRAVES, Esq., shipowner.
C. GRAYSON, Esq., ship builder.
WILLIAM HADFIELD, Esq.
G. HAMILTON, Esq.
JOHN HARTNUP, Esq., F.R.A.S., Liverpool Observatory.
ROBERT MCANDREW, Esq., F.R.S., F.R.A.S.
EDWARD HEATH, Esq., President of Chamber of Commerce.

S. HJORTH, Esq.
T. H. HOLDERNESS, Esq., shipowner.
WILLIAM INMAN, Esq., shipowner.
E. JONES, Esq., engineer.
JOHN JONES, Esq., shipowner.
J. JONES, Esq., ship builder.
A. KING, Esq., engineer.
JOHN LAIRD, Esq., ship builder.
ROBERT LAMONT, Esq., shipowner.
L. H. MACINTYRE, Esq. shipowner and underwriter.
N. MCLEOD, Esq., examiner of masters and mates.
WILLIAM MANN, Esq., shipowner.
S. MARTIN, Esq., ship owner and underwriter.
W. C. MILLER, Esq., ship builder.
JOSEPH MONDEL, Esq., shipowner.
JAMES NEWLANDS, Esq., borough engineer.
W. POTTER, Esq., shipowner and underwriter.
W. RENNIE, Esq., ship builder.
C. F. SALT. Esq., Secretary of Polytechnic Society.
Captain SCHOMBERG, R.N., Chief Emigration Agent.
M. SCOTT, Esq., engineer.
B. J. THOMSON, Esq., Secretary of Steam Ship Association.
D. P. THOMPSON, Esq., M.D., Honorary Secretary of the Literary and Philosophical Society.

Honorary Secretaries.

JOHN GRANTHAM, Esq., Naval Architect and Consulting Engineer.
JOHN T. TOWSON, Esq., Examiner and Secretary to Local Marine Board.

Secretary.

Mr. W. W. RUNDELL.

---

40 TOWER BUILDINGS EAST,
Liverpool, 1856.

TO CAPTAIN ———.

SIR: Among the more prominent questions which occupy the attention of the Compass Committee, in relation to the deviation of the compass in wooden and iron ships, are the following: What is its nature and amount? Does it differ, and to what extent, in the same ship at different times, and under what circumstances? What changes, transient or permanent, are caused by cargo, concussion, straining, or change of geographical position? How may compass errors be obviated, and what practical rules or remedies are most applicable? To obtain satisfactory data for solving questions of so much importance to the safety and perfection of modern navigation, the assistance of the practical seaman is absolutely necessary, and the members of the Compass Committee feel assured that the captains of our mercantile marine, sailing from Liverpool, can afford that valuable aid so requisite to the investigation.

It is hoped, therefore, that you will give the committee the benefit of your experience in this matter, and favor them with answers to as many as possible of the questions in the following list. A tabular form is also inclosed for the entry of observations to be made at sea. Records of the kind required in this form, obtained from a number of ships, and from different parts of the world, will be of great service. Assistance may also be afforded by the loan of log-books which contain compass observations. Such books, if left with the secretary to the committee, Mr. Rundell, at his office, 40 Tower Buildings East, will receive due attention, and be returned at the time which may be requested.

The whole of Mr. Rundell's attention is given to the Compass Inquiry, and he will be happy, at all times, to receive communications from you on this subject; he will also, when invited, attend on board ships while they are being swung, to co-operate with the captain and compass adjuster, and make such observations as may tend to advance the important objects which the committee have in view.

Begging your active assistance, we are, sir, your obedient servants,

JOHN GRANTHAM,
JOHN T. TOWSON,
Honorary Secretaries.

QUERIES.

1. Name of ship in which the error of the compass was observed
2. Wooden or iron ship....................................
   a. If iron, can you state what point of the compass her head was directed when she was built?..........................
3. Steam or sailing vessel...................................
   a. If steam, is she paddle wheel or screw?..................
4. Wooden or iron masts?..................................
   a. If iron, were they in at the time the compasses were compensated by magnets, or when the deviation was observed?...
5. The age of the vessel at each time the deviation was observed, and her present age ....
6. Her chief dimensions:
   Length Breadth Depth
7. Number of compasses....................................
8. Where placed, and state the distance of each from the rudder head; and if a steamer, how far from the funnel, and whether dipping needle compasses or otherwise............
9. Was the compass compensated by magnets, or was a table of errors provided?......................................
   a. Was the cargo on board when the deviation was determined or corrected; and if so, what was the nature of it?........

10. If compensated by magnets, can you state the greatest amount of error before and after the magnets were applied, and the direction of the ship's head when the greatest amount of error was observed?...............................

11. If not compensated by magnets, what was the greatest amount of deviation observed, and the direction of the ship's head at the time?...

12. Did any practical inconvenience arise, either from the magnetic compensation, or the table of errors, as the case may have been?..

a. Did you observe any change in the deviation as given in the table; or any error in the compasses after they were compensated?..

13. If a change took place, was it sudden or gradual?..........

14. If sudden, under what circumstances did it occur?..........

a. If consequent on a collision, state the direction of the ship's head at the time, and whether the change was permanent or temporary?...

15. If gradual, was it a constant increase, or a constant decrease of deviation, or did it sometimes increase and at others decrease?..

16. Particularize the nature of the cargo at the time the change in the deviation took place. If iron, state of what kind, and in what part of the ship it was stowed..............

17. Was the voyage coasting or foreign; confined to the northern hemisphere, or extended south of the equator?...........

18. Did the change of deviation occur on the passage to the southern hemisphere? If so, state..........................

a. The latitude and longitute in which the greatest error was observed..

b. The maximum amount of change in the deviation..........

c. Whether any amount of the change experienced when south of the equator remained when the ship returned to port...

19. Did the compass vary when the ship heeled? If so, state the amount of deviation..................................

a. What was the mean angle of heeling, and what means had you of ascertaining this?.............................

b. The position of her head at the time it occurred...........

c. If an iron ship, how far was the compass above or below the highest iron top-side plating, whether on bulwark or otherwise?..

d. If a wooden ship, were there any iron tanks, iron tiller, or iron steering wheel, barrel or spindle, or iron davits, or was there iron in any form near the compass?............

e. Was the north pole of the needle drawn towards the upper or lower side of the ship when she heeled?..............

f. If observed in both hemispheres, was the north pole of the needle drawn to the same side in both cases?............

g. State how the boat's davits were turned at the time........

20. Has there been any inconvenient amount of oscillation observed in the compass? If so, state..................

a. The situation of the compass so affected..................

b. The circumstances under which it occurred, including the position of the ship's head at the time...................

c. Were any means adopted to prevent it, and with what success?..

21. Has any inconvenience been experienced from the sluggish action of the needle? If so, describe the compass so affected, and any other circumstances connected with this evil.

22. Was the ship struck by lightning? If so, describe the effect, if any, produced upon the compass..................... }

23. Has an elevated compass been tried? If so, state where it was placed, and with what result...................... }

24. Have you used an azimuth compass? If so, state if any advantage has arizen from its use, either on the high seas or in the channels.................................... }

25. Will you send a copy of any tables of deviation which have been made, and state the localities and circumstances under which each table was constructed?................ }

Ship's head.	Deviation of compass.	Deviation of compass.	Ship's head.	Deviation of compass.	Deviation of compass.
North			South..........		
N. by E.........			S. by W........		
N. N. E.........			S. S. W.........		
N. E. by N......			S. W. by S...		
N. E.............			S. W...........		
N. E. by E.....			S. W. by W...		
E. N. E.........			W. S. W........		
E. by N.........			W. by S........		
East..............			West...........		
E. by S..........			W. by N.......		
E. S. E..........			W. N. W......		
S. E. by E......			N. W. by W..		
S. E..............			N. W...........		
S. E. by S......			N. W. by N...		
S. S. E..........			N. N. W........		
S. by E..........			N. by W.......		

Place where the ship was swung, | Date,

a. Is the bearing of the ship's head as given above "true magnetic," or as observed by the compass to which the table of deviations belongs?................................ }

26. Are you aware of any means having been successfully adopted to prevent or correct the deviation of the compass not alluded to in the foregoing queries? If so, describe them.. }

APPENDIX No. 3.

INSTRUCTIONS, &c.

This tabular form is intended to receive the observations indicated at the top of each column, and has been prepared for the purpose of ascertaining the magnetic deviation experienced on board ship, and the change in its amount which is occasioned by difference of magnetic latitude.

The required observations will be of service in any future voyage that the ship may make to the same place, and will afford the Compass Committee much valuable assistance in the investigations which they are now making.

To obtain the deviation for every point of the compass, it is not necessary that observations should be made on all of them; but it is desirable that in each instance observations should be made on as many points as may be practicable; and it is essential to their utility that they should be made on at least four opposite bearings, as far from the cardinal points as is convenient, and also one on a cardinal point. In cases in which ships pass over nearly the same track on the homeward as on the outward voyage, it will be sufficient to have half of the required observations taken on the outward, and the remainder on the homeward voyage, as the ship approaches the same places.

A number of observations, with the ship's head on a few points of the compass, unless they include the five points before mentioned, will be of no utility in the present inquiry; but when the five are included, the more numerous the observations on the same point, the more correct will be all the results which can be obtained from them.

When ships do not return by the outward route, it is necessary that they should be veered from their course (during a short time, and when circumstances will permit) until the required number of observations can be taken, or through 24 points in all.

If there is no azimuth compass on board to obtain the true position of the ship's head by the sun, as she is being taken round, the compass which is supposed to be most correct should be distinguished. Observations with an elevated compass are always desirable.

It will be evident to captains of vessels that the entries in these tabular forms, when the observations have been made with care, and in wooden ships, will afford data by which variation charts may be corrected, or from which new ones may be constructed. If each captain would make only two or three complete sets of observations during each voyage, the joint observations of all the captains who may receive these tables will, in the course of two or three years, afford a large amount of valuable information.

It is intended to present each captain, from whom assistance is received, with a copy of the reports, which from time to time will be published by the committee.

Name of ship....................	
Name of commander.........	
Length and breadth of ship..................................	
Whether built of iron or wood, and if of iron, whether the bulwarks are also of iron	

Name of compass.	Height from deck.	Distance from rudder head.	If corrected by magnets or not.
Nature of cargo when the observations were made, and if containing iron, the number of tons.........			

Tabular form issued by the Liverpool Compass Committee for observations on magnetic deviation.

[This form should be filled up during the voyage and forwarded to the committee on the return of the ship to England.]

[Name of ship.]

Year.	Month.	Day of month.	Greenwich mean time.			Latitude.			Longitude.			Sun's bearing by azimuth compass.	Ship's head by azimuth compass.	Ship's head by compass.	Ship's head by compass.	Ship's head by compass.	Mean heeling of ship.	
			Hour.	Min.	Sec.	Deg.	Min.	N. or S.	Deg.	Min.	E. or W.						Mean angle Deg.	Lower side, whether port or starboard.
185																		

O

SECOND REPORT

FROM

THE LIVERPOOL COMPASS COMMITTEE

TO

THE BOARD OF TRADE.

1856.

To the Lords of the Committee of Privy Council for Trade:

In the report of proceedings which the committee had the honor to forward to the Board of Trade in January last, particulars were given of the mode of action of the committee, of the kind of information which its members were seeking, and the nature and object of the experiments which they had undertaken. In the present report, which is made in compliance with the terms of your Lordships' letter of May 5, 1856, (No. 4,418,) it is intended to continue this account, and to furnish a statement, as brief as the subject will permit, of the results which have to this time been attained.

At an early date, it became apparent to the committee that additional means of obtaining information were required; that besides the difficulties belonging to the subject, they would have to overcome the apathy of shipowners and the inertia or active opposition of persons interested in maintaining "things as they are." Even when merchants and shipowners were willing to accede to the wishes of the committee, they were met by the heavy expense and delays attendant on experimenting upon and moving such ponderous masses as iron ships. To these must be added, impediments arising from frequent changes in ships' steering apparatus, and the position of the binnacle; from new fittings and the varying quantity and stowage of the iron in a ship's cargo; the proximity of other iron ships on the building slip, or by the wharf; and numerous other retarding or vitiating accidents which will readily suggest themselves to persons conversant with maritime affairs.

In some cases there was reason to suppose that information forwarded to them was not to be depended upon; that with compass deviations arising from the iron of the ship, they were favored with others due to personal and accidental causes, imperfect instruments, local attraction on the shore compass, and a bad system of "swinging." The returns made to the committee, and really available for the inquiry, were by such causes so much reduced, that it is chiefly by the co-operation of a comparatively small number of captains, and the strenuous exertions of the committee, that any progress has been made. It is, however, believed that this report will contain valuable and trustworthy information respecting the direction and amount of what is now generally termed a ship's sub-permanent or retentive magnetism, and the fluctuations to which the more changing part of her magnetism is subject. The part of the inquiry which depends on observations made in other latitudes must for the most part be reserved for the next report, when the data in the possession of the committee will be much increased.

Many of the difficulties and hindrances which have been alluded to were overcome by the introduction of a complete system of magnetic bearings, painted, by request of the committee, upon the dock walls of the port, and the use, in conjunction with these, of a gimballed "dumb-card." The nature of the bearings will be readily understood from the diagram and description given, Plate 3. These bearings, besides affording the captain of every ship which enters or leaves the docks or swings with the tide in the Mersey, the means of testing the accuracy of his compasses, have enabled the committee to gather much important information which would otherwise have been quite unattainable. They have proved, too, most decisively, that the deviations of the compass on board iron ships, when properly ascertained, are not of that irregular and erratic character which many cards of deviation might lead one to suppose, but that they accord most closely with the deductions of theory and experiment, as exemplified in the works of the Astronomer Royal and Mr. Archibald Smith. The committee have been practically convinced that a good deviation table, when projected by Napier's or any similar method, assumes so simple, regular, and intelligible a form, that the practised eye can at once decide upon the degree of confidence it should command, and on the general distribution of the ship's magnetism at the place of the compass to which the table belongs. Ample illustration of this will be afforded in other parts of the report.

The "dumb-card," or "azimuth card without a needle," has been found a most convenient instrument. The constant use of it for nearly twelve months, on shore and on the river, as well as at sea, proves to the committee that, when properly constructed and skilfully employed, it is superior to the azimuth compass for swinging ship, and for quickly and correctly giving the direction of ship's head. The difference between the use of the azimuth compass and dumb-card at sea may be stated thus: With the former, we have the inconvenience arising from an oscillating card, and one which is subject, through its needle, to the influence of local attraction and variation, the correction for which must be found and applied before "*ship's head true*" can be obtained; with the latter, the true direction of ship's head is seen by inspection, the moment the sight-vanes and card are turned to the object, to whose true bearing they have been previously adjusted.

In harbor, or under circumstances when "*ship's head true magnetic*" is required, its use is equally simple. The lubber line of the instrument having been turned towards and fixed at ship's head, the sight-vanes are adjusted to that part of the card showing the magnetic bearing of the given object; immediately on turning the sight-vanes and card towards the object, the true magnetic bearing of ship's head is seen opposite the lubber line, and may be compared with that given by each of the compasses mounted on board the ship.

When, as has frequently been the case with the committee, only a brief space has been allowed for experiment, as in moving a ship from one dock to another, or in putting her in and out of graving-dock, this instrument has strongly commended itself by the rapidity and accuracy with which the necessary observations could be made; and in describing the means employed by the committee to collect information, it demands a prominent place.

The dumb-card is so easily added to any azimuth or ordinary compass, that it will, no doubt, speedily come into general use. In two or three instances, it has for some time past been so added; in two of these in so very imperfect a form as to call for notice, inasmuch as errors attributed to heeling in iron ships may, in some cases, have been caused by the non-horizontality of these cards, or the corresponding azimuth circles. This imperfection arises from want of the necessary gimballs, and produces not only an error dependent on the heel of the ship as compared with the direction of the observed object, but also another, which rapidly increases with the altitude of the object; yet in both these instances telescopes are attached to the instrument, and the direction of the chief meridian is to be ascertained by observations of the north star at altitudes of 50 or 60 degrees!

These remarks complete to some extent the account which was commenced in the last report, of the means employed by the committee, and its mode of operation. Other topics now demand attention.

The records of the committee no longer allow a doubt as to the connection which exists between the direction of a ship's original magnetism and her position when upon the building slip. In all the ships which have been examined, the north end of the compass needle invariably deviated towards that part of the ship which was furthest from the north while she was building, if the compass was placed in a central position, and free from the influence of individual masses of iron. When this is admitted, the following question is immediately suggested: Of ships built in various positions, which have the smallest deviating action on the compass?

To answer this satisfactorily, it is necessary to consider not only the amount but the permanence of this action; to refer to experience gained in long as well as short voyages; and to free the observations from the influence of bulkheads, pumps, rudder-head, and stern-post, or proximity to other individual masses of iron. This involves an amount of labor and research which few persons besides those who have attended to the subject will be able to appreciate. Before concluding their investigation, the committee hope to be able to give the question a practical answer; in the meantime, they proceed to lay before your Lordships such facts as belong more immediately to what may be termed the "home inquiry," or that which may for the most part be tested in port, reserving that which must depend upon evidence obtained at sea for their final report.

The original magnetism of a ship, by which is meant that dependent on her direction when building, as it forms a leading characteristic, will be first treated of. In amount it appears to have close relation to the size of the ship or the quantity of iron used in her construction. In a ship of 400 tons, built head to east, where the deviation of the compass is always towards the starboard side, if a compass be carried fore and aft on the middle line, about three or four feet from the deck, the deviation may be 10 or 12° when her head is north or south. In a ship of 1,000 tons, it may, under the same conditions, be 25° or 30°, or more, depending to some extent on the breadth of the ship. This deviation of the compass to starboard in ships built with head to east, and to port in ships built head to west, must be remembered to be caused by a differential action only. Both sides of such ships (in north magnetic latitudes) attract the north end of the compass needle, as will be seen by approaching either side with a compass, either internally or externally. The illustration on the opposite page will exemplify this, as also the effect of the bulkhead or water-tight compartment at A. One side, however, attracts the needle more strongly than the other; and, as will be seen in the diagram, this is the side which was furthest from the north when the ship was building. In discussing observations made in opposite hemispheres, and in considering the effect of heeling, it is important to remember this. If these ships be turned with head to east or west, the north end of the needle will tend to the bow or stern respectively, according to the direction in which lies the greater mass of iron, except when influenced by bulkheads or proximity to bow or stern, the stern especially, as here the stern-post, rudder-head, and other masses of vertical iron will control the attraction of the remainder of the ship. Fig. 2 and table on Plate 6 will further illustrate this. The experiments were made on board the same ship as those recorded on the preceding page. Plate 5 and the table opposite to it show the deviations of a compass at different places on the poop of a much larger ship, and also exhibit the value of ship's magnetic force, at each position

Iron sailing barque "NAUPHANTE,"

Brunswick graving-dock.

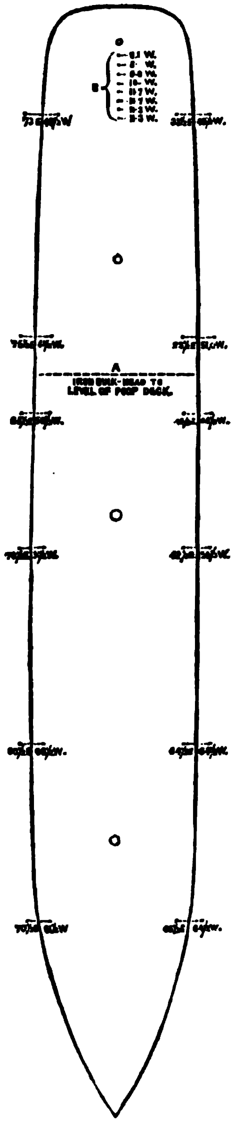
Head S. 8½ W.

Ship built head to East.

Compass deviations observed near the level of the top of iron bulwarks, and at two feet distance, showing attraction of north end of compass needle by both sides of the ship, but most by the starboard side; the side furthest from the north when the ship was building.

B. Deviation of compass three feet above the deck, on middle line of ship, also showing the stronger action of the starboard side.

Fig. 1.



of the compass, compared with that of the earth, as obtained by vibration experiments.

In a ship built head to north, or near it, there will be no apparent attraction of the needle towards the sides while she lies in a N. or S. direction. In all other directions, a strong attraction towards the stern will be noticed, except the needle be carried very near to the bow or the aft side of a water-tight compartment, when the contrary action may be seen. At a considerable distance from the stern in such vessels, the deviation may amount to 40°, and at three or four feet from the rudder-head to 100°, 150°, or even 180°. In ships built head to east, where the attraction aft is not nearly so strong, the deviation of a compass placed near the rudder-head, &c., will approximate to these amounts. In one such instance the error in the first position of the binnacle was 101°. As the ship was going to the East Indies, the compass adjuster objected to compensate so large an amount, and the binnacle was then placed three feet forward; here the error was reduced to two points. In another and much larger ship, (the "Dreadnought,") the compass in the first position of the binnacle deviated 14 points; on moving it a little further forward, the error was reduced to 2½ points.

To ships built head to south the same principles will apply. The deviation is chiefly towards the bow. Usually in these ships there is a space near the stern where the attractions are so nearly balanced, that frequently no compensation of the steering compass is attempted; yet elevated compasses placed aft in the same ships will show considerable deviation, the errors increasing for some distance as the compass is carried aloft. The diagrams and illustrations, Plates 10, 23, and 24, will afford examples of these peculiarities.

The prominent characteristics of ships built with head towards the cardinal points have now been described. In ships built in intermediate positions these characteristics will be combined. Thus, in ships built head to N. E., the attraction will be aft and to starboard; head N. W., aft and to port. If the head be S. E. or S. W., the deviations will be forward and to starboard, or forward and to port, respectively.

As before remarked, it must not be hastily concluded that these positions for building which give the smallest errors aft are to be preferred. The choice must depend on many other considerations. Ultimate permanence of deviation under change of geographical position is a quality to be more highly valued.

This original magnetism of an iron ship is frequently very permanent as regards direction, but is believed to undergo rapid changes in its amount, both in reality and in its apparent effect on the compass; the most striking change being at and immediately after launching, and during the first voyage. It is usually more evident in a steamer than in a sailing vessel. There are cases in which the deviations in a steamer have changed so much as two points in the first two days at sea, while afterwards the change has not been more than three degrees in as many months. In new sailing ships the change is generally, but not always, more gradual, and extends over a longer period. A change of 10° to 15° is not infrequent.

In proof of this—besides the cases under the immediate inspection of the committee and those reported to them by ship captains—may be quoted the general testimony of compass adjusters. Each time a ship is re-swung, the compensating magnets are usually placed at a greater distance from the binnacle, or one or more are taken away altogether. In such instances, there can be no doubt as to a reduction of the ships magnetism having taken place. In the comparatively few cases in which compensating magnets have been added or placed nearer to the binnacle, the contrary inference is not so certain. The magnets may have lost their power more rapidly than the ship hers, or the ship's force in one direction may have been unmasked by a more rapid change in another, examples of which are on record*.

Under some circumstances, considerably more than one-half of a ship's original magnetism, or rather that part of it which affects the compass, may be lost, or may become balanced in the course of a year. Of this the "Royal Charter" is an example. (See letter from the Astronomer Royal at page 44.) In support of the foregoing, the following are taken from a number of examples to the same effect, which have been collected by the Compass Committee:

1. The "Panic," iron sailing ship, built head to east; one of the oldest sailing iron-built ships in the port. It is stated that each time this ship has been swung, the magnets were found to be too strong. When swung in 1856, after her return from the East Indies, (to which she has made several voyages,) one compensating magnet, a transverse one, was removed entirely; the fore-and-aft magnet was placed at a greater distance from the binnacle.

2. The "Sarah Palmer," iron sailing ship, built head E. by N. On the building slip at Warrington, the attractions balanced each other between five and six feet from the rudder-head. A few days after launching, at Liverpool, head nearly in the same position, the balance did not take place till the compass was placed more than twenty feet further forward. Of a number of observations made on the deck-house, near the centre of this vessel, and similar observations made a few days afterwards, the ship's head being within 8° of the same direction, the average reduction of the deviations was from 37° to 11°. Making a liberal allowance for the small difference in the direction of the ship's head, the change may be taken as three to one.

3. The "Astræa," three masted sailing schooner, built head to south and west, was adjusted in the Clyde, and a table of residual deviations given. She sailed to the West Indies, and the deviations corresponded with the table. On the home voyage, the captain observed a change of nearly two points, and before he met with any bad weather. The deviations of this compass after her return to Liverpool, as compared with those observed in the Clyde, are given in diagram No. 1, Plate 4. The

* The table already referred to, Plate 6, shows a change both in the transverse and fore-and-aft magnetism of the ship, but greater in the former.

difference was shown to be due to a reduction of the ship's magnetism by taking away the compensating magnet. There being no time allowed for readjustment, the magnet was again put in place, and she sailed to the Mauritius with deviation table, this being considered sufficient precaution for "clearing the Irish channel and getting sea room." Recent letters show that she experienced still greater changes in going south*.

4. The "Nauphante," iron sailing barque, built head east. Fore-and-aft and transverse magnetisms decreased after launching. See table already referred to on Plate 6.

5. The "Bœotia," S. S., built head south and west, was swung, adjusted, and table of residual deviations given to the captain, who re-swung her immediately after, and before sailing from east coast round to Liverpool. Before reaching the English channel, the steering compass was discovered to be two points out, and the same amount of deviation was also observed by the pilot on bringing her into Liverpool. Other particulars respecting this vessel are given, Plates 23 and 24, with deviation curves for her three compasses.

The "Ionia," S. S., built same place and direction, was also swung and adjusted under the inspection of an able captain. Had rough weather before rounding the Lizard, on her voyage to the Mersey. After passing the Smalls, opportunities occurred for testing the compasses; the deviations then observed, compared with the first set, are given in the diagram at Plate 25.

7. The "Imogene" iron sailing ship, built head easterly. On her first voyage, the steering compass was discovered to be more than 1½ points out, before clearing the English channel.

The following is an easy mode of testing the fact which these cases illustrate. It has frequently been adopted when no other presented itself, and is almost universally applicable. With a small pocket compass ascertain the direction of the north poles of the compensating magnets. This will indicate pretty correctly the direction of the ship's original magnetism. Observe the direction of ship's head, and whether any deviation exists. Cases in which sufficient deviation for this test is not to be found are extremely rare. It will be seen that the deviation is in the direction contrary to that which would be caused by the ship's magnetism, and is therefore due to the magnets being too strong. When the compensation is partly effected by chain-boxes, there can be no uncertainty on this point; in other cases the result may appear equivocal, unless the effect of horizontal induction be considered.

No apology will be required for pausing a moment to inquire, what would be the effect of such reduction of the transverse magnetism in

---

* It is stated that when to the south of the Cape of Good Hope, towards the end of October, the sun bore at *rising* by the *steering compass* N. by W.!

ships built with head easterly, as is the case with so many vessels belonging to this port. It is evident that the north end of the needle of an adjusted compass will be repelled from the starboard side, giving east deviation on southerly, and west deviation on northerly courses. Further, if the reduction of the transverse magnetism forward from the binnacle affected the balance of the fore-and-aft attraction, the attraction of the needle towards the stern would be relatively increased, and there would also be east deviation on westerly, and west deviation on easterly courses. Thus these vessels, whether on southerly or westerly courses, and particularly on southerly and westerly courses, would tend to the right of their course. That these ships do so, is well known. To quote only one, though another and most painful instance will also suggest itself: Captain Heron, of the "Mystery," built at Warrington, head E. by N., states that, after leaving Liverpool, with compasses adjusted, on her first voyage, he shaped a course for the Smalls, and kept to it. He found, however, that it took him so much to the right of his apparent course, that he considers he must have been about mid-channel. Had he set a course for the Tusker, or even for mid-channel, instead of one near the Welsh coast, the consequences might have been serious. From what has already been stated, it will be inferred that the larger the ship the greater will be the amount of change, and so much the more to the right of her course, under the same circumstances, would such a vessel be taken.*

After this early reduction of a ship's magnetism has taken place, the remaining portion, as far as may be judged from examinations made in the same place and under the same circumstances, appears to be comparatively permanent. The illustrations, Plates 8, 9, and 11, will show both its degree of permanence and its amount of change under special conditions. The most striking case that can be quoted is, perhaps, that of the "Great Britain," Plate 11. This extraordinary ship has been stranded, and strained, and altered; has traversed both hemispheres, and been very many years in active service; yet her lines of no deviation are now much the same as Dr. Scoresby would indicate them to have been

* The "Nauphante" is another instance of some interest, on account of the number of experiments which were tried on her for the committee. After launching, she was kept head to west for some time, this being the position most favorable to the reduction of her original magnetism. When ready for sea, her transverse magnetism was purposely under-compensated, in anticipation of further reduction, and the attraction to the stern, only about 3° or 4° when she was ready for sea, was *over*-compensated by nearly the same amount, by a small bar of iron placed vertically within the skylight forward. The result was, as found by swinging her in the river as she was going to sea, to give a deviation of about 10° W. on a S.W. course. See deviation curve, Plate 4. Instead of allowing for the full amount of this error, the captain steered only half a point west of his course, yet, in spite of this precaution, he saw both Wicklow lights when he considered himself to be well towards mid-channel.

when she was upon the stocks. In the illustration, these lines are exhibited, as taken in the London graving-dock, No. 2, January, 1856; again, as taken December, 1856, after being for some weeks head N.N.E., in the same graving-dock. We next see them as they appeared two days after, with her head in the opposite direction; and again, as determined January 6, and January 24, 1857, after being in the same position, and undergoing constant hammering in almost every part for forty-three days. Yet how small is the change! a proof apparently, that no circumstances can permanently *conceal* or greatly alter the direction of an iron ship's original magnetism.* These experiments also show, what has so frequently been insisted upon by Dr. Scoresby, that the tendency of these lines, with the lapse of time, is to approach the horizontal direction; but, except towards the middle of the vessel, little more than a tendency to it. The experiments with the vibration needle, in different positions or stations during the time this ship was undergoing her refit, are recorded opposite Plate 12, and will still further illustrate her magnetic condition.†

Some remarks must now be made upon the more changeable portions of a ship's magnetism, the *vertical inductive* and the *horizontal inductive;* the latter being now very frequently termed a ship's quadrantal magnetism, from the change in the direction of the deviation due to it in each quadrant of the compass as the ship is swung round.

It is not required that a ship should change her geographical position to show the existence of either of these effects of the earth's inductive action, though it is only by such change that the full effect of the former can be properly estimated. By experiments with the vibration needle, a change in the value of the ship's magnetic force will be observed, as she is turned with her head in opposite directions. Two values are thus obtained, which give the sum and difference of the ship's permanent magnetism, and that due to induction, the changing vertical, and the changing horizontal, for the place of the experiment. The Astronomer Royal has shown that the chief feature of the ship's vertical induced

* It is admitted that the "neutral lines" give only a partial view of the changes which take place in a ship's magnetism. The real change in its amount, as intimated in the text, may be very great, and the "neutral lines" show no variation.

† The Compass Committee owe their thanks to Messrs. Gibbs, Bright & Co. for their courtesy in allowing this noble ship to be reversed in the graving-dock. It afforded an opportunity which had been long waited for. It was thought by some persons that the lines of no deviation obtained in the graving-dock were very much due to the ship's position at the time of the experiment, and that by turning the ship end for end a considerable change in their direction would be exhibited. This is not in accordance with trials made in the same dock on ships built head to south and head to east, examples of which were given in the last report; and it has very little support from the case of the "Great Britain." Change may be conceived to have been here entreated at an angle of 40°, but how little of the alteration expected by turning the vessel through 180° is, in fact, exhibited.

magnetism, in this hemisphere, is to constantly diminish the earth's directive power on the compass needle. There is reason to believe, that it is also, or rather that it gives rise to, a fluctuating quantity, which is liable to influence the deviation tables of ships that change their latitude only to a small extent, or not at all, by a portion of it being retained for a time. In amount it appears to vary with the position of the ship, the time during which she remains in a given position, and the circumstances to which she may be subjected while maintaining it.

The following facts, with some experiments to be afterwards described, are offered in support of this position:

1. Deviations observed with the Admiralty compass on board the the "Royal Charter," after she had been lying for some weeks head to N.N.E., differed by several degrees from those observed after she had been for ten days with her head W.N.W. See "curve of deviations," Plate 22.

2. The "Drogheda," paddle-wheel steamer, plying between Liverpool and Ireland. Captain Toker states that he has commanded her for seven years, during which time she has had her compasses adjusted twice or thrice. The compass adjuster stated on the last occasion, that he had not known any ship which, after a lapse of three years, required so little alteration. The captain informs the committeo, that after each time she has been in graving-dock, head N.N.E., for a few days, to be scraped and painted, he has observed her to deviate considerably to the north of her course, both in going to and returning from Ireland. He could not offer any reason for this. On the first occasion of his noticing it he sailed in company with another steamer. Instead of keeping parallel with her, as had been usual, he remarked that her captain had changed his course. Eventually he discovered that it was himself that had done so, though he appeared by compass to be steering as before. After making a few voyages, this extra deviation disappeared, and he was able to steer his accustomed courses. These deviations indicate increased attraction aft, and would probably arise from the ship's northerly position in graving-dock.

3. The captains and overlookers of several steamers, trading to the Mediterranean, state while in this sea they make certain courses very correctly. In attempting the same after leaving Cape Finisterre, with ship's head northerly and easterly for two or three days, they get to the north of their course. Thus, in the run from Point Lynas to the N.W. light-ship, or the bell-buoy, course about E.S.E., they sometimes get so much as six, eight, and nine miles to the north. The cause already spoken of appears an adequate one.

4. Similar experience is reported by the captains of iron steamers on the North American lines. On the homeward voyage, towards Newfoundland, they get to the north (or left of their course,) after making

what is considered to be ample allowance for deviation and the rapid change which occurs here in their variation.

The captain of the "Laconia" steamship, trading to the Mediterranean, stated, that in two or three successive voyages, in departing from Cape Finisterre for the Irish channel, he had kept the ship in the same direction by the mast compass, and narrowly watched the steering compass. He had found its deviation gradually increase as he came northwards, till, on reaching the Smalls, it amounted to three-quarters of a point.

All these cases show a deviation to the north of the usual courses, after the ship's head has been northerly for a short time, and they require some explanation of a general and comprehensive kind.

The following instance of change is somewhat different in the details, but also illustrates the subject in question.

6. Captain Williams states that when he commanded the "New Granada," on the west coast of South America, (ship built at Govan, head S. and W., no compensation,) he left Callao with fine weather, bound for Valparaiso, steering the course which by repeated voyages he had found a correct one for this vessel. Some hours after, and near midnight, feeling an uneasy motion in the ship, he went on deck, and found her among the rollers. He put her head off-shore immediately, and on heaving the lead found only three fathoms of water. After getting her into deep water, finding fault with the mate, and giving strict injunctions as to the course, he again went below. Before one o'clock, the same uneasy motion again called him on deck. He then stood by the compass to satisfy himself that the course which he gave took her in-shore, and soon found that he had to alter it full half a point. On inquiring further particulars, it appeared that this was the first voyage after a refit, during which the vessel had been moored at Callao, with her head to the south, there not being room for her to swing. The same captain states that he has commanded several steamers on the line between Valparaiso and Panama, and that with *new* vessels it generally took him six months before he could place much confidence in his courses. These ships are understood to have had no magnetic compensation.

In this place may be introduced some particulars of the committee's vibration experiments, as bearing especially upon this topic. It is believed that they will show fluctuations both in the amount and direction of a ship's induced magnetism of considerably greater extent than is generally supposed to exist. These fluctuations do not appear, however, to affect *practically* an authoritative statement which has already been supported by the committee, and which, as it forms the key to the correction and calculation of compass deviations, cannot be too earnestly repeated; namely, that a ship's magnetism for any given place may be very closely represented by a permanent polar magnetic force in combination with a quadrantal force, or one changing its deviation in each quadrant as a ship is swung round.

In the table opposite Plate 16, is given the results of experiments on the "Royal Charter," made while she was being swung for Dr. Scoresby. The position of the vibration needle is described opposite Plate 12, and shown in the drawings of this ship, Plate 12, as well as the relative positions of the other compasses which were used at the time. The value and direction of ship's force are also exhibited by diagrams, Plate 16, and in rather a different manner, Plates 17 and 19. These will, perhaps, convey through the eye the best conception of the fluctuations referred to. When they were first exhibited in this manner, it was almost impossible not to suspect large errors of observation, but it is believed that such do not exist. One test of this will be, to compare these diagrams with the results of Mr. Airy's experiments on the "Ironside," exhibited in the same manner, Plate 18. In the latter, the changes both in quantity and direction will be found to be greater. A further and most instructive comparison may be made with the records of similar experiments on board the "Royal Charter," which were made immediately before she proceeded on her second voyage to Australia. They exhibit in the most definite manner the real difference in the magnetism of the ship on the two occasions.

Similar experiments have been gone through on board the "Bœotia" and the "Great Britain." To include the whole of them in this report would unnecessarily increase its length. A selection from those made on the "Great Britain," while in graving-dock, will be appended, (opposite Plate 12.) The last are very remarkable, as showing in one position of the compass, at a distance of nine feet from the nearest mass of vertical iron, a magnetic intensity for the ship very nearly double that of the earth.*

In reference to the disturbance of the compass due to horizontal induction or quadrantal deviation, the committee have to remark that its peculiar character is too frequently overlooked. This is proved as well by the practice of a majority of compass adjusters as by the appearance of a circular which has recently been submitted to the inspection of the committee. This is the more to be regretted as in all the iron merchant ships and steamers which have been examined in Liverpool it forms an important feature. Unless its character be understood and its value

* Appended to the illustrations are many particulars which could not be introduced into the body of the report. The vibration needle employed in these experiments, is considered to be a very beautiful instrument. It was constructed under the immediate care of Mr. Towson and the secretary, and no necessary expense or trouble was spared. It was exhibited at the Glasgow meeting of the British Association. The needle is made of steel of excellent temper, and has not sensibly lost any magnetic power during the last fifteen months.

estimated, an approximate curve of deviations cannot be projected from four observations with any chance of success. Two cases have been named in which it exceeded a point; on board the "Royal Charter" it amounted to six and seven degrees. In such instances it might give rise to an uncertainty in the deviation of twice this amount. (See note from Mr. Airy at page 44.)

While the deviations arising from permanent magnetism and vertical induction vary as the sine of the angle of direction of ship's force, at the station of the compass, with the magnetic meridian as indicated by the disturbed needle, the quadrantal deviation has been shown to vary as the sine of twice the azimuth of ship's head by disturbed compass very nearly. In practice these two deviations are combined in every conceivable manner. On Plate 26 are given illustrations, showing the combination of a *plus* quadrantal curve, with polar magnetism towards ship's bow and towards ship's stern; with a polar force of the same amount to starboard of ship's bow, and with the same polar force to the starboard side. These are projected by Napier's method; on Plate 27 they are represented on rhumb lines with the same details.

With the exception of one or two cases of elevated compasses, the whole of the deviation tables which have been obtained in Liverpool by the committee have exhibited *plus* quadrantal attraction. Perhaps a *minus* deviation of this kind would be found to exist in a compass placed within a skylight, in which the iron deck beams are cut off on each side of it, or in an iron ship with wooden beams.

Having now given an account of a portion of the more general inquiry, and some deductions which appear to arise from it, the committee proceed to the following practical topics:

I. Errors induced by heeling, in iron ships.
II. Elevated or mast and standard compasses.
III. Modes of swinging ship.
IV. Modes of adjusting compasses.
V. Projection of deviation tables by curves.
VI. Miscellaneous operations of the committee.

I. *Errors arising from the heeling of iron ships.*—These are among the most perplexing which demand a captain's attention. As a number of causes may conspire to produce, modify, or cancel their effect, it is not surprising that the evidence before the committee on this branch of the investigation is yet very incomplete.

Among such causes may be named the following:

a. The rising or lowering of the attracting mass, causing its magnetism to act with more or less leverage as it approaches to or recedes from the plane of the campass card.

b. Vertical iron or magnets below and near the compass.

c. Induced vertical polarity in iron deck beams, increasing as they incline from their usual horizontal position.

d. Proximity of badly proportioned and badly placed chain-boxes.

e. Action of horizontal compensating magnets when they are placed below and too near the compass card.

The last, though partially corrective of some errors from heeling, in certain positions of the ship, appear to aggravate them in others.

The three first-named causes may be described as tending to attract the north end of the needle to the weather side of the ship in north magnetic latitude, and to leeward in the south magnetic hemisphere, and as increasing or decreasing the usual deviations, according to their name and the direction of the ship's head. These three may act in the same direction and in the same ship. It is difficult to estimate their separate effects, but the last is supposed to be most prejudicial. The great expense attendant on heeling and swinging ship in port, and the delay caused by such an experiment, where every hour is valuable, have prevented the committee from directly testing this. Deductions can only be made, therefore, from the evidence afforded by various captains and an inspection of the arrangement of the iron near the compasses of their respective ships.

Evidence from a number of captains shows—

1. That in a large proportion of iron ships the compasses are affected by heeling.

2. That errors from heeling are generally most complained of when ships are on or near four-point courses.

3. That when iron ships have heeled over for a considerable time upon northerly courses, they have been found to windward of their dead-reckoning.

To these may be added the existence of an impression among compass adjusters and others who have paid attention to the subject, (among the latter may be named the managing owner of the Cunard Company, Mr. Charles M'Iver, a gentleman of great experience in iron ships,) that iron deck beams are a chief cause of compass disturbances.

The following may also be quoted from a number of other causes:

Captain Bonfellow, of the steam-ship "Laconia," states that the same course which, with an even beam, would make the Smalls from the coast of Spain, with wind at N.W., would make the Tusker to windward, and on the opposite side of the Irish channel.

The captain of the "Sarah Sands" states, that his compensated steering compass has acted remarkably well, except when his vessel has heeled to some extent. This compass is placed over and comparatively near large masses of vertical iron.

Captain Leitch, of the "City of Baltimore" steamship, has favored the committee with observations made during several voyages. In every instance the north end of the needle has been attracted to the high or weather side of the ship. This is the most extreme case which has been recorded. From slight list to starboard to slight list to port, the standard compass, placed about five feet above the deck-house, has been observed to change eight degrees. The apparent cause is the iron beams of the deck-house.

There seems reason to suppose that when the deck beams are divided to make space for a skylight, a position for a compass may be found in which the errors from heeling might naturally compensate each other. The errors from vertical induction of deck beams would certainly vary with change in geographical position, or with the earth's vertical intensity. Thus, in the "City of Baltimore," Captain Leitch mentions variations in the deviation of three-quarters of a point while his ship was in the Mediterranean, but in the North Atlantic, as he approached America, he has noticed an extreme instance of more than a point and a half.

The committee are anxious to collect all the information possible on this intricate and important section of the Compass Inquiry, as it is felt how very imperfect must be any deductions which may be made from the evidence which has to this time been placed before them.

II. *Elevated or mast and standard compasses.*—Great variety of opinion prevails as to the utility of mast compasses. Though in some ships they have been discontinued after a trial, their use is becoming very general. Several examples were given in the last report to show that they were not always free from a considerable amount of error. Many others could be quoted, especially those belonging to ships built with their heads to the south. In moderate weather and large ships, mast compasses are stated to act well; but in small ships, where the motion is greater, the oscillation prevents their being of service, except in fine weather. In nearly every case they show an attraction to ship's head in north magnetic latitudes, (giving east deviation with ship's head east, and west deviation with ship's head west, *taking ships to the south of their course,*) and very little quadrantal deviation. The usual *plus* quadrantal deviation is found to decrease as the compass is carried aloft, and is believed, in some cases, to change to *minus* quadrantal after a certain elevation is attained. The effect of the transverse iron, and iron placed before and aft the compass, appears to be cancelled, and in some cases exceeded, by the action of the ship, as a long bar placed below the compass.*

* Here, as in some other parts of the report, when the action of iron beams is alluded to, statements are made which appear to contradict a portion of the "Supplement to the Practical Rules," printed for the Hydrographic Office, in which it is stated, that iron deck beams, if continued from side to side, give a negative value to the quadrantal deviation, and that, if interrupted by a hatchway, they may give it a positive value. This statement

III. *Modes of swinging ship.*—Undoubtedly the easiest and best mode of ascertaining the deviations of a compass is by reference to the bearings by it of a distant object, whose true magnetic direction is known; but in a river or a confined dock, such distant object is seldom attainable. Next to this, the committee approve of the system of fixed magnetic bearings of a conspicuous object, which has been adopted at this port. (See printed description, Plate 3.) The principle is the same as that of reciprocal bearings, with the two advantages of freedom from error in the shore compass, and saving the time usually lost in repeating and deciphering the shore signals. There is another mode sometimes adopted in Liverpool and at other places—that of carrying the shore compass round the dock, so as always to be in a line with the ship's masts, and, by preconcerted signals, checking the ship as she approaches the true points of the compass. This plan does not admit of accuracy, even when pains are taken to insure it. To an adjuster who understands his business it must be tedious, while in the confined situations, in which only it can be employed, the shore compass is liable to varying disturbances, which give rise to most inconsistent tables of deviations. In some cases in this port it has occasioned serious errors. In one case, an uncompensated steering compass was made to have east deviation on every rhumb. Two examples are given to show the effect of error in the shore compass, but neither of them extreme cases. (See "Sappho" and "Mexicana," Plate 28, also "Royal Charter," Plate 13.)

IV. *Adjustment of compasses.*—Much difference of opinion has existed, not only as to the modes of adjustment, but also as to the propriety of attempting it mechanically in any way. Although this question may be considered as settled in practice, the committee have not failed to give it their careful attention.

It is believed that in only one instance which requires to be named, besides that of the Royal Navy, is magnetic compensation dispensed with in iron ships, and that is in a line of steamers plying north and south for 1,200 miles on each side of the magnetic equator, on the west coast of South America. The experience of the committee proves, that magnetic compensation is seldom so perfect as to dispense with the necessity for a table of deviations even in short voyage ships, while in ships making long voyages the change is frequently so great as to make a deviation table worthless, except for first clearing the land. This is more especially the case with steering compasses; and here the inconvenience complained of is as often want of *directive power* in the needle as

is probably an oversight, as the reverse follows from premises laid down in an earlier page of the same book. It is certainly a mistake. (Since the above was written, Mr. Rundell has communicated with the talented author of this work, Mr. Archibald Smith, who states, in reply, that the words "negative" and "positive" have by mistake been substituted for "positive" and "negative.").

the extent of the deviation or the difference between the indications of this compass and the standard. In almost all iron ships which sail round the Cape of Good Hope, perhaps in all which reach 40° south latitude, and 40° east longitude, complaints are made of this. In the "Great Britain," a temporary steering compass had to be fitted much higher than the one commonly used. In the "Sarah Palmer," the binnacle compass was quite useless, and a "vertical compass" fixed on the top of a companion, about seven feet above the poop, had to be fitted with lanterns, so as to steer by it instead. Reports of seven or more points of deviation are not unusal from ships traversing this part of the world. After deduction has been made for variation of the same name being included with the deviation, as may sometimes be the case, sufficient remains to show that upon some courses the earth's directive power must be most materially diminished. Statements of a similar kind have been made respecting some of the North American steamers. In both localities, the earth's directive or horizontal force is small, and when it is further reduced by the opposition of the ship's magnetism, it will readily be seen how weak must be the directive power which remains. Slight causes will then turn the needle aside, or a small roughness of the agate or bluntness of the pivot will prevent the card from traversing freely, perhaps from moving at all, until it is entreated at a large angle; and then, by resting on the other side of the magnetic meridian, a report might next day arise of a sudden derangement of the compass, from the ship being found forty or fifty miles on one side of where she was expected to be.

The want of directive power on some courses in uncompensated compasses is thought to be the strongest argument in favor of mechanical adjustment. Full information on this portion of the Compass Inquiry will not be available for some months. In the meantime, the committee's experiments on board the "Royal Charter," with the deviations for her compasses obtained at Melbourne by the Rev. Dr. Scoresby, will afford some interesting data. The large diagram, Plate 14, gives a general view of the deviation curves of the compasses, placed in different parts of this ship, at different times. All show the characteristic forms of the curves obtained in ships built with their heads to the north and west. In the table opposite Plate 14 are given the magnetic co-efficients, obtained by analysis of the deviations here represented, by Mr. Archibald Smith's method; also, the corresponding values of the transverse and fore-and-aft attractions of the ship for the position of each compass in terms of the earth's horizontal force. These are taken by inspection from Mr. Airy's table of polar magnetic deviations, and the resultant force and angle of direction are taken to the nearest degree from a traverse table. As the horizontal force of the earth at Melbourne is greater than at Liverpool, by 167 to 100, the deviations obtained there by Dr. Scoresby have been "reduced to Liverpool measure."

The tables opposite Plate 15 have been arranged so as to contrast the deviations of the two compensated compasses with those of the Admiralty standard compass, both with and without magnets. After averaging the results of the three sets of experiments (not the most favorable mode of comparison for compensation by magnets,) the ratios are:

For the steering compass......	21 : 12		
" companion compass......	24 : 22	in favor of compensation.	
" Admiralty compass......	26 : 23		

Even without any attempt to correct the original adjustment; and this in a new ship, one, therefore, subject to extreme changes.

It is worthy of notice, that adjustable magnets were fixed to the steering compass, but their position was not altered during the voyage, and most fortunately so, for otherwise the comparison could not have been so perfect. The result shows, that had the compensating apparatus been employed, as was intended, the whole of the adjustment which was required is the following: 1. To screw the fore-and-aft magnets a fraction of an inch nearer the compass card at Melbourne, and to screw them back again a little as the ship returned to Liverpool. 2. To screw the transverse magnet (which was rather above the middle of its containing box) gradually lower and lower through the whole of the voyage, until the ship's return to Liverpool, when it would probably be at the bottom of the case. Simple as this appears, it would thus have been possible to keep the steering compass correct, and to give the needle the full effect of the earth's directive power. This is possibly an extreme case, and the relatively small change in the steering compass may be due to its position so far forward as in front of the mizzen mast. In another instance of a compass placed very near the stern post of an iron sailing ship, where the adjustable magnets were also applied and actually used, the following movements took place: The three fore-and-aft magnets had to be gradually removed as the ship went south, and afterwards two were required placed the reverse way. In this condition the ship rounded Cape Horn. Before reaching Valparaiso, one of these magnets was again removed. On the homeward voyage, one fore-and-aft magnet, placed in the original direction, was sufficient while within the tropics, and another was required on reaching 40° north. Only one transverse magnet was in place when the ship left Liverpool. While in the southern hemisphere, a second was required in the same direction. On the ship's return, one magnet athwart-ship was found to be sufficient, but it had to be screwed to its highest possible position in the case. In the previous voyage (the ship's first,) before the captain knew how to use his adjusting magnets, the deviations were so excessive that he had to remove the magnets altogether.

Though the various modes of compensation now in use are mostly founded upon the experiments and instructions of the Astronomer Royal, the committee regret to find that several modifications are made by adjusters, which appear defective and in some instances liable to produce much mischief. Some adjusters omit the chain box, or soft iron compensation for correcting the horizontal induced magnetism of the ship, and thus ignore the quadrantal deviation altogether. If tables of deviation were always given, this would not be of much moment, but captains are sometimes led to believe that the adjustment is complete without it. Others attempt compensation who appear quite ignorant of its nature, and make vain efforts to correct a ship's attraction with permanent magnets only. Possibly the deviation curve at Plate 28, (No. 1) may afford an illustration. The card of deviations from which it was projected was given to a captain, who appeared much pleased with it, and highly praised the adjuster for putting the vessel round three times, *so as to ensure accuracy.*

An inspection of the curve at once shows that it is an improbable one, and occasions the doubt whether it may not be a bit of patchwork, made up from each of the three swingings. A trial made in the river before the ship left port, the result of which is given upon the same diagram, appears to confirm the suspicion.

Theory and practice combine to prove, that when the chain-box compensation is once properly applied, no further change in it is required whatever be the voyage, and the committee feel confidence in expressing the opinion that it should never be neglected. The chain-boxes at present in use are seldom large enough to correct more than 3° or 3½° of quadrantal error. They may with advantage be made of twice their present length. The increased length would also tend to correct a portion of the errors which generally arise from heeling.

In many cases, the committee have observed the use of oblique, inclined, and vertical magnets, in positions which must necessarily produce large errors when the ship heels. In one instance an error of four points was reported from this cause. The committee object to the *ordinary* use of any but the horizontal compensating magnets, and would always have them placed fore and aft or athwart ship—not only for the reasons already stated, but also because the oblique positions render any attempt at change while at sea by the captain more difficult, and make his attempts at compensation in the same way almost hopeless.

Horizontal magnets, if placed *near* and *below* the compass bowl, may also have an injurious action, and possibly have given rise to some of the fluctuations in the deviations recorded of some floating compasses. One captain, when spoken to on the proximity of a compensating magnet to his steering compass, said, he observed when it was first fixed how a small difference in its position affected the compass needle; yet, he stated, as a matter worthy of attention, that on one occasion when water from a rusty tank was used to float the compass bowl, the rust in the water so changed his deviations that he was obliged to take it out again. It had not occurred to him that the difference in the level of the bowl might have been the real cause. In this, as in many similar instances, the facts may be accepted when the explanations or alleged causes are inapplicable. When circumstances will not admit of the compensating magnets being placed a sufficient distance below the compass they should be fixed on the same level as the card.

V. *Projection of deviation tables by curves.*—The projection of deviation curves has been recommended as a means of obtaining a table of probable errors on every point of the compass from observations made from a few points only. Napier's method of projection, or the modification of it by Captain Ryder, Royal Navy, is also extremely valuable for converting *compass courses* into *magnetic courses*, or the reverse. Sufficient attention to this, or even the knowledge that it is necessary, is exceedingly rare in the merchant service. Few captains or compass adjusters appear aware that considerable difference may exist in the deviation between ship's head by compass and ship's head true magnetic on the different points of the compass. It is neither taught to them or noticed in any way in the examination for a certificate of competency. In many deviation tables it is left to be gussed whether "*ship's head by compass*" or "*ship's head true magnetic*" is intended. In nearly every instance they are given for "ship's head true magnetic," the reverse of the practice of the Royal Navy.

The projection of deviation curves is also useful to the initiated, for the purpose of testing the probably accuracy of the observations, and the care which has been taken in swinging ship. Some examples of this have already been given, and others are appended. No. 1, on Plate 29, may be taken as an instance. On noticing that the west deviations very much exceeded the east deviations in amount, while the curve showed general symmetry, it was conjectured that the "lubber line" was not towards ship's head. Examination proved this to be the fact, and showed that the binnacle (*as in many other cases*) was only secured by lanyards, and that through these having become slack the "standard bridge compass" was "considerably slewed." It proved, too, that the ship had been swung with the binnacle in this position, and that she had so made the voyage from Bristol to Liverpool. This was also confirmed by a second swinging under the direction of the committee, the result of which is exhibited on the same diagram. Though this careless mode of fixing a standard compass was pointed out to the captain, and he immediately gave directions to the carpenter to secure it with wooden cleats, the ship left England for the first time without its being attended to, further than by "taking in the slack" of the lanyards. Similar cases have been observed. Compass records from such ships are entirely valueless.

VI. *Miscellaneous operations.*—Among the miscellaneous operations of the committee during the past year may be noted the distribution of circulars conveying information as well as asking for it. Copies of some of these, with new additions of old ones, are appended to this report. The committee have also examined as far as possible all new inventions relating to the compass or compass management, and have considered various suggestions for facilitating the detection of compass errors at sea. Some of the former will require notice in a final report, and of the latter, one which promises to be of much use, will probably be published by the committee in the course of a few weeks.

No remarks have been made upon the changes in the magnetism of iron ships produced by collisions at sea. Records of one or two cases have been obtained, and the attempt has been made to get others. It is difficult to obtain reliable evidence—not so much personal as respecting the previous condition of the ship's compasses. In some instances iron work so near as to influence the compass has been carried away; in others the vessels have been in sight of port and the compasses were not noticed, while considerable repairs and alterations have been made before the ships again went to sea. In another case the steamer went her usual voyage in foggy weather after the collision, and nothing amiss was observed. Another steamer, ever since the collision by which an iron sailing ship was sunk, has been lying alongside other iron vessels, and the captain can offer no information. Under these circumstances, any observations on this department of the inquiry must be postponed for the concluding report.

The Liverpool Compass Committee have now endeavoured to present to your Lordships the results of their observations to the present period. Long as is the statement, compared with the limits to which they might wish to condense it, they know that it is yet deficient in one or two important particulars. To these slight allusion must be made, although it is believed that a better and perhaps more satisfactory view of one portion of the subject could be obtained in six months by the action of the Board of Trade, than the committee could hope to gain in a much longer period. There is more than an appearance of unfairness in a number of private individuals requesting copies of deviation tables and information of this kind from compass adjusters and others, and then using the information thus kindly granted to prove the incompetence or carelessness of some of the donors. Compass adjusters, the competent and incompetent alike, already suffer from imputations which do not attach to them.

A sufficient degree of information on this intricate subject can scarcely be expected at present from the merchant captain, or he might superintend and control the operations of swinging ship and adjusting compasses in the same way as he does any other duty which devolves upon him. Even where an interest is felt in the subject, the great demand on a captain's time, at the busy period of fitting for sea, usually prevents him from doing more than inquire the errors on one or two particular courses, and to charge the adjuster "not to compensate her too much," as he does not like "too much compensation." As to the general distribution of the ship's magnetism, or the real nature and direction of the force which will be constantly pulling at his compass needle, perhaps, neither he nor the compass adjuster has any adequate conception. In some cases the captain will stand by in a sort of selfish spirit and see that everything is done which the compass adjuster requires, but will abstain from making any remark or expressing an opinion, so that, if perchance anything goes wrong afterwards, the whole of the blame may be thrown upon the adjuster; or if this expression be too personal, that the fault may be placed upon "the compasses."

Until masters are competent to attend fully to the subject, some kind of authoritative supervision in this matter would undoubtedly be beneficial, but the committee confine themselves at present to showing how proof of this may be obtained. Copies of all deviation tables which may be given both for adjusted and non-adjusted compasses; particulars as to the number, direction, and distance of the magnets which may be applied for the compensation; and the amount of original error on two cardinal points, 90° apart, would afford ample information, to any one competent to examine such returns, on nearly all that requires to be known on this part of the subject. Information somewhat of this kind was collected for a short period by Mr. Towson of the Local Marine Board, and Mr. Hartnup of the Liverpool Observatory, under authority from the Board of Trade.* From such data correct inferences may be drawn as to—

1. General ability of the adjuster.
2. Whether the ship was properly swung.
3. Approximate amount and direction of ship's magnetism at the position of each compass.
4. To what extent compensating magnets are placed in positions which are known to produce great and variable errors on the heeling of the ship.
5. By returns from the same ship each time she is swung or re-adjusted; information as to the changes which may occur in her magnetism.

Returns similar to those which have been suggested can cause no delay, or in any way interfere injuriously with the captain, the merchant,

---

* See copy of one of these forms, as filled up for the S. S. "Calpe," at page 46.

or the shipowner, while they would afford some sort of guarantee to each that an important subject is being adequately cared for. It must also be evident that occasionally, in cases of accident, these records would afford valuable evidence.

In conclusion, the members of the committee have to inform the Board of Trade of their intention to close their labours in the course of the coming summer. At that time they hope to be able to furnish some further information on the two most difficult parts of the inquiry—the changes of deviation produced (1) by heeling, and (2) by change of magnetic position while at sea in iron ships. Already they have been favoured with some valuable records on this topic. Dr. Scoresby's observations and experiments during the voyage of the "Royal Charter," to and from Melbourne, are also expected to be available very shortly. Several most intelligent captains now at sea are making observations for the committee. To these they would gladly add some projected experiments to be made at sea with the vibration needle, which appear necessary to complete the compass investigation. It is thought that suitable experiments by their secretary, who has gained much experience and facility by conducting the local investigation for the committee, if made on board two of the iron steamers trading to Alexandria from this port, would afford the requisite data in the shortest and easiest manner. Steamers are proposed as showing the effect of new magnetic conditions more rapidly than sailing vessels, and it is considered that two built in widely different directions should be selected. The voyage to Alexandria is named as the shortest compatible with the requisite magnetic range. Taking the values adopted by Gauss in his *Atlas des Erdmagnetismus*, it is seen that the earth's vertical intensity, on which chiefly the change in the ship must depend, varies from about 1,300 at Liverpool, to 650 at Alexandria, or as 2 to 1. The horizontal intensity, which governs the amplitude of the deviations to be observed, varies from about 450 at Liverpool to 900 at Alexandria, or as 1 to 2. Both these ratios combine to produce a maximum effect on the deviations of the compass in this voyage. Whether this project will be carried into effect must depend on the aid which may be afforded by your Lordships; as unless the committee are favoured with a repetition for the present year of your annual grant, the investigation must close at midsummer with a discussion of the returns before alluded to. If the final report should be thus incomplete, they yet hope that, under the numerous difficulties which have had to be contended with, it will be found trustworthy and as complete as under the circumstances could reasonably be expected.

No arrangement has yet been made for publishing a general report of the proceedings of the committee. On this point its members will be much influenced by any action which my Lords of the Council for Trade may think fit to take on the compass question, and more particularly in reference to their disposal of the report which is now most respectfully submitted to their attention.

Signed on behalf of the committee,

THOS. BROCKLEBANK, *Chairman*,

LIVERPOOL, *February* 1857.

APPENDIX No. 1.

Letter from the Astronomer Royal addressed to Mr. W. W. Rundell, Secretary Liverpool Compass Committee, on the Magnetic Changes of "Royal Charter" during her Australian Voyage in 1856.

ROYAL OBSERVATORY,
Greenwich, October 2, 1856.

MY DEAR SIR: Business of the observatory has prevented me, for some time, from examining the observations of the deviations of the standard compass in the "Royal Charter," which you were so kind as to send me. I have, however, now taken them up, and find the following results:

1. Quadrantal deviation—

Liverpool,	1856,	January	+ 6° 40′
Melbourne,	"	May	5° 50′
Liverpool,	"	August	5° 51′

These agree well with each other, and with the values which you have deduced. Their magnitude shows that the use of a mass of soft iron, to produce correction of the quadrantal deviation by its transient induced magnetism, must never be neglected. In this instance it would have left an uncertainty of 12°. I fear persons who correct compasses have been too much in the habit of omiting this.

2. Ship's subpermanent magnetism towards the head (estimated in absolute measure in Gauss' manner, the units of measure and weight being the English foot and English grain.) Whole horizontal force of terrestrial magnetism at Liverpool = 3.54; at Melbourne = 5.94.

Liverpool,	1856,	January	— 0.199
Melbourne,	"	May	— 1.147
Liverpool,	"	June	— 0.106

3. Ship's subpermanent magnetism towards the starboard side, similarly estimated—

Liverpool,	1856,	January	— 1.156
Melbourne,	"	May	— 0.895
Liverpool,	"	August	— 0.206

The value of these numbers will, perhaps, be best understood by remarking, that at Liverpool a deviation of 1° will be produced by .062 in either of these magnetisms; at Melbourne a deviation of 1° will be produced by .104.

It appears, therefore, that the ship's magnetism (subpermanent) has diminished in both parts of the voyage; the fore-and-aft magnetism has diminished very uniformly; the transversal magnetism has diminished more in the second or homeward part of the voyage than in the first or outward part.

Perhaps you may think fit to communicate this, with my best wishes for their success, to the Liverpool Compass Committee.

I am, &c.,

G. B. Airy.

APPENDIX No. 2.

PAGE ______.

Form to be filled up by the person employed to correct or to determine the deviation of the standard compass of *Screw Steamship "Calpe."*

One compass shall be permanently placed on the midship fore-and-aft line of the vessel. This compass is to be regarded as the standard compass.

When the compass has had its deviation determined, as directed below, no compensation for deviation is to be made; nor must any alterations be made in any previous compensation until twenty-four hours' notice has been given to ______________________, nor until the deviation has been determined on three or more of the following points:

N.___ N.E.___ E.___ S.E.___ S.___ S.W.___ W.___ N.W.___

If the compass be compensated, state—

1. The number of magnets, if employed for that purpose	5.
2. Their length	30 *inches.*
3. When last magnetized	*October*, 1852.
4. The angular position of each magnet with regard to the direction of the ship's keel	| | | — o *ship's head.* —
5. The description of soft iron, if used	
6. The length of box containing the above	
7. The breadth of box	*No chain-boxes.*
8. The depth of box	
9. The distance of the centre of the box from the deck	2 *feet* 5 *inches.*

Under all circumstances, state—

The distance of standard compass from the deck	2 *feet* 5 *inches.*
Whether above or below	*Above.*

Also fill up the following table, to at least each alternate point, with the deviation determined by actual observation, after the final compensation has been adjusted, if any plan of compensation has been adopted:

Form—Continued.

Ship's head.	Deviation.	Ship's head.	Deviation.
North	N.	South	*True.*
N. by E.		S. by W.	
N. N. E.	3 N.	S. S. W.	2 S.
N. E. by E.		S. W. by S.	
N. E.	4 N.	S. W.	3¼ S.
N. E. by E.		S. W. by W.	
E. N. E.	2¼ N.	W. S. W.	3¼ S.
E. by N.		W. by S.	
East	*True.*	West	*True.*
E. by S.		W. by N.	
E. S. E.	*True.*	W. N. W.	5 N.
S. E. by E.		N. W. by W.	
S. E.	1 S.	N. W.	6 N.
S. E. by S.		N. W. by N.	
S. S. E.	*True.*	N. N. W.	3¼ N.
S. by E.		N. by W.	

When the deviation has been determined by the bearing of a distant object, state—

The name of the object ____________

The distance ____________

Its bearing by standard compass on shore ____________

When the deviation has been determined by reciprocal bearings, the table on the other side of this paper must be filled up.

Taken at *Liverpool,* (Signed) *John Gray.*
23 day of *Decr.,* 1852.

Bearing of a distant object by the compass to be used on shore ____________

Bearing of the same object by the standard compass on shore ____________

Form—Continued.

Ship's head by the standard.	Bearing of the shore compass from the standard compass.	Bearing of the standard compass from the compass on shore. Observed.	Bearing of the standard compass from the compass on shore. Corrected for the difference of the compasses.	Deviation of the standard compass.
North				
N. by E.				
N. N. E.				
N. E. by N.				
N. E.				
N. E. by E.				
E. N. E.				
E. by N.				
East				
E. by S.				
E. S. E.				
S. E. by E.				
S. E.				
S. E. by S.				
S. S. E.				
S. by E.				
South				
S. by W.				
S. S. W.				
S. W. by S.				
S. W.				
S. W. by W.				
W. S. W.				
W. by S.				
West				
W. by N.				
W. N. W.				
N. W. by W.				
N. W.				
N. W. by N.				
N. N. W.				
N. by W.				

"LALLA ROOKH."

(Iron sailing ship, 1,000 tons, built head easterly.)

Table showing deviations of a compass placed in different positions between the steering apparatus and first skylight on poop deck, with relative proportion of ship's force to that of the Earth. (Earth's horizontal force = 1.) Ship's head to magnetic north.

[Needle's vibrations on shore = 20 per minute.]

	No. of observation.	Deviation.	Vibrations per minute.	Value of force acting on needle.	Ship's force to stern.	Ship's force to starboard.	Total ship's force.	At angle from stern.
At 3 feet from deck	*a*	75° E.	13.16	.435	.97	.42	1.06	23½°
	b	58	14.2	.504	.73	.43	.85	31
	c	52	15.26	.585	.64	.46	.79	36
	d	47½	16.28	.663	.55	.49	.74	42
	e	45½	15.66	.616	.57	.44	.72	38
	f	43½	16.	.64	.54	.44	.70	39
	g	43½	16.	.64	.54	.44	.70	39
	h	32¾	13.5	.456	.62	.25	.67	22
	i	37	15.5	.601	.52	.36	.64	35
	j	39	16.3	.664	.58	.42	.64	41
	k	40½	16.1	.648	.51	.42	.66	39½
	l	58½	17.5	.766	.60	.65	.88	47½
	m	50	....	....	....	....	....	....
	n	43½	....	....	....	....	....	....
	o	41½ E.	....	....	....	....	....	....
At 4 feet from deck	*a'*	63 E.	13.76	.476	.78	.42	.89	28½
	c'	44½	15.33	.587	.58	.41	.71	36
	e'	41	16.16	.656	.51	.43	.67	40
	g'	38	16.66	.697	.45	.43	.62	43½
	h'	21¾	13.44	.450	.58	.16	.60	16
	i'	29	15.26	5.85	.49	.28	.57	30
	j'	31½	16.	6.40	.45	.33	.56	36
	k'	33	16.28	.664	.44	.36	.57	39
	l'	53	17.84	.792	.52	.63	.82	50
	m'	46½	17.1	.731	.50	.53	.73	47
	n'	41½	16.88	.714	.47	.47	.67	45
	o'	37 E.	16.78	.705	.44	.42	.615	43½

The experiments exhibited above are also shown graphically on Plate 5.

EXPERIMENTS ON BOARD THE "NAUPHANTE."

As the table of experiments on Plate 6 may require some explanation, the following is appended:

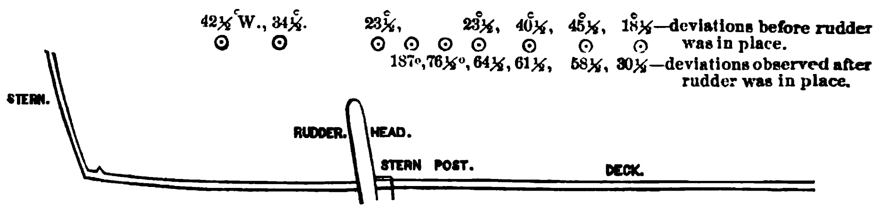
In the upper part of the table are given—

First. The deviations observed at regular distances from the front of the stern post, and at the heights above the deck which are stated in the first column, at three different periods, when the ship was nearly ready for launching, viz: before the rudder was in place, immediately afterwards, and before the rudder plates were all riveted; again when the riveting was completed.

Second. Observations made at the same stations after the ship was launched.

These show the dominant action of the stern post and vertical iron near the stern, on a binnacle placed very near to them; also, how much the deviation of the compass is increased by the rudder, not only by its own magnetism, but by conveying up the magnetism of this part of the ship to where it can act with greater leverage. Thus, at 1 foot 8¼ inches above the deck, and at the stations indicated in the following diagram, the deviations, with and without the rudder, were as under:

Fig. 2.



The next experiments were made the day after the ship was launched, August 20, ship's head westerly; and again September 1. As this was the opposite direction to that of the ship upon the building-slip, no direct comparison can be made.

On September 3, however, the owner, Mr. Cotesworth, at the request of the committee, had the vessel turned round. Reference to the table against this date and September 4, will show that a great reduction in the magnetism of the ship had taken place, and particularly in the sides of the ship. Notwithstanding the reduction in the attraction aft, it now balances the attraction forward at fourteen feet from the stern post, while on the building slip it could only balance it at six feet. (See curves on the diagram at the top of Plate 6.) The lines of no deviation, which these experiments exhibit, show by their peculiar curvature, that that a large portion of the disturbance is due to iron that is *very near to the compass.* (See also, experiments on "Lalla Rookh," Plate 5 and preceding page.)

Next, if we examine the deviations observed while the ship was head to south in the graving-dock, a position favorable to the reduction of the attraction aft, it will be seen that, between September 3 and September 17, such reduction really took place, as is shown by the increased deviation to starboard.

STEAM SHIP "GREAT BRITAIN."

DEVIATIONS OF COMPASS OBSERVED IN THE SANDON GRAVING-DOCK, No. 2.

Port side.—January 24, 1856.

a	30½ E.	28¾ E.	22½ E.	15 E.	4¾ E.	1 W.	5½ W.	6¾ W.	11 W.	10¾ W.	8½ W.	7½ W.
b	(25½ E.)?	10 E.	5½ W.	14½ W.	21 W.	25½	25½	24	22½	20	15	7½
c	7½ E.	6½ W.	20 W.	31½ W.	31½ W.	38¾	34½	33	29	23	17	12
d	1 W.	17 W.	28½ W.	38½ W.	43 W.	43 W.	38 W.	34½ W.	29½ W.	24 W.	18 W.	7½ W.

Port side.—December 10, 1856.

a	....	....	....	....	....	....	....	....	....	....
		19.5 E.	15.5 E.	2.5 W.	5.0 W.	9.5 W.	14.5 W.	15.0 W.	16.5 W.	7.5 W.
b	....	14.5 E.	6.8 W.	11.8	17.5	....	21.0	21.0	19.6	
c	5. E.	14.5 W.	25.0 W.	39.0	40.0	....	35.8	33.5	25.0	{11.5 / 12.5
d	9. W.	22.8 W.	32.5 W.	44.0 W.	45.0 W.	....	38.0 W.	35.5 W.	27.8 W.	13.5 W.

Port side.—December 12, 1856.

a	22.0 W.	13.3 W.	6.1 W.	5.3 W.	8.2 W.	5.5 W.	4.5 W.	6.9 E.	7.0 E.	9.2 E.
b	17.5 W.	4.5 W.	2.2 E.	5.8 E.	5.5 E.	6.5 E.	7.3 E.	16.4	19.7	16.1
c	0.6 W.	14.5 E.	27.5 E.	36.0 E.	43.9 E.	48.8 E.	47.1 E.	44.2	40.8	35.5
d	6.8 E.	23.0 E.	35.5 E.	44.3 E.	55.0 E.	62.8 E.	62.2 E.	56.5 E.	52.5 E.	47.0 E.

Port side.—January 6, 1857.

a	22.3 W.	12.7 W.	5.2 W.	5.2 W.	5.3 W.	6.5 W.	3.0 W.	3.6 E.	6.5 E.	8.0 E.
b	18.1 W.	3.2 W.	3.2 E.	7.3 E.	7.7 E.	6.2 E.	8.0 E.	15.0	17.7	15.2
c	0.8 E.	15.7 E.	27.7 E.	37.2 E.	48.4 E.	49.5 E.	44.5 E.	43.2	41.5	35.1
d	9.4 E.	26.8 E.	35.5 E.	44.7 E.	58.5 E.	63.8 E.	60.5 E.	55.3 E.	50.5 E.	47.5 E.

Port side.—January 24, 1857. (*Screw in place.*)

a	22.5 W.	11.1 W.	4.5 W.	4.5 W.	5.5 W.	5.5 W.	4.7 W.	2.5 E.	6.3 E.	10.0 E.
b	14.7 W.	3.8 W.	2.3 E.	8.0 E.	9.0 E.	7.2 E.	6.9 E.	12.3	15.5	14.2
c	1.8 E.	18.5 E.	28.0 E.	38.0 E.	47.3 E.	50.5 E.	45.0 E.	41.5	41.4	35.4
d	14.2 E.	27.5 E.	35.5 E.	46.2 E.	59.9 E.	65.5 E.	60.0 E.	54.5 E.	51.0 E.	46.5 E.

DEVIATIONS OF COMPASS OBSERVED ON THE STARBOARD SIDE.

Starboard side.—January, 1856.

d′	....	9 E.	20 E.	46 E.	64½ E.	69½ E.	65 E.	62½ E.	54½ E.	....	46½ E.	25½ E.
c′	12 W.	3 W.	3½ E.	22½ E.	38½ E,	51¾ E.	51½ E.	51	47½	40½ E.	33	21
b′	(21 W.)?	17½ W.	12½ E.	2 W.	5½ E.	12½ E.	20½ E.	25½	31½	29 E.	24	17½
a′	24 W.	25½ W.	22½ W.	19½ W.	17½ W.	14 W.	8½ W.	1 E.	9 E.	13 E.	10¾ E.	11½ E.

Starboard side.—December 10, 1856.

d′	15.0	5 E.	31.0 E.	63.5 E.	71.5	64.5 E.	60.5 E.	....	51.5 E.	32.0 E.
c′	3.0	5 W.	13.5 E.	39.5 E.	51.5 E.	53.5 E.	52.0 E.	....	44.3 E.	25.5 E.
b′	....	....	....	....	....	....	....	....	....	....
							11.0 E.	15.5 E.		
a′	....	....	....	....	....	....	....	....	....	....

Starboard side.—December 12, 1856.

d′	1.2 W.	11.2 W.	15.4 W.	22.7 W.	31.3 W.	36.6 W.	36.0 W.	33.3 W.	31.3 W.	31.0 W.
c′	7.5 E.	5.6 W.	18.3 W.	19.7 W.	27.0 W.	29.9 W.	28.7 W.	27.5	26.5	25.6
b′	22.3 E.	13.0 E.	4.8 E.	1.7 W.	3.4 W.	4.4 W.	5.4 W.	10.8	12.0	14.2
a′	29.0 E.	21.1 E.	12.9 E.	11.5 E.	11.7 E.	11.0 E.	7.5 E.	2.0 W.	4.6 W.	7.1 W.

STEAMSHIP "GREAT BRITAIN."—Continued.

Starboard side.—January 6, 1857.

d′	1.2 W.	9.5 W.	16.0 W.	23.5 W.	32.2 W.	38.5 W.	35.7 W.	33.3 W.	31.5 W.	31.3 W.
c′	3.9 E.	5.1 W.	12.5 W.	20.8 W.	28.3 W.	31.2 W.	27.6 W.	26.5 W.	26.1	25.7
b′*	....	....	....	3.7 W.	5.2 W.	5.8 W.	4.4 W.	9.7 W.	13.7	14.1
a′*	....	....	....	10.3 E.	11.4 E.	11.2 E.	9.4 E.	1.5 E.	4.5 W.	5.0 W.

* The screw, and other large masses of iron near these stations, prevented the deviation being observed.

Starboard side.—January 24, 1857. (Screw in place.)

d′	5.5 W.	11.3 W.	17.3 W.	24.0 W.	35.5 W.	38.5 W.	36.0 W.*	32.1 W.	31.0 W.	29.5 W.
c′	1.9 E.	7.4 W.	13.1 W.	21.5 W.	27.5 W.	32.5 W.	28.7 W.*	26.3 W.	26.5	25.8
b′	17.5 E.	11.5 E.	2.5 E.	4.5 W.	4.0 W.	6.5 W.	4.5 W.*	8.0 W.	13.2	14.8
a′	24.5 E.	19.3 E.	12.5 E.	10.0 E.	10.0 E.	8.5 E.	9.4 E.*	2.4 E.	4.3 W.	4.8 W.

* An iron cannon near this station.

VIBRATION EXPERIMENTS WHILE THE SHIP WAS IN GRAVING-DOCK.

These experiments are intended to assist in giving a proper conception of the changes which occurred in graving-dock, and by turning the ship from head N.N.E. to head S.S.W.

[Vibrations on shore 20 per minute.]

Position of compass, as shown on the diagram, Plate 11.	1856.								1857.			
	December 10, ship's head N.N.E.		December 11, ship's head S.S.W.		December 18, ship's head S.S.W.		December 27, ship's head S.S.W.		January 6, ship's head S.S.W.		January 24, ship's head S.S.W.	
	Deviation.	Vibrations per min.	Deviation.	Vibrations per min.	Deviation.	Vibrations per min.	Deviation.	Vibrations in 1 min.	Deviation.	Vibrations in 1 min.	Deviation.	Vibrations in 1 min.
1	120° W.	15.85	17° E.	33.3	19° E.	34.*	18¾° E.	34.†	18¾° E.	33.9‡	19¼° E.	33.6§
2	5 W.	14.03	8¼	24.95	10½	26.	15	24.5	14	24.3	12.6	25.8
3	6¾ W.	18.	9¼	24.	14	24.04	8½	23.45	6¼	22.33	11.5	22.46
4	....	19.04	5	22.4	9	22.1	11¼	22.28	12½	22.1	8¼	22.34
5	¼ W.	20.	9	22.1	9¼	21.8	7	21.9	4.7	21.1	8¾	22.
6	9 W.	19.69	8¼ E.	22.3	9¼ E.	22.33	9¼ F.	22.2	8¼ E.	22.	9¼ E.	21.2

* Between December 11 and 18, several plates and one massive piece of iron were added to the part of the ship marked *a* in the diagram, Plate 11.

† Two iron tanks added since last experiments, as shown by *b* in diagram of deck, Plate 11. The temperature was considerably below freezing; on some other days it was about 50° Fahrenheit.

‡ Rudder partially in place.

§ Rudder and screw in place.

At stations 7, 8, Jan. 24, the deviations were, respectively .... 10¾ E. and 12½ E.
And the vibrations .... 24 " 23.7
At the stations adopted for the two steering compasses, *c*, *d*, on the plan, Plate 11, the deviations were, respectively, (Jan. 24, 1857, head S.S.W.) .... 10½ E. and 22½ E.
And the vibrations .... 27 " 26.6

NOTE.—The starboard steering compass was adjusted by permanent magnets and chain-boxes only.

The port compass (by permission from Messrs. Gibbs, Bright) was compensated by magnets, soft vertical iron, and chain-boxes.

When the ship's head was west, the deviation of the port steering compass was forty-five degrees east; two points of this error was compensated by about three cwt. of vertical iron, placed before it at the spot indicated in the diagrams by a dot,* 1½ points by magnets, and the remaining half point was left uncompensated.

"ROYAL CHARTER."

In the following pages are exhibited the results of some of the principal experiments made on board the "Royal Charter" by the Compass Committee, as well as those at Melbourne, particulars of which were furnished by the Rev. Dr. Scoresby.

The stations of the several compasses are given below; they are also indicated on the drawings of the ship, Plate 12.

No.	Station of compass.	Feet from the deck.	Feet from aft part of the stern.
I	Occasional compass placed aft the aftermost skylight	3.6	31.6
II	Mast compass fixed seven feet aft of mizen-top	42.2	48.
III	Steering compass fixed before the mizen-mast. Compensated by three small fore-and-aft magnets and one large transverse magnet, and chain-boxes. Original error, head north 35 west; head west 45 east	3.6	57.
IV	Companion compass. Compensated with chain-boxes, one fore-and-aft magnet, and two transverse magnets. Original error, head north 23½ west; head west 20½ east.	3.0	88.0
V	Mr. Gray's azimuth compass	4.6	93.6
VI	Admiralty standard compass	4.5¼	130.6
VII	Compass committee's dipping-needle and vibration compass	5.3½	141.6
VIII	Occasional compass placed on the fore-bitts	3.0	297.

* This *dot* "before the port compass," at *c*, is omitted on the figure in Plate 11.—B. F. G.

Table of co-efficients of ship's magnetic force, as per Admiralty Rules, and value of ship's force in terms of Earth's horizontal force = 1, as taken by inspection from Mr. Airy's tables.

Compasses.	A.	D.	E.	B. Co-efficients.	B. Ship's force to head.	C. Co-efficients.	C. Ship's force to starboard.	$\sqrt{(B^2+C^2)}$ ship's total force.	Angle of force from ship's head.	Maximum deviation for B and C.	Earth's directive power.
MAST COMPASS.	° ′	° ′	° ′	° ′		° ′			°	° ′	
Liverpool, Jan., 1856	—0 35	+2 28	+0 9	+ 0 46	+ .013	— 2 56	— .051	—.053	284	3 3	.947
Melbourne, May, 1856*	—1 0	+0 33	+0 11	— 0 15	.005	— 0 9	.003	....	....	....	....
Melbourne, "Liverpool measure"*	....	....	....	....	.009	....	.005	.010	209	0 32	.99
Liverpool, August, 1856†	....	....	....	....	....	....	....	....	....	....	....
STEERING COMPASS.											
Liverpool, Jan., 1856	+0 20	+2 0	—1 20	+ 0 32	+ .01	+ 1 50	+ .032	+.032	88	1 50	.968
Melbourne, May	—0 59	+2 34	—0 45	— ? 30	....	+13 53	....	....	....	....	....
Melbourne, "Liverpool measure"	....	....	....	— 4 18	— .075	+23 35	+ .400	+.49	105	29 21	.51
Liverpool, August	—1 12	+1 37	+0 3	— 0 15	— .005	+22 29	+ .382	.383	91	22 33	.617
Approximate, before compensation	....	+5 0	....	—27 7	— .456	—30 7	— .52	—.70	220	44 26	.30
Approximate, for Melbourne, without compensation	....	....	....	....	— .541	....	— .152	.56	195	34 3	.44
Approximate, for Liverpool, August, without compensation	....	....	....	....	— .471	....	— .17	.50	200	30	.50
COMPANION COMPASS.											
Liverpool, Jan., 1856	—0 2	+2 15	—0 50	— 0 56	— .017	— 1 49	— .031	.035	241	2 0	.965
Melbourne, May	—1 16	+1 56	—0 27	— 1 59	....	+ 9 2	....	....	....	....	....
Melbourne, "Liverpool measure"	....	....	....	— 3 20	— .058	+14 30	+ .25	.26	348	15 5	.74
Liverpool, August	+0 43	+1 38	—0 6	+ 1 15	+ .022	+17 31	+ .301	.305	86	17 45	.695
Approximate, before compensation	....	....	....	— 8 0	— .14	—25 0	— .423	.44	251	26 7	.56
Approximate, for Melbourne, without compensation	....	....	....	....	— .181	....	— .141	.23	219	13 18	.77
Approximate, for Liverpool, August, not compensated	....	....	....	....	— .101	....	— .090	.13	223	7 28	.87
ADMIRALTY STANDARD COMPASS.											
Liverpool, Jan., 1856	—0 27	+6 59	—0 52	— 3 48	— .067	—19 42	— .337	.35	259	20 29	.65
Melbourne, May	—1 27	+6 23	—0 16	— 1 11	— .02	— 8 59	— .156	.165	261	9 29	.835
Melbourne, "Liverpool measure"	....	....	....	— 1 58	— .035	—14 29	— .25	.255	261	14 47	.745
Liverpool, August	—0 3	+6 10	+0 56	— 1 6	— .02	— 3 22	— .058	.061	250	3 30	.939
Melbourne, if compensated at Liverpool	....	....	....	....	+ .024	....	+ .087	.091	255	5 15	.909
Liverpool, August, if compensated at first	....	....	....	....	+ .047	....	+ .279	.283	260	16 26	.717
Liverpool, Jan., 1856, if compensated	....	....	....	....	0	....	0	0	0	0	1.0
Liverpool, Sept., after alterations	—0 19	+6 0	—0 22	+ 1 13	.021	— 8 33	.15	.152	262	8 44	.848
Liverpool, Oct., after alterations	—0 9	+6 41	—1 37	— 4 55	.086	—14 0	.241	.257	250	14 53	.743
DIPPING-NEEDLE COMPASS.											
Liverpool, Jan., 1856	—1 0	+7 10	—1 20	—10 25	.18	—17 30	.300	.350	239	20 29	.650
Liverpool, Sept., 1856	—0 8	+6 45	—1 15	— 8 48	.154	— 7 21	.128	.201	220	11 35	.799

* Probably the compass was too sluggish for exact experiments.

† The compass was so sluggish that no satisfactory observations were recorded.

Comparison of "Royal Charter" compasses.

By selecting from the preceding table the values of ship's attraction to head and to starboard, and ship's total force, for the two compensated and the Admiralty compasses, we obtain the following:

Compasses.	Head.			Starboard.			Total.		
	Jan'ry.	May.	August.	Jan'ry.	May.	August.	Jan'ry.	May.	August.
Steering compass	—.456	—.541	—.471	—.52	—.152	—.17	.70	.56	.50
Companion compass	—.14	—.181	—.101	—.423	—.141	—.090	.44	.23	.13
Admiralty compass	—.067	—.033	—.02	—.337	—.25	—.058	.35	.255	.061

Both the companion and the steering compasses show increased attraction towards the stern at Melbourne. The reduction of the attraction to port is very considerable, and continues throughout the voyage, in the companion and Admiralty compasses.

Comparison of compensated and non-compensated compasses.

When compared.	Steering compass.				Companion compass.				Admiralty compass.			
	Compensated.		Not compensated.		Compensated.		Not compensated.		Compensated.		Not compensated.	
	Max. deviation.	Min. directive power.	Max. deviation.	Min. directive power.	Max. deviation.	Min. directive power.	Max. deviation.	Min. directive power.	Max. deviation.	Min. directive power.	Max. deviation.	Min. directive power.
	° ′		° ′		° ′		° ′		° ′		° ′	
January	0 0	1.	42 26	.30	0 0	1.	26 7	.56	0 0	1.	20 29	.65
May	29 21	.51	34 3	.44	15 5	.74	13 18	.77	5 42	.9	14 47	.754
August	22 33	.617	30 0	.50	17 45	.696	7 28	.87	17 3	.709	3 26	.94
Ratio in favor of compensation	2.127 to 1.24				2.435 to 2.2				2.609 to 2.344.			

On Plate 15 is represented the relative values of ship's force, and its direction, at the station of each of the three compasses, viz:

The amount and direction at Liverpool, in January.
The amount and direction at Melbourne, in May.
The amount and direction at Liverpool, in August.

An arrow also shows the same for the Admiralty compass immediately before the "Royal Charter" sailed on her second voyage to Australia, October, 1856.

Vibration-needle experiments, January, **1856.**

(On shore, at Liverpool, the needle makes 20 vibrations in 60″.)

No. of observation.	Ship's head, true magnetic.	Deviation.	No. of vibrations in 60″.	(Vibrations)^2	Magnetic intensity in direction of needle, Earth = 1.	Intensity to north.	Disturbing force to north.	Disturbing force to east.	Total disturbing force.	Starboard angle of disturbing force.	Force towards ship's head.	Force to starboard side.
										°		
1	N. 5° E.	—17 (W.)	19.3	372.5	.931	.890	—.110	—.272	.294	243	—.133	—.262
2	36.40	—12	20.5	420.3	1.050	1.028	+.028	—.218	.220	241	—.108	—.192
3	62.45	—12	21.	441.	1.102	1.078	+.078	—.229	.242	227¼	—.163	—.179
4	85.30	—11	22.5	506.3	1.266	1.243	+.243	—.242	.342	228	—.226	—.257
5	112.15	— 7	23.	529.	1.322	1.312	+.312	—.161	.351	220	—.266	—.229
6	138.15	— 2.45	22.9	524.4	1.311	1.309	+.309	—.063	.316	211	—.273	—.159
7	168.15	+ 7 (E.)	22.7	525.3	1.288	1.278	+.278	+.157	.319	221	—.243	—.207
8	196.23	+18	22.3	497.3	1.243	1.182	+.182	+.384	.425	227	—.292	—.309
9	225.30	+27	20.	400.	1.000	.891	—.109	+.454	.466	236	—.258	—.389
10	248	+26.30	18.5	342.3	.855	.765	—.235	+.382	.448	234	—.263	—.383
11	260	+20	17	289.	.722	.677	—.323	+.247	.407	243	—.187	—.361
12	274.30	+16	16.5	277.3	.681	.655	—.245	+.188	.393	240	—.217	—.328
13	286	+ 7	16	256.	.640	.635	—.365	+.078	.373	242	—.177	—.329
14	297.5	— 6 (W.)	16.8	282.3	.706	.702	—.298	—.074	.307	257¼	—.065	—.300
15	305.30	—14.45	16.5	272.4	.621	.659	—.341	—.173	.383	261	—.059	—.378
16	335.30	—22	17	289	.722	.669	—.331	—.271	.428	243	—.192	—.382

Equations derived from the above give the following mean values for ship's magnetism:

Polar magnetic force to ship's head... .... — .196

Polar magnetic force to ship's starboard side....................... — .314

Or, a total polar force of .37, at an angle of 238° to starboard of the ship's bow.

Vertical induction plus horizontal induction, as.................... — .146

Vertical induction minus horizontal induction, as.................. + .05

Or, a force constantly tending to decrease Earth's intensity... = .048

And a force producing quadrantal magnetism....................... = .098

Vibration experiments made before the ship sailed on her second Australian voyage, and after the alterations in graving-dock.

(Vibration on shore, 20 in 60″.)

No. of observations.	Ship's head, true magnetic.	Deviation.	Vibrations in 1 minute.	(Vibrations)^2	Magnetic intensity, Earth's taken as = 1.	Intensity to north.	Disturbing force to north.	Disturbing force to south.	Force to ship's head.	Starboard force.	Total ship's force.	Starboard angle of ship's force.
												°
1	N.	9 W.	18.9	357.2	.893	.882	—.118	—.139	—.118	—.139	.182	229
2	N. 22¼ E.	5¼ W.	19.1	364.8	.912	.908	—.092	—.088	—,117	—.042	.164	200
3	196	9 E.	21.8	475.2	1.188	1.174	+.174	+.185	—.218	—.130	.259	211
4	253¼	17¼ E.	17.9	320.4	.801	.764	—.236	+.241	—.164	—.294	.339	241
5	268	14 E.	17.2	295,8	.740	.718	—.282	+.179	—.167	—.288	.334	240
6	295	2¼ E.	17.14	297.78	.734	.733	—.267	+.032	—.142	—.227	.269	239
7	307½	2 W.	17	389.	.722	.721	—.279	—.025	—.145	—.247	.280	238¾
8	314	4 W.	17.38	298.2	.745	.744	—.256	—.052	—.141	—.220	.261	237¼
9	320¼	5¾ W.	17.48	302.1	.755	.751	—.249	—.076	—.144	—.217	.260	236¼
10	349	9 W.	18.57	345.6	.864	.854	—.146	—.135	—.117	—.160	.198	234
11	357	9 W.	18.9	357.2	.893	.883	—.117	—.139	—.110	—.145	.182	233

These show a considerable reduction in ship's magnetism, as compared with the first set of experiments. They were obtained when the ship was partially swung. There was no opportunity afforded for completely swinging the ship.

Vibration experiments, 1855.

At the station of the aftermost compass only four observations were made. They show a much greater magnetic force than those obtained with midship experiments.

Ship's head.	Deviation.	No. of vibrations per minute.
North	39½ West	14.8
East	22½ West	22. 5
South	16 East	27.3
West	51 East	17.8

The vibrations on shore, as before, 20 per minute.

These experiments exhibit a much greater amount of changing magnetism than those on board the "Rainbow" and the "Ironside."

8

CURVES OF DEVIATION.

Description of diagrams to exhibit the nature of deviation curves and the effect of quadrantal deviation in altering the circular form of the curves due to polar magnetism only.

I. Polar Deviations.—As these vary as the sines of the angles of ship's force with direction of disturbed needle, circular curves are obtained as exhibited by figures Nos. 1, 2, 3, 4, and 1′, 2′, 3′, 4′, on Plates 26 and 27. *

II. Quadrantal Deviations.—These vary as the sines of twice azimuth of ship's head by disturbed compass; they produce, when projected, oval or looped curves. Figures 5 and 5′.

III. Combinations of I and II.—As all deviation curves must be made up of these two, it is important to accustom the eye to the combinations which may in this way be produced. Figures 6, 7, and 6′, 7′, afford examples; they combine Nos. 1 and 5 (1′ and 5′) and 4 and 5 (4′ and 5′.) Several other combinations are exhibited.

Figures 1 and 1′, north end of needle attracted to the stern.

Figures 2 and 2′, north end of needle attracted towards the bow.

Figures 3 and 3′, north end of needle attracted towards the starboard side.

Figures 4 and 4′, (Nos. 2 and 3 combined,) north end of needle attracted four points to starboard of bow.

Figures 5 and 5′, quadrantal attraction (+) giving east deviation in the first or N.E. quadrant.

Figures 6 and 6′, combination of Nos. 1 and 5 (1′ and 5′.)

Figures 7 and 7′, combination of Nos. 4 and 5 (4′ and 5′.)

To assist in exhibiting these curves, the spaces within the deviation lines have been differently shaded: West deviation, broken lines; east deviation, continuous lines. On Plate 27, instead of showing the curves 6′ and 7′ in this way, only the quadrantal excess or deficiency has been shaded.

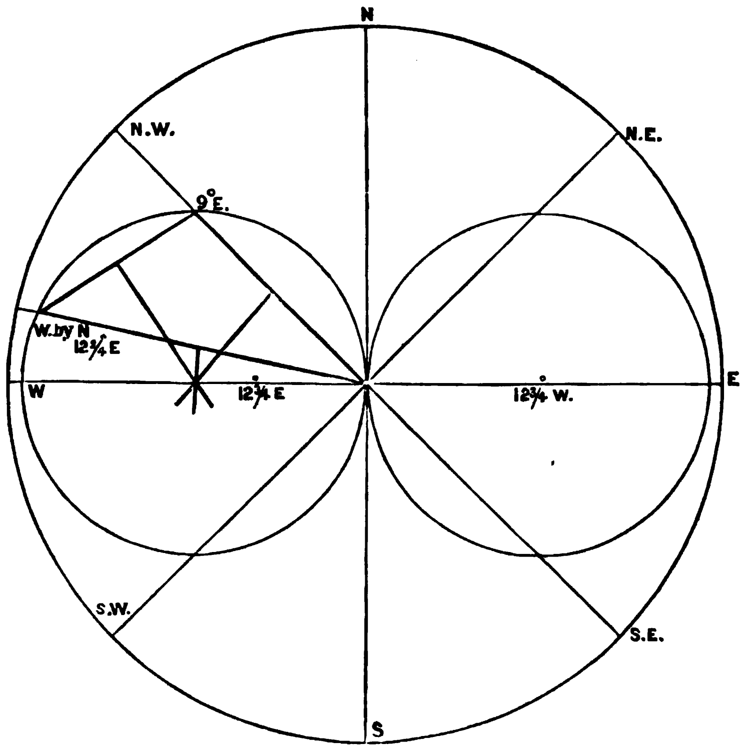
Thus, if with the ship's head W. by N. a deviation of 12½° E. were observed, and with ship's head N.W. a deviation of 9° E., these would afford three points in the circumference of a circle, and therefore the circle altogether. If there were no *index* error the west deviations would be the same in amount as the east upon opposite points. (See Figure 3.) But if, for instance, the lubber line of the compass was 2° to port of ship's head, all the westerly deviations must be made twice this amount greater than easterly ones, and the approximation throughout would not be so close.

---

* The numbers with *accents* (′) apply to the corresponding figures on Plate 27. B. F. G.

If observations of this kind were made at sea, and the variation at the place of experiment were not known within two or three degrees, a close approximation could be made to it by four azimuths, two with ship's head near the courses which usually give maximum west, and the other two near maximum east deviation. Half the difference between the diameters of the two deviation circles thus obtained, would be the correction to be applied for error in the assumed variation, *i. e.*, supposing no index error; if such existed, it also would have to be allowed for.

Fig. 3.



NOTE.—It is worthy of remark, that when the quadrantal deviation of a ship has been carefully compensated, the remaining portion, (either in a compensated or uncompensated compass, for the polar deviation,) or any deviation that may arise from change of condition in the ship while at sea, may be represented on the rhumb lines of a compass by a *circle*. This being the case, it at once follows that two good observations of deviations of the *same name*, will suffice to give an approximate table of deviations for every point of the compass.

APPENDIX No. 3.

THE ACCUMULATION OF SMALL COMPASS ERRORS IN WOODEN SHIPS.

LIVERPOOL COMPASS COMMITTEE,
40 *Tower Buildings East*, *May* 15, 1856.

DEAR SIR: Some months since I ventured to call your attention to the fact, that while the "variation" in the Irish channel between Wales and Ireland was slightly less than two and a quarter points of the compass, the general practice with shipmasters and pilots was to allow two and a half points. I find, by inquiry, that in many cases this allowance is still made, and, in some instances, even so much as two points and three-quarters. It will be easy to show, that though on some courses such allowance for compass error may be quite correct, it is most unsafe to attribute so much to "variation," and allow it on every course.

That the remarks I am about to make in elucidation of this and some associated topics may be generally intelligible, allow me to explain that, though some persons use the terms *variation of the compass* and *deviation of the compass* as if they were of the same meaning, the well-informed seaman makes a great distinction between the two, and for the following reasons: The error from *variation* arises from the magnetic north not coinciding with the true north; and, as this affects every point of the compass to the same extent, the allowance for it, whatever be the direction of the ship's head, is always the same at the same place and time. It is quite independent of the position of the ship. Not so with *deviation*, which is caused by iron on board the ship, and which varies in amount with her position, but in so regular and simple a manner that its changes may easily be understood. On whichever side of the compass the disturbing cause is situated, it will be seen that, as the ship turns round, the compass and it alter their relative bearings. Let it be supposed that the disturbing piece or pieces of iron are towards the stern, aft of the compass, then when the ship's head is north the disturbing cause will be south, when her head is east the iron will be west, and so on throughout the whole circuit, taking in succession every possible horizontal direction. Now, though we may conceive the disturbing cause to exercise the same energy in each of these directions, it does not act with the same leverage, with the same mechanical advantage in each, and therefore does not produce the same effect on the compass needle. When its attraction is in the same direction as the needle, or when it is north or south of the compass card, no deviation of the needle is produced. When it acts at right angles to the observed direction of the needle it causes the greatest deflection or deviation. The general effect of iron aft and below the compass, the case we are contemplating, is this: when the ship's head bears north there is no error; as it turns easterly, the iron aft turns westerly, and (in north latitudes) attracting the north end of the needle, causes *westerly* deviation, producing its greatest effect when the ship's head bears east. The deviation then decreases, slowly at first, afterwards more and more rapidly, till her head is south, when there is no error. The ship still turning round to the westward, the disturbing iron is carried eastward and draws the north end of the needle to the east, now producing *easterly* deviation; arriving at its greatest when the ship's head shows west, and again decreasing until she regains her original position.

In few words, we see that iron aft and below the level of the compass produces westerly deviation, that is, takes a vessel to the *left* of her course when her head is easterly; and produces easterly deviation, causing a vessel to trend to the *right* of her course, when her head is westerly. To state the result yet more briefly, its effect is always to take the ship to the north of her course, and to the greatest extent when her head bears due east or west. A walk round our docks will show that many ships have a considerable amount of iron in the position we have supposed. Without venturing at present to estimate the amount of its action, I merely ask you to remember that, in the Irish channel, with the ship's head westerly, its tendency, like too large an allowance for variation, is to take a vessel to the right of her course.

But it will also be seen by any one who visits our shipping, that nine out of ten ships have long and more or less massive horizontal iron spindles connected with the steering apparatus, in some cases at a higher and in some at a lower level than the compass card; and I proceed to ask your attention to the action of such bars upon the compass. Now these bars, and in fact the fore-and-aft horizontal portion of all the iron in the ship, produces an effect which has aptly been termed "qudrantal," (for the reason that it changes its character in each quadrant of the compass,) and produces easterly deviation when the ship's head is between N. and E.; westerly deviation when between E. and S.; easterly deviation again when the ship's head is between S. and W.; and again westerly in the remaining quadrant. It is worthy of remark that this deviation is independent of locality, and has the same effect at the equator as at the pole.

As before, I will not attempt to estimate the amount of this kind of error, but only direct your attention to the fact, that in two quadrants of the compass it will tend to decrease, and in the other two to aggravate, those deviations which arise from iron situated aft and below the compass.

There is another cause of error which must be mentioned here, though it does not affect so large a number of ships as the preceding. I allude to the double binnacle. In many cases where these are used, the compasses are placed so close as to disturb each other, and the result is a quadrantal error of precisely the opposite kind to that arising from fore-and-aft iron; but, like it, alternately increasing and decreasing the errors due to that cause of deviation which was first discussed.

These remarks convey but a very imperfect idea of the "compass question." They should be taken in the restricted sense in which they are given, and as illustrating the possible accumulation of small errors; but I protest against their being received as merely theoretical, for they are the result of ample and practical experience. My desire is to briefly state as much as may enable any one who will give the subject a little attention to understand the nature of the deviations likely to arise from the iron fittings about the rudder and steering apparatus on board wooden ships. When deviations occur in our merchant ships, which do not arise from iron cargo, the cause is almost invariably found in this direction, and the errors are consequently of the opposite kind to those observed in men-of-war. (This should be borne in mind by persons reading different works which have been published on compass deviations, in which the observations have been mostly derived from officers of the Royal Navy.)

The recent loss of a noble vessel, happily without the horrors which usually attend the wreck of an emigrant ship, will, no doubt, give some interest to the discussion of those compass errors which are usual on board wooden ships. I hope the few remarks I have made may be sufficient to enable most persons to rightly estimate any facts bearing on this subject, which may be ascertained in relation to the ship in question, and that they may induce those seamen who have not yet fully considered the matter to give it the attention its importance demands.

I am aware of the contempt the seaman has for small compass errors, and the general belief that no course can be depended upon within "a quarter of a point or so." This belief is a good reason why the greatest accuracy should at the least be attempted. True, small errors frequently compensate each other; but when this is not the case—when they all fall in the same direction (as must unfortunately be the case sometimes, and nowhere with worse results than in the Irish channel)—when to a "quarter point" of *easterly deviation*, arising from wrong allowance for variation, and another "quarter point" or more of *easterly deviation*, from iron aft and below the compass, is added a trifle of *easterly deviation* from the spindle of the steering wheel being within eighteen inches or so of the compass card, these small deviations may not be safely neglected. In fact, a full acquaintance with those compass errors which are probable, or even possible, cannot be too soon or too perfectly acquired by those whose business is upon the sea. Certain it is, that casualties often occur to ships while steering courses on which these small errors accumulate; and we not unfrequently hear of cases in which a fatal catastrophe was imminent, and only averted by the merest accident—a timely lookout, the appearance of a light in an unusual direction, a change of wind, or the opportune break of day.

My letter has extended to a greater length than I anticipated, but I trust the subject and its occasion will be sufficient excuse.

Believe me, &c.

W. W. RUNDELL,
Secretary Liverpool Compass Committee.

THOMAS COURT, Esq.,
Secretary to the Liverpool Underwriters' Association.

USE AND ABUSE OF THE MAGNETIC BEARINGS OF VAUXHALL CHIMNEY, AND THE UTILITY OF THE "DUMB CARD" ON SHIPBOARD.

40 TOWER BUILDINGS EAST,
Liverpool, October 13, 1856.

DEAR SIR: I am directed by the Liverpool Compass Committee to send you some remarks on the use and abuse of the magnetic bearings of the Vauxhall chimney, which have been painted upon the dock walls, with a view to their publication for the information of underwriters, shipowners, and others. In addition to employing these bearings, as at first proposed, for testing the accuracy of compasses which have been compensated in dock, and for ascertaining the amount of existing compass errors, a tendency has been observed to use them for the magnetic *adjustment of ships' compasses in the river*, a purpose never intended by the committee, and which, though quite possible under favorable circumstances, should, as a general practice be discouraged. It may be thought if a captain be expected to adjust his compasses at sea, that a professional compass adjuster should be able to do the same in the river with the additional facilities afforded by the dock marks. Abstractly, such adjustment is very simple, but in practice difficulties supervene to make the attempt, to say the least, undesirable, if not hazardous, as will be seen by the following considerations:

To render the compensation of a ship's magnetism easy, and prevent the necessity for calculation, it is usual to consider her attraction as resolved into two directions, at right angles to each other—an attraction fore-and-aft, and another towards the sides, or across the ship. To compensate the last, the ship is held as steadily as possible in the direction of the magnetic meridian, while the necessary magnets are placed across the deck. To compensate the fore-and-aft attraction, the ship must be kept for a short time with her head magnetic east or west, to allow the fore-and-aft magnets to be placed in position. Now, to do this across the tide of the Mersey, while in tow of a steam-tug is very difficult, as well as attended with great risk of collision with the ships which crowd the river. Again, it may so happen that, at the time the ship is leaving dock to proceed at once to sea, the chimney to which the bearings refer may be concealed by fog, or that delays in getting clear of the dock may consume the short time allotted for river adjustment, and then the ship must either be hurried to sea in an unsatisfactory condition, or be obliged to anchor in the river, with a loss to those concerned, instead of the anticipated saving of time and expense.

Reference to the circulars issued by the Compass Committee will show that its members never contemplated the *adjustment* of ships' compasses in the river, and they take an early opportunity of warning shipowners against wishing it, except under very special circumstances. Compass adjustment should be attended to in dock, care being taken to select for it such docks as will allow a favorable position for the shore compass; or better still, one of the docks prepared for the process should be employed, and then the chance of error from local attraction on shore will be prevented, as here no shore compass is necessary.

The proper uses of the magnetic bearings of Vauxhall chimney are, *to test* the accuracy of dock adjustment by a few observations made in the river; to ascertain if the deviations given in the tables are correct or not; to afford shipmasters in general facilities for testing the quality of their compasses, and the existence of any local attraction from the presence of iron in the fittings of the ship or in her cargo; to enable the captains of iron ships, on their return to port, to decide whether new adjustment be necessary, and to assist them to obtain for themselves with great ease and accuracy new deviation tables. These are the important and legitimate uses for which the bearings were proposed, and to which the Compass Committee desire to confine them.

Another subject connected with these bearings, to which attention is invited, is the utility on shipboard of a portable gimballed dumb-card, fitted with a lubber line and sight-vanes. When properly made, the dumb-card is in many respects superior to the azimuth compass. Unfortunately, comparatively few ships are supplied with either, and in very many the only compass in use (the steering compass) is so placed below the bulwarks, or concealed by the binnacle, that it is next to impossible to take bearings with it within half a point of the truth; and to such the newly painted magnetic bearings can be of little service. But the dumb-card aptly meets the difficulty, and enables any one in the river to obtain the true bearing of the ship's head almost instantaneously, and with surprising facility and correctness; and that whether the ship be at anchor, swinging with the tide, or moving ever so rapidly through the water.

In short, the Compass Committee esteem this instrument so highly, as to be of opinion that its use in port will double the value of the magnetic bearings which have been painted on the dock walls at their suggestion, and at sea that it will be found more accurate and useful than the azimuth compass itself.

Believe me, dear sir, your very obedient servant,

W. W. RUNDELL,
Secretary.

TO THOMAS COURT, Esq.,
Secretary to the Underwriters' Association.

APPENDIX No. 4.

LIVERPOOL COMPASS COMMITTEE.

Chairman.

THOMAS BROCKLEBANK, Esq.

Deputy Chairman.

J. PALMER PALMER, Esq.

Treasurer.

THOMAS COURT, Esq.

Members.

J. ABRAHAM, Esq.
JOHN AIKIN, Esq.
JAMES BEAZLEY, Esq.
Commander BEVIS, R.N.
T. M. BLYTH, Esq.
SWINTON BOULT, Esq.
R. CARLYLE, Esq.
F. A. CLINT, Esq.
H. DAWSON, Esq.
J. B. EDWARDS, Esq., Ph.D., F.C.S.
R. GETTY, Esq.
S. R. GRAVES, Esq.
C. GRAYSON, Esq.
WILLIAM HADFIELD, Esq.
G. HAMILTON, Esq., F.C.S., F.R.A.S.
JOHN HARTNUP, Esq., F.R.A.S.
EDWARD HEATH, Esq.
S. HJORTH, Esq.
T. H. HOLDERNESS, Esq.
WILLIAM INMAN, Esq.
E. JONES, Esq.
JOHN JONES, Esq.
J. JONES, Esq.
A. KING, Esq.
JOHN LAIRD, Esq.
ROBERT LAMONT, Esq.
ROBERT MCANDREW, Esq., F.R.S.
L. H. MACINTYRE, Esq.
N. MCLEOD, Esq., F.R.A.S.
WILLIAM MANN, Esq.
S. MARTIN, Esq.
W. C. MILLER, Esq.
JOSEPH MONDEL, Esq.
JAMES NEWLANDS, Esq.
W. POTTER, Esq.
W. RENNIE, Esq.
C. F. SALT, Esq.
Captain SCHOMBERG, R.N.
MAXWELL SCOTT, Esq.
B. J. THOMSON, Esq.
D. P. THOMPSON, Esq., M.D.

Honorary Secretaries.

JOHN GRANTHAM, Esq., C.E. JOHN T. TOWSON, Esq.

Secretary.

Mr. W. W. RUNDELL.

40 TOWER BUILDINGS EAST,
Liverpool.

SIR: At the close of 1854, when the Liverpool Compass Committee was appointed, there appeared a growing conviction in the minds of persons conversant with maritime subjects—

That the present modes of correcting or compensating compass errors was insufficient to meet the requirements of many ships, and more especially of those iron-built vessels which trade to the southern hemisphere.

That many apparently well authenticated cases of unlooked-for and sudden compass changes called for the immediate investigation of the merchant and underwriter; and, generally,

That full and trustworthy information relating to the magnetism of iron ships, and the changes to which it is liable, was highly desirable, and was demanded as much by the interests of the shipowner and builder, as for the general satisfaction and security of the public.

It was foreseen that an inquiry of this nature would require much caution and patience, and that it must necessarily extend over two or three years before decisive information could be collected and arranged, and its practical results be eliminated. Without anticipating an earlier conclusion to their labors, the committee believe that advantage may arise at this time from the circulation of a brief statement of the present position of the investigation, of the deductions which have already been made by the committee, and of the probable result of their labors.

Though the information which has already been collected shows most emphatically the necessity for the investigation which has been entrusted to them, the members of the committee feel bound to record, as early as possible, their conviction that the talents and energy of the captains of iron craft have generally been sufficient to overcome all the difficulties arising from the magnetism of their ships, and to make the navigation of these vessels, upon the whole, as safe, if not so easy, as that of a wooden ship. It must not, however, be concealed that these difficulties have sometimes been great, and that the navigation of an iron ship on her *first* voyage, particularly if it extend very far to the south, severely taxes the care and prudence of her commander. At present it is quite uncertain, until trial be made, to what kind of compass errors an iron ship will be liable; whether they will be increased or diminished, or alter their character by change of geographical position, or whether magnetic compensation will lessen or aggravate the evil. Cases of each kind have been recorded; but, from a variety of causes, it is found that at present the experience of the captain of one ship, in aught besides the necessity for constantly correcting his compass indications by solar or stellar azimuths and amplitudes, is seldom or never applicable to the wants of another.

There is reason to believe that compass disturbances may be very much lessened; that by attention to the circumstances under which a ship is built, and care in selecting a suitable position for the binnacle, the original error of the compass may be reduced within small limits. By the aid of captains of iron ships in filling up the forms which are freely distributed to them for the entry of compass observations made at sea; by the experiments which are being made here; by other experiments in the southern hemisphere under the care of Dr. Scoresby; and by the careful discussion of the facts which are brought under their notice, the committee hope to be enabled ultimately to present some general rules which will materially facilitate the navigation of iron ships; and in cases where large deviations are inevitable, greatly to assist the captain by forewarning him of the kind of errors to which, under given circumstances, his compasses will be liable.

The labors of the committee are taking this direction, and promise some interesting and practical results. The time at which these results will be available depends to a great extent on the co-operation of the captains of iron ships themselves, and it cannot be too generally known that their furnishing tables of deviation for the same compass (uncompensated by magnets) obtained at places differing considerably in latitude, will remove one of the chief difficulties attendant on the investigation.

Step by step with the inquiry into the deviations experienced on board iron ships information is also being collected as to the compass errors of wooden ships; the effect of iron cargoes, of the various kinds of iron steering apparatus, and the proximity of other masses of iron, in order to ascertain what precautions are required in each case. It is proposed that this shall be published, with the general result of the compass investigation, for the benefit of the mercantile community.

It having been reported that ships with cargoes of iron frequently leave this port without being swung, though liable to deviations exceeding a point of the compass; and also that iron ships are not swung so often as is desirable, through the delay, expense, and risk attendant on moving them into a dock suited for the purpose, the committee are about to introduce a plan which will greatly facilitate the process of swinging ship, and that will enable it to be satisfactorily gone through in the river when an opportunity in dock is not afforded. The mode proposed is very simple, requires only a short time, and involves no additional expense. It will probably be in operation in a few weeks.

The funds by which the inquiry has so far been carried forward have been derived from a very limited area. Increased assistance is now necessary, and the committee claim the liberal support of all who are interested in the investigation.

The expenses incurred to this date amount to about £400, and it is estimated that a similar sum will be required annually for the next two years. The Board of Trade has granted £100 towards the expense of the past year. The letter which accompanied the grant is quoted to show the interest which is felt by the government in the investigations of the Liverpool Compass Committee:

"Office of Committee of Privy Council for Trade,

"*Marine Department*, *Whitehall*, *February* 28, 1856.

"Sir: I am directed by the Lords of the Committee of Privy Council for Trade to acknowledge the receipt of your letter of the 6th instant, together with the report of the Liverpool Compass Committee for the year 1855.

"My Lords desire me to express their sense of the great pains that appear to have been taken in carrying into effect the objects for which the committee was formed. They have read with much interest the report of their proceedings, and request that the committee will be good enough to favor them with the result of any further investigations. They direct me, in reply to your request, to inclose an order on Her Majesty's Paymaster General for the sum of £100, in favor of Thomas Court, Esq., the Treasurer of the Compass Committee.

"I am, sir, your obedient servant,

"J. Em. Tennent.

"The Secretary to the Compass Committee,

"40 *Tower Buildings East, Liverpool.*"

Soliciting attention to the above statement, and your pecuniary aid towards the expenses of the investigation,

We are, sir, your obedient servants,

John Grantham,

John T. Towson,

Honorary Secretaries.

LIST OF SUBSCRIPTIONS.

Subscriptions.

	£	s.	d.
Board of Trade	100	0	0
Lloyd's Committee, London	50	0	0
Trinity Board, London	25	0	0
Colonial Land and Emigration Commissioners	25	0	0
Messrs. W. Denny & Co., Dumbarton	20	0	0

Liverpool Subscriptions.

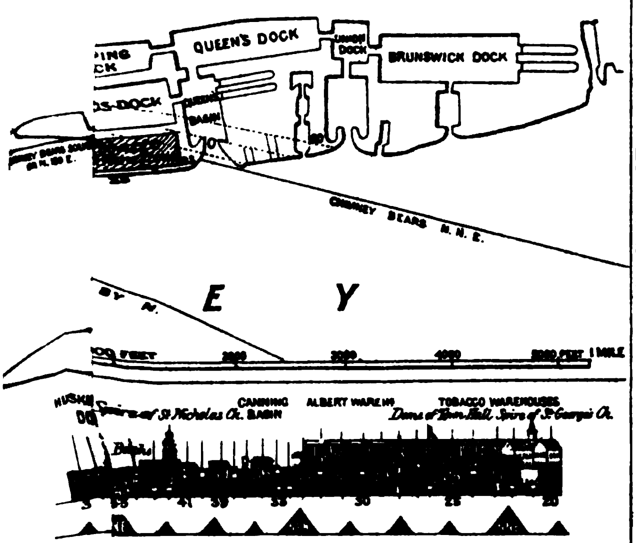
	£	s.	d.
Underwriters' Association	30	0	0
Shipowners' Association	30	0	0
Mr. John Laird, Birkenhead	20	0	0
Mr. Thomas Brocklebank	15	15	0
Messrs. D. and C. MacIver	10	0	0
Messrs. Gibbs, Bright & Co.	10	0	0
Mr. W. Inman	5	5	0
Mr. James Beazley	5	0	0
Mr. S. R. Graves	5	0	0
Mr. C. Langton	5	0	0
Mr. J. Grantham	5	0	0
Messrs. T. and J. Brocklebank	5	0	0
" Brice, Friend & Co.	5	0	0
" Colesworth, Wynne & Co.	5	0	0
" K. Dowie & Co.	5	0	0
" Cunard, Brett & Austen	5	0	0
" Finlay, Campbell & Co.	5	0	0
" Fowler & Dagnall	5	0	0
" Humble, Grayson & Co.	5	0	0
" Jones, Palmer & Co.	5	0	0
" Lamport & Holt	5	0	0
" Charles Moore & Co.	5	0	0
" Henry Moore & Co.	5	0	0
Messrs. Thomas Morris & Co.	5	0	0
" W. Potter & Co.	5	0	0
" Rathbone Brothers & Co.	5	0	0
" Rawson, Aikin & Co.	5	0	0
" Rotheram & Gair	5	0	0
" Sutton Brothers & Kirkby	5	0	0
" Willis & Co.	5	0	0
Liverpool Steam-tug Company	5	0	0
Messrs. Boult, English & Brandon	2	2	0
" Bowring & Co.	2	0	0
" Heap & Sons	2	0	0
" Lamont, McLarty & Co.	2	2	0
" Rathbone & Martin	2	2	0
Mr. W. M. Moss	2	2	0
Messrs. Imrie & Tomlinson	2	0	0
" Bibby & Son	2	0	0
Mr. Cato	2	0	0
Messrs. L. H. MacIntyre & Co.	1	0	0
" W. Jewitt & Co.	1	1	0
Captain J. Jones	1	1	0
Mr. I. L. Cross	1	1	0
Mr. John Longton	1	0	0
Mr. J. T. Towson	1	1	0

Special subscriptions towards Dr. Scoresby's Australian Investigation.... £50.

No. 3.

No. 4.

DOL.



easurement of Compass Errors.

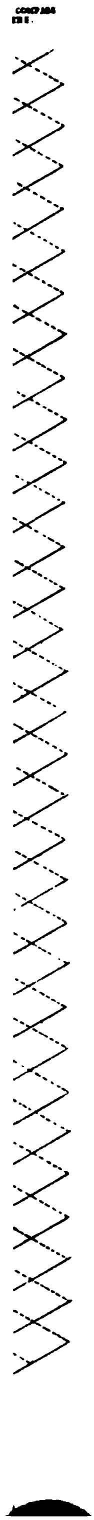
The
it must deviate to the *East* to make the Chimney
orrect bearing.
ing the vessel describe a circle, and noting, as the
pass, the bearing of the Chimney as observed by
he difference or deviation against those points of
he the observations were made. But, as the pivot
the compass-card in the same direction in which
and once against the sun's apparent motion. The
rors. The compass-bowl should also be frequently
ip is not very steady, several observations should
s, and the mean of the whole taken as the true

the river, she should be kept at least 60 feet from

f the Dock walls, others are painted on the inside of
hese Docks have been selected as the best adapted
and of large masses of iron on the wharves, it is
ns, or to compensate the magnetism of a ship in
ct the ship's compasses, as well as the adjuster's

ck show the bearings of a tall post, distinguished
. 144° W.; those on the north side give bearings
right o
The s give bearings of the centre of the Victoria Clock
and a st side show bearings of the Vauxhall Chimney,
towar
appea f a set should be accidently obscured by the ship's
vention of other vessels.

In mpass Committee,
reason RUNDELL, Secretary, 40 Tower Buildings, East.

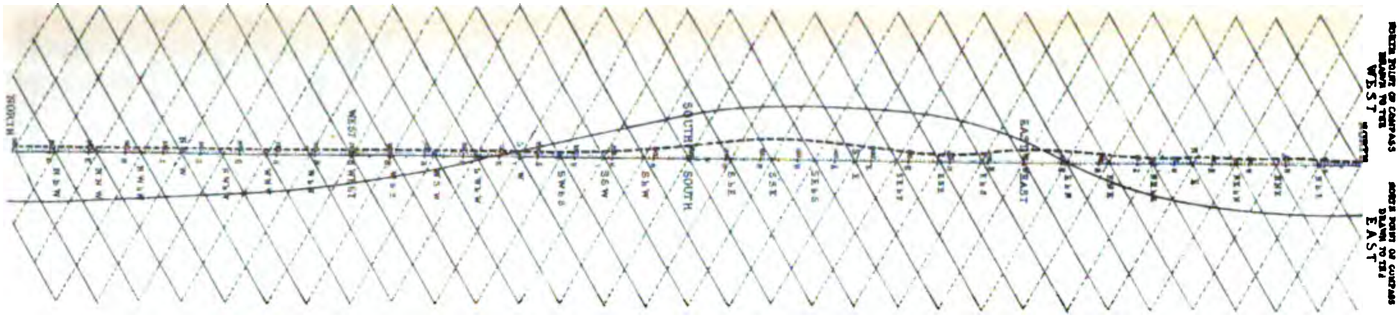


J. Bien photo lith.

No. 4.

No. I.

DIAGRAM



No. I. – *Deviation Curves of adjusted Steering Compass of three-masted schooner "Astrea."* *Built, Head S. and W.*

--------Curve exhibits the deviations as given by the Compass Adjuster in the Clyde. Only one magnet (a transverse one) was applied.

——— Curve shows the deviations observed in the Mersey, after the ship had made a voyage to the West Indies, the magnet still in place.

This shows an attraction to stern of 6°

And an attraction to starboard of $15\frac{3}{8}$°.

which is caused by the magnet, and indicates a decrease in the ship's magnet i.e. force towards the port side = about one-fourth of Earth's horizontal force.

The quadrantal co-efficient is $+3\frac{1}{4}$°,

and is neither compensated nor noted in the Clyde Deviation Table.

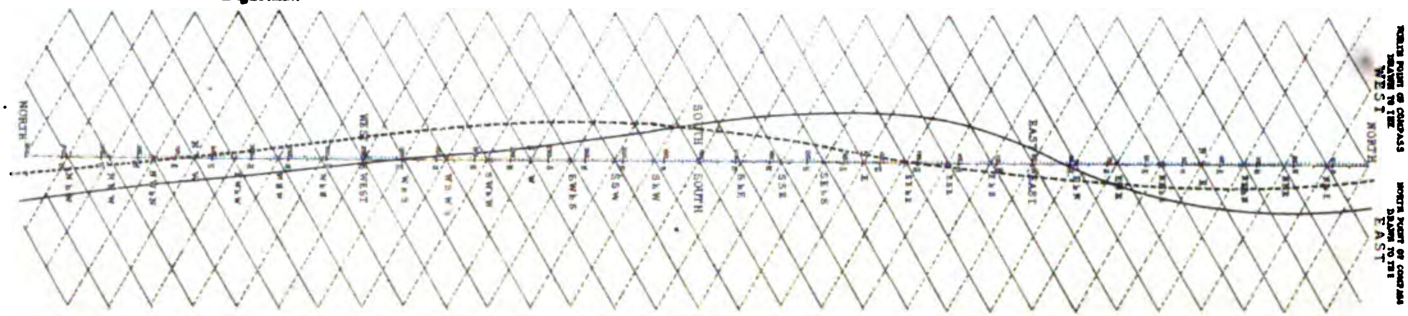
No. II.—*Deviation Curves of "Nauphante."* *Built, Head to East.*

——— Curve represents the Deviations of a Compass placed about six feet in front of rudder head, and three feet from the deck.

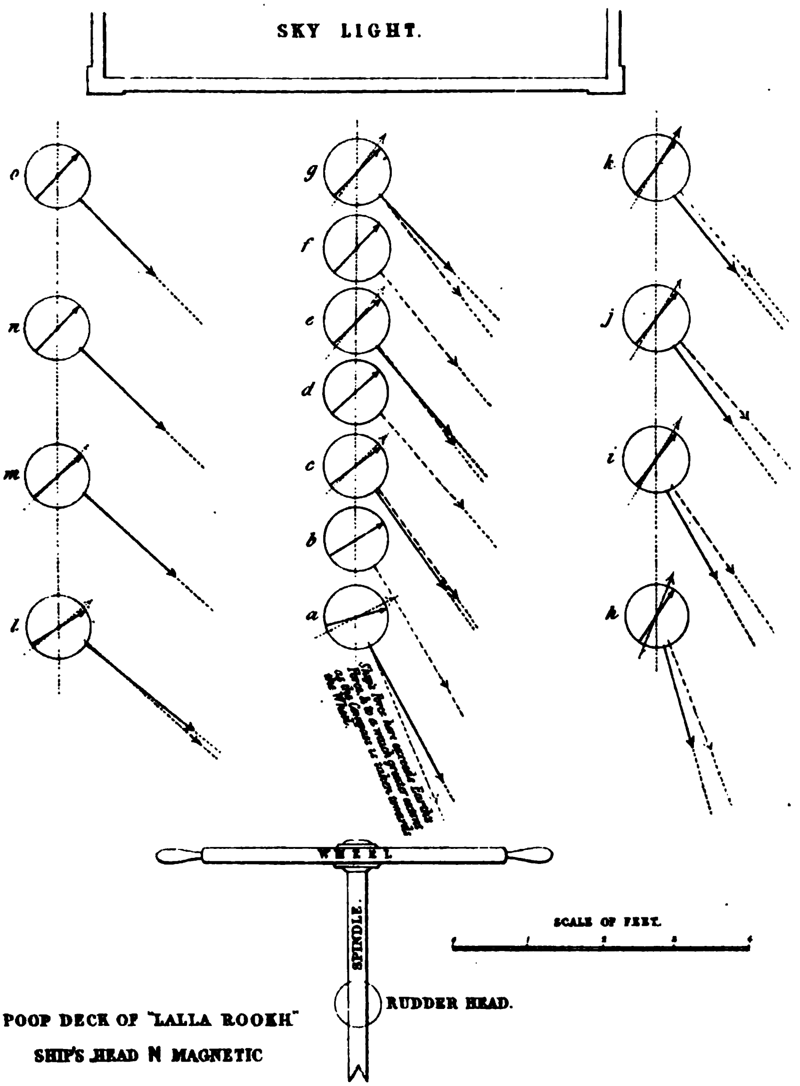
-------Curve gives the Deviations of the Steering Compass (placed the same distance forward as the last, but rather nearer the deck) after partial compensation of transverse magnetism, *over* compensation of fore-and-aft magnetism and perfect compensation of quadrantal magnetism.

No. II.

DIAGRAM



"LALLA ROOKH"



The small arrows show the direction of the Compass-needle in each position at 3 feet from the Deck, and the dotted arrows at 4 feet from the deck.

The long arrows indicate the direction and relative value of the ship's force the broken ones at 3 feet, the unbroken at 4 feet from deck.

J. Bien, photo lith

N° 6

"NAUPHANTE."

Explanation on opposite page.

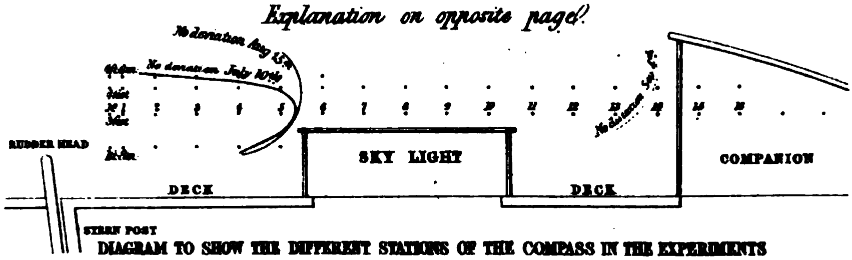


DIAGRAM TO SHOW THE DIFFERENT STATIONS OF THE COMPASS IN THE EXPERIMENTS ON BOARD THE "NAUPHANTE" BEFORE AND AFTER THE LAUNCH.

	Height above Deck.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		DISTANCE OF COMPASS FROM FORE PART OF STERN POST "NAUPHANTE"															
HEAD E ½ S		ft. in. 1·6	ft. in. 2·6	ft. in. 3·6	ft. in. 4·6	ft. in. 5·6	ft. in. 6·6	ft. in. 7·6	ft. in. 8·6	ft. in. 9·6	ft. in. 10·6	ft. in. 11·6	ft. in. 12·6	ft. in. 13·6	ft. in. 14·6	ft. in. 15·6	ft. in. 16·6
July 10th 1856 on the Building Slip. No Rudder	ft. in. 1·6	23½ W	40½ W	46½ W	18½ W	21½ E	23½ E										
Aug 12th Rudder in place, but not completed	"	64½ W	61½ W	58½ W	30½ W	16½ E											
Aug 15th Rudder touched, hammering done on board	"	66 W	64½ W	61 W	31½ W	19 E											
Sep. 3rd Head E b S after Launch	"	40½ W	48 W	41½ W	19½ W	4 W											
Sep. 4th	"	29 W	46½ W	30 W	20½ W	1 W											
July 10th Building slip	3 feet	21½ W	13½ W	13½ W	7½ W	3½ W	5½ E										
Aug 12th Rudder in place	"	40 W	33 W	25½ W	14 W	2 W	1½ W	1° E	2° E	13½ E							
Aug 15th Rudder riveted, much hammering & vibration of stern during these experiments	"	42 W	36¾ W	29½ W	16½ W	3¾ W	3½ E										
	"	41½	36½	28½	17	2½ W	2½ E										
Sep. 3rd after launch Head E b S.	"	34 W	29½ W	25½ W	15½ W	9 W	6¾ W	6½ W	7 W								
Sep. 4th	"	33 W	29½	23½ W	17½ W	8½ W	7¾ W	8½ W	7 W	7½ W	8½ W	9 W	7½ W	½ W	1¾ E	1½ W	2 W
July 10th Building slip	ft. in. 4·5½	1½ W	1½ W	1½ E	1½ E	5 E											
Aug 12th	4 ft.	18½ W	15 W	12 W	6½ W	2½ W	½ W										
Aug 15th	4 ft.	21 W	18 W	16 W	9½ W	3½ W	1½ E										
Sep. 3rd after launch	"	21½ W	20½ W	17½ W	13 W	10 W	7½ W	7½ W	6 W								
Sep. 4th	"	21 W	18¾ W	15½ W	12½ W	9 W	7½ W	5½ W	6½ W	5½ W	5¾ W	5¾ W	2¾ W	2¾ W	0	½ W	½ W
HEAD SOUTH																	
Sep. 13th Head S b W	ft. in. 1·6½	7·5 W	7·5 W	9 W	12 W	17 W											
Sep. 3rd	3 ft.	4½ W	5 W	6½ W	8 W	7 W	8½ W	9 W	9 W								
" 17th	3 ft.	8·1 W	8 W	8·8 W	10 W	11·7 W	11·7 W	11·8 W	11·3 W								
" 3rd	4 ft.	5½ W	6 W	6½ W	7 W	7½ W	7¾ W										
" 17th	4 ft.	7·5 W	7·8 W	8·7 W	9·1 W	9·7 W	11·1 W	11 W	11·2 W								
HEAD WEST																	
Aug 20th Head W b E	ft. in. 1·8½	49 E	34 E	28½ E	22 E	10 E	0										
Sep. 1st	"	44 E	34·6 E	29·5 E	23 E	6·5 E	4 E										
Aug. 20th	3 ft.	21 E	17¾ E	13 E	8 E	5 E	4 E										
Sep. 1st	"	21·8 E	17·6 E	12·8 E	6·5 E	2·8 E	1·7 E	2·8 E	2·3 E	1·8 E							
Aug 20th	4 ft.	15 E	11½ E	9 E	8 E	5 E	4½ E										
Sep. 1st	"	13 E	11·2 E	8 E	5·2 E	2 E	2 E										
HEAD NORTH																	
Sep. 3rd Head N b E	3 ft.	18 E	16 E	15 E	13¾ E	14 E	13½ E	13½ E	13½ E	13½ E							
Sep. 3rd Head N b E	4 ft.	12¾ E	12½ E	11¾ E	11½ E	11½ E	11 E	10¾	14½								

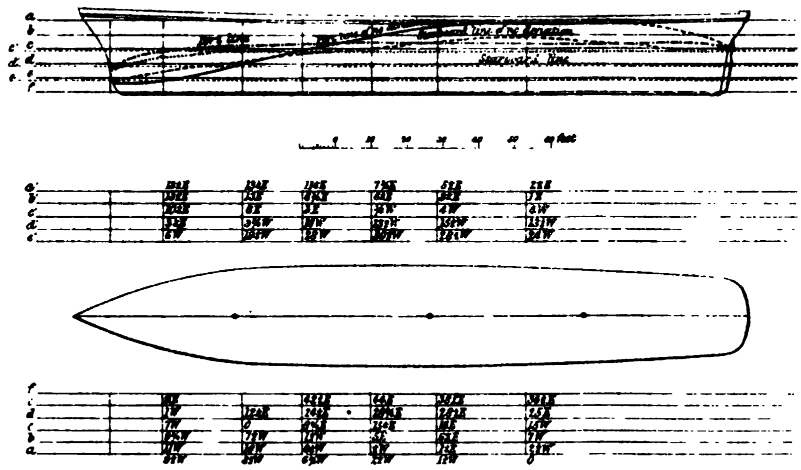
J. Bien, photo lith

"NAUPHANTE."

BUILT HEAD EAST.

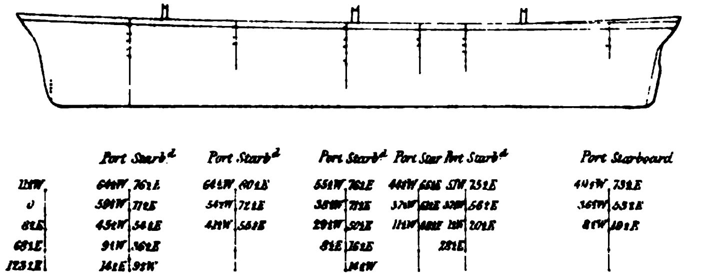
Lines of no deviation obtained in the Brunswick Graving Dock.

Head S 8¼ W.



——·——·——·—— .... lines are lines of no deviation as obtained by a compass let down over the side at a distance of two feet only. This distance probably gives a more correct delineation of the neutral plane of the ship but it is not so convenient for experiment as the steps of the graving dock, neither does it admit of so much accuracy of observation.

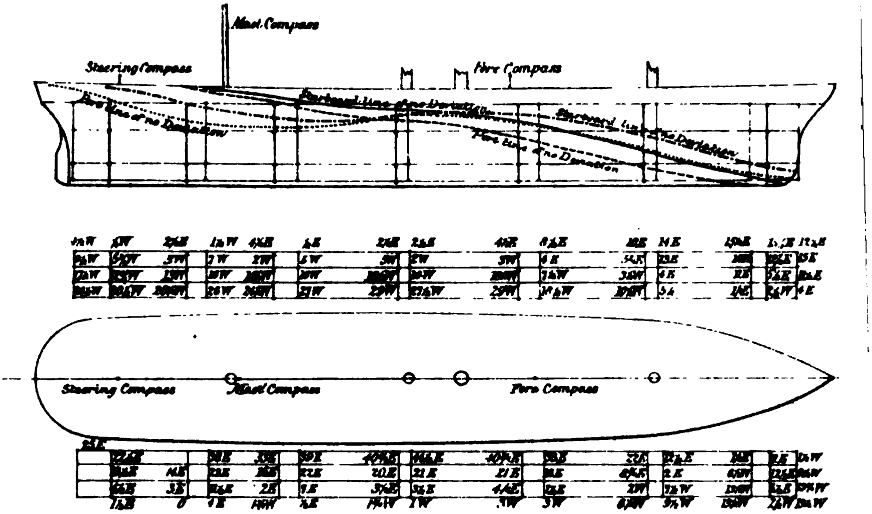
The diagram placed below gives the deviations which were actually observed September 12 1856.



S. S. BŒOTIA

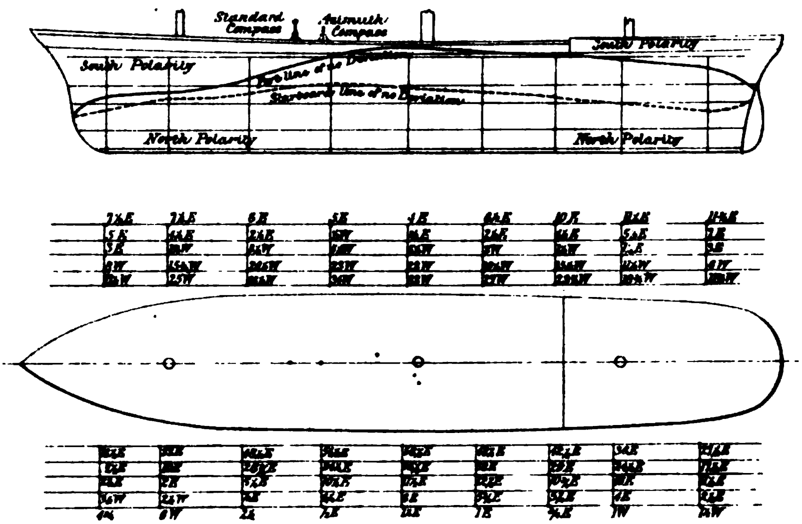
Sandon Graving Dock Head N.N.E.

——— *lines show curves of no Deviation when new April 2.56* - - - - - *lines show curves of no Deviation after two voyages to the Mediterranean. Sept^r 8·1856.*



SARAH PALMER. IRON SAILING SHIP BUILT N 76° E

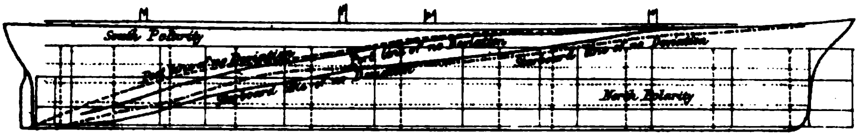
In Sandon Graving Dock. July 12·1856. after a voyage to the East Indies. Head S,S,W.

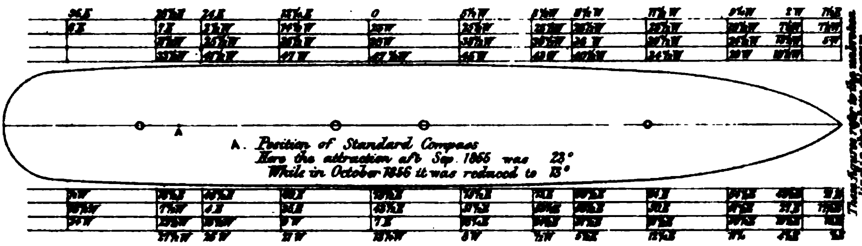


J. Bien, photo lit

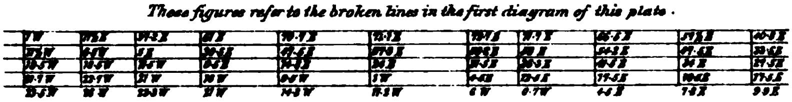
S.S. CITY OF WASHINGTON.

Sandon Graving Dock Head, N.N.E.





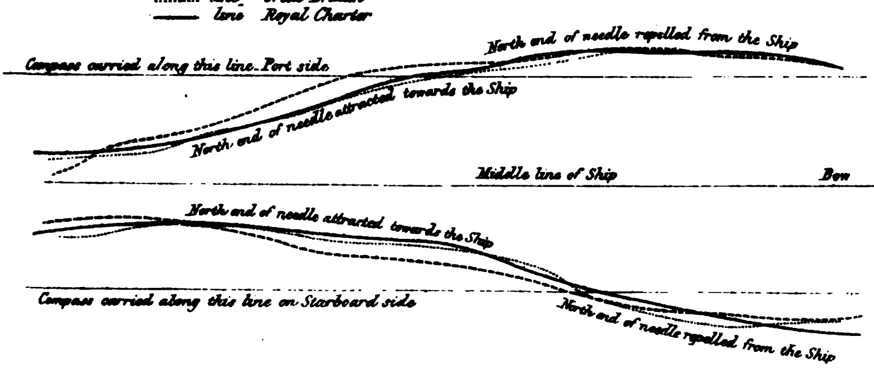
These figures refer to the broken lines in the first diagram of this plate.



——— *lines and figures were obtained January 1856.*
- - - - *lines and figures, October, 1856. During the intervening period the ship was in constant service in the Mediterranean, &c.*

It will be observed on reference to the drawings of the City of Washington, the Great Britain and the Royal Charter, that they very much resemble each other in the distribution and amount of their magnetism. Below is represented graphically the deviation of a compass needle caused by each at a distance of 40 feet from the centre line and about 26 feet above the level of the keel.

- - - - - *line* *City of Washington*
.... *line* *Great Britain*
——— *line* *Royal Charter*



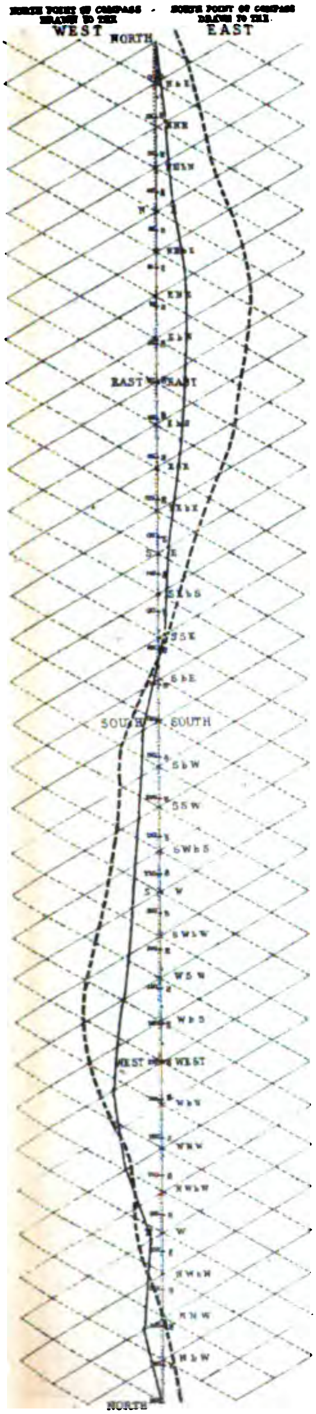
J. Bien, photo lith.

S. S. ETNA.

No. I.

Mast & Standard Compasses not Compensated.

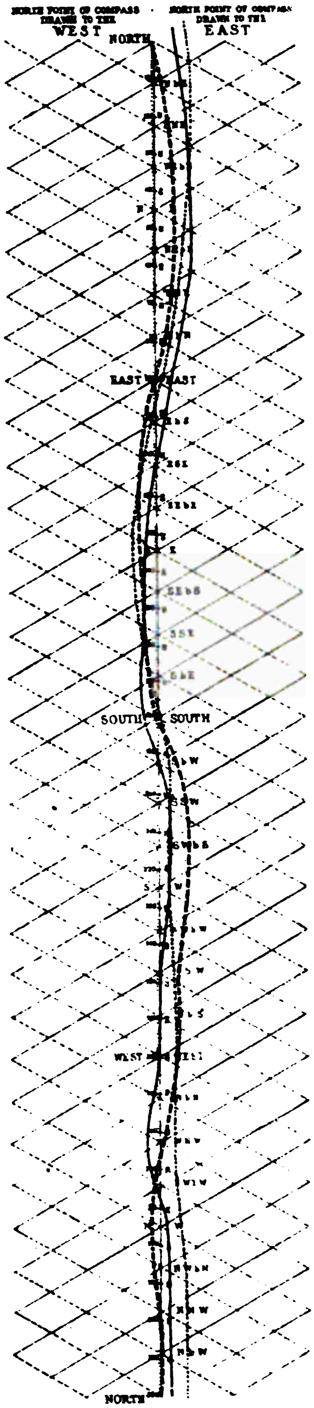
DIAGRAM



No. II.

Compensated Compasses.

DIAGRAM



Deviations as copied from the Cards supplied when the Ship was swung, January, 1856.

Not Compensated .... No. I. { ——— Curve - Mast Compass. / - - - Curve - Standard Compass.

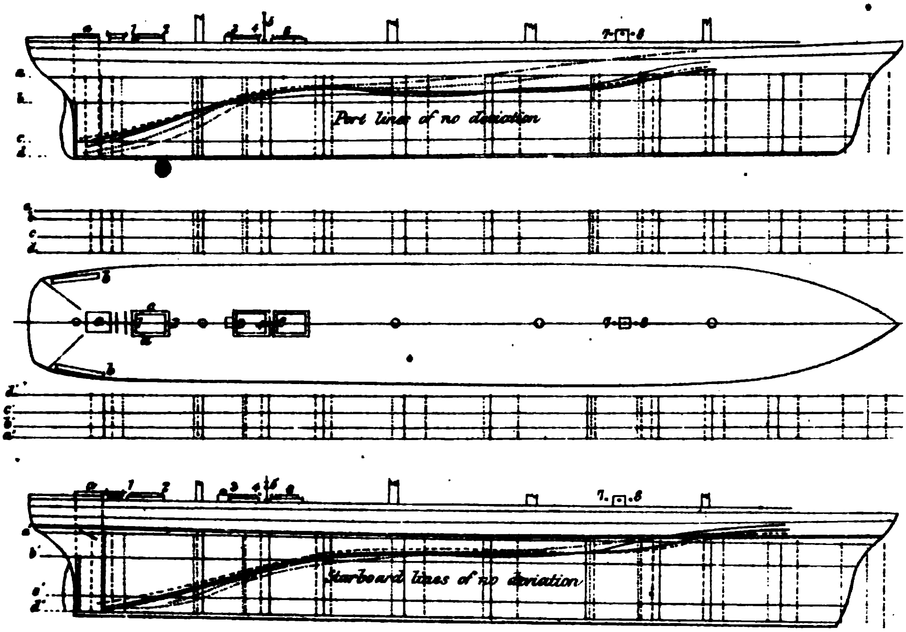
Compensated Compasses ...... No. II. { - - - Curve - Bridge Compass. / .... Curve - Fore Main-deck Compass. / ——— Curve - Aft Main-deck Compass.

These show the characteristic curves of a ship built head to south and west.

The Compensated Compasses show a considerable amount of quadrantal deviation.

The Standard and Compensated Compasses show an average index error of nearly a quarter of a point, most probably from local attraction on the Shore Compass.

"GREAT BRITAIN"



S.S. "Great Britain." Experiments to determine the direction of her Lines of No Deviation with her head turned in opposite directions. (In the Sandon graving Dock No. 2.)

————— Lines were obtained January 24, 1856, after she had been with her head N.N.E. for eleven days.

.... Lines, December 10, 1856, after being in graving Dock, head N.N.E., for one hundred and twenty-seven days, during which time new and very heavy stern-posts had been fitted, and a sort of well or shaft through which to raise the screw, extending nearly two feet above the poop,—marked *a* in the figures.

————— Lines were obtained two days later, her head having meanwhile been turned S.S.W.

————— Lines were noted January 6, 1857, after lying head S.S.W. for twenty-five days; and

- - - - - - - - Lines eighteen days later, during which time the ship was removed from the dock and again put in on the next tide.

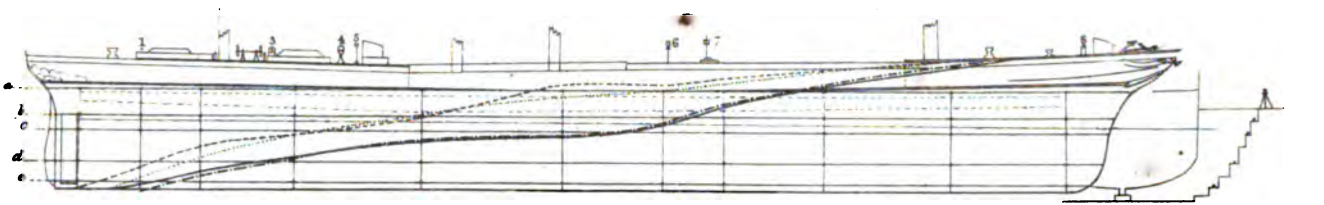
From August 5, 1856, to January 24, 1857, a great number of workmen were constantly employed, and the ship was subject to daily small concussions and vibrations.

Vibration experiments were also tried at frequent intervals at the stations indicated by the numbers 1, 2, 3, 4, 5 and 6

J. Bien, photo lith

ROYAL CHARTER

Sandon Graving Dock Head, N. 22½ E.

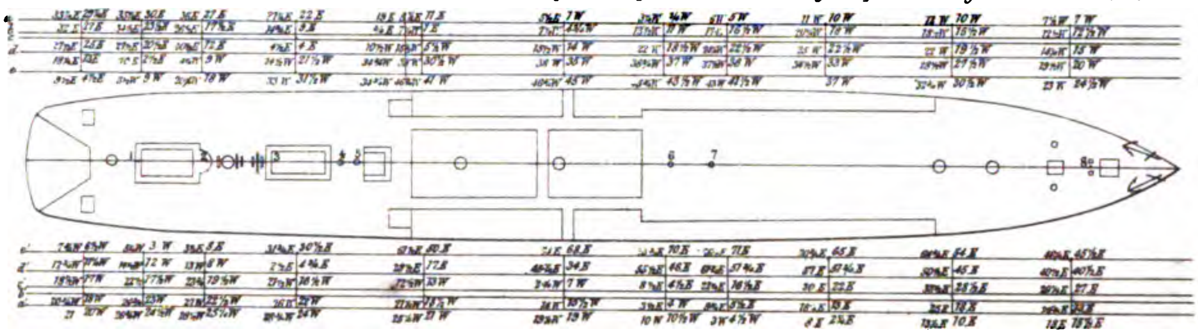


Half Section of Graving Dock. The dots indicate the positions of the Compass in the steps of the Dock.

Port line of no Deviation { - - - - - line as observed August 23. 1856. / .... line as observed September 16. 1856. (Screw in place)

Starboard line of no Deviation { ——— line as observed August 23. 1856. / —·—·— line as observed September 16. 1856. (Screw in place)

Figures to the right show the deviations Aug. 23. 1856. and the left figures as observed Sept.r 16 1856. in the intervening time about 50 tons weight of iron plates were added along the space marked by broken horizontal lines

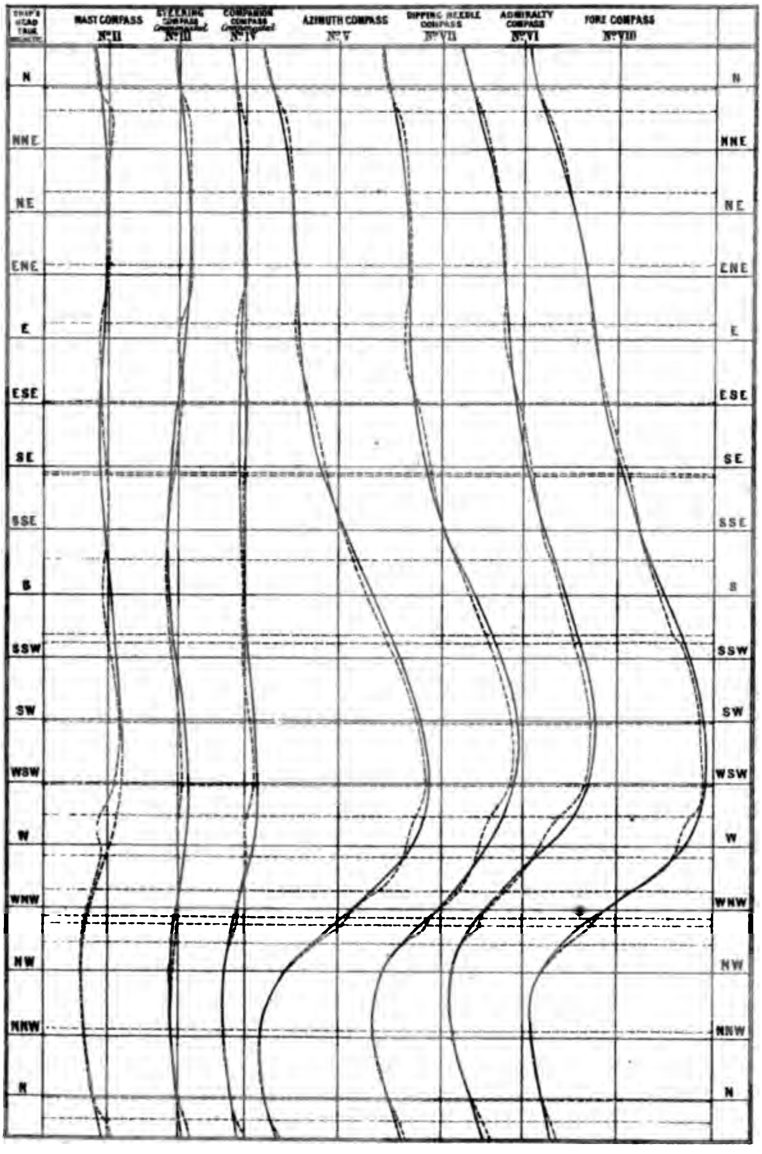


Note. *While the Ship was in graving dock about 50 tons weight of iron plates (double) were added to the sides of the ship between the parts of ships side which are indicated by the broken horizontal lines.*

J. Bien, photo lit

DIAGRAM TO SHOW THE EFFECT OF ERRORS IN THE SHORE COMPASSES, DURING THE SWINGING OF THE ROYAL CHARTER. JANUARY 1856.

Broken horizontal lines show the direction of ship's head when each observation was made, & broken curves exhibit the corresponding deviations for each compass. Unbroken curves are an attempt to indicate the more probable deviations, and are drawn so as to make the errors due to the shore compasses correspond in each as nearly as possible. They probably give the ship's polar magnetic force somewhat in excess.

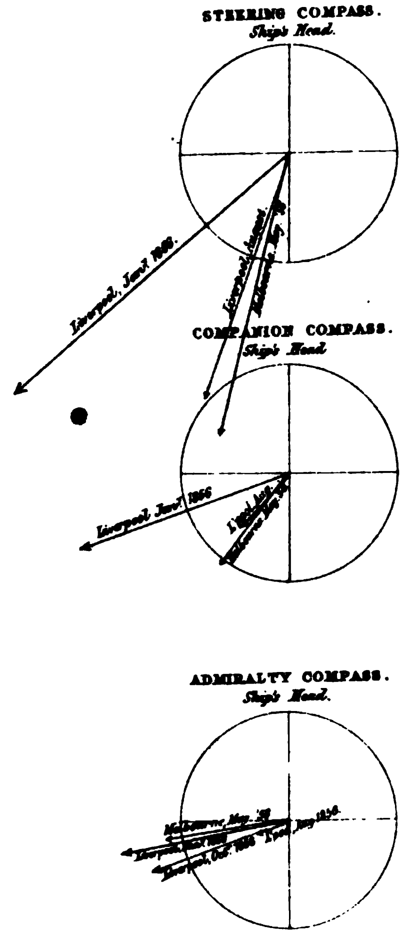


J. Bien, photo lith.

N°18

ith.

"ROYAL CHARTER"



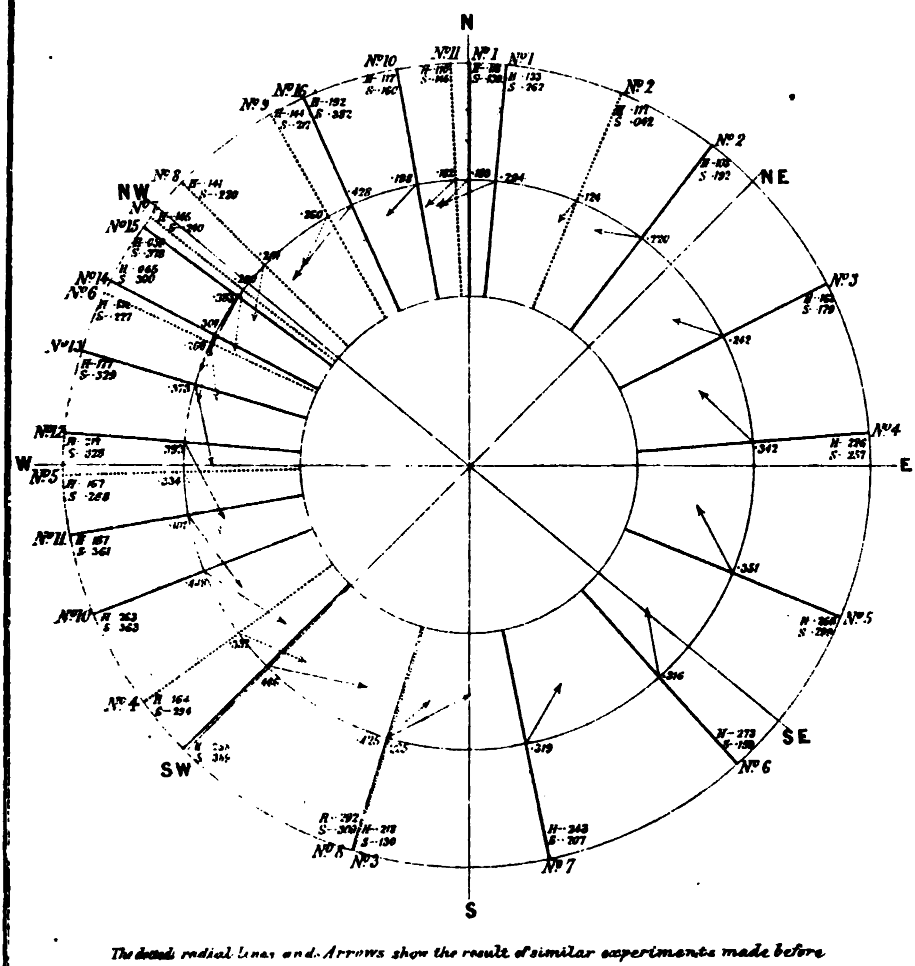
The arrows show relative force and direction of Magnetism of Royal Charter at the position of each compass, and at the times indicated.

J. Bien, photo lith.

ROYAL CHARTER

This diagram gives a graphic representation of the result of the experiments which are tabulated on the preceding page.

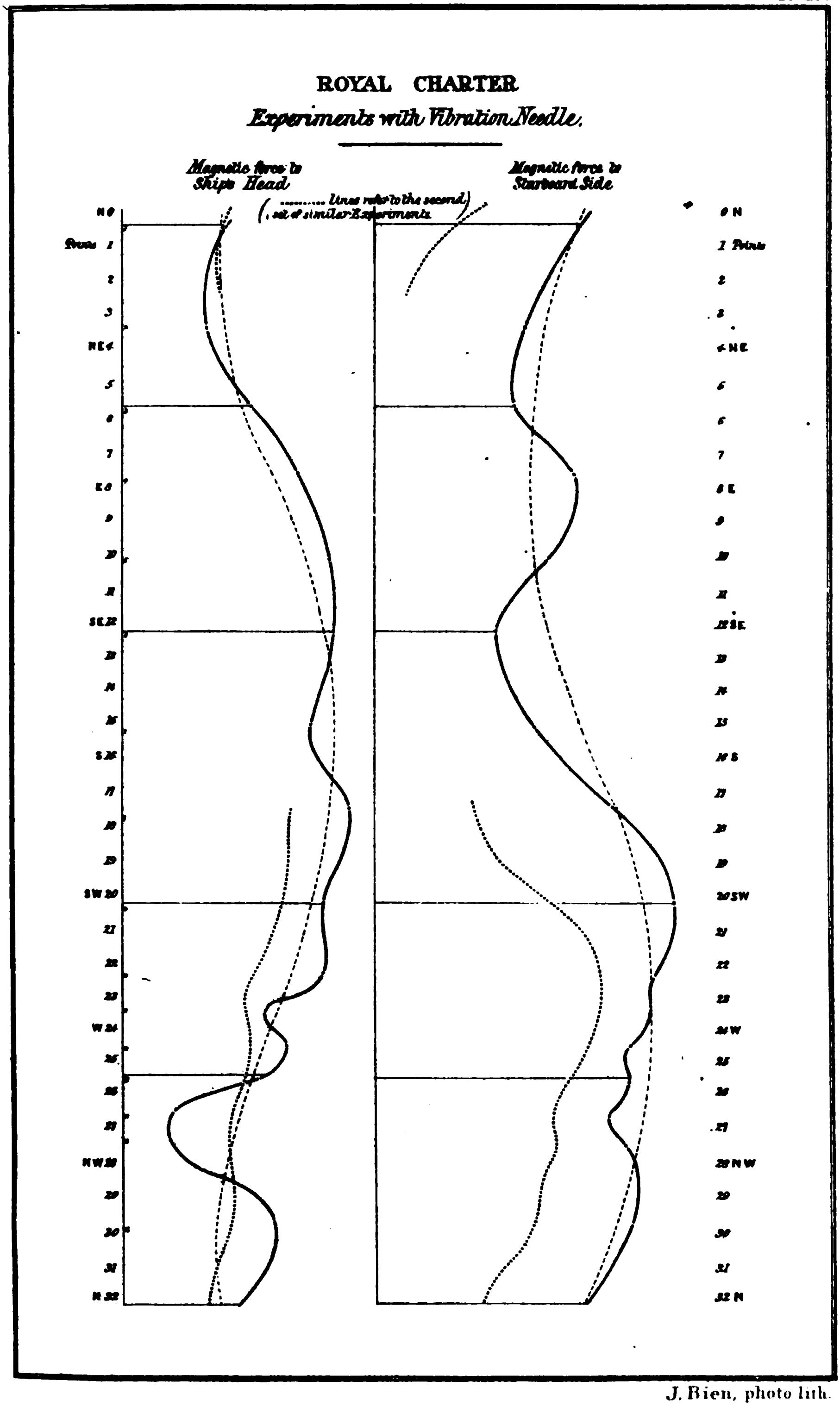
The radial lines show position of the ship – the Arrows represent force and direction of ship's Magnetism for each position. –



The dotted radial lines and Arrows show the result of similar experiments made before the Ship sailed on the second voyage, and indicate the reduction which took place in the Ship's Magnetism.

The figures give value of Ship's force, Earths horizontal force being taken as one – the figures with H & S. against them show relative force of **Head** *and* **Starboard**, *respectively.*

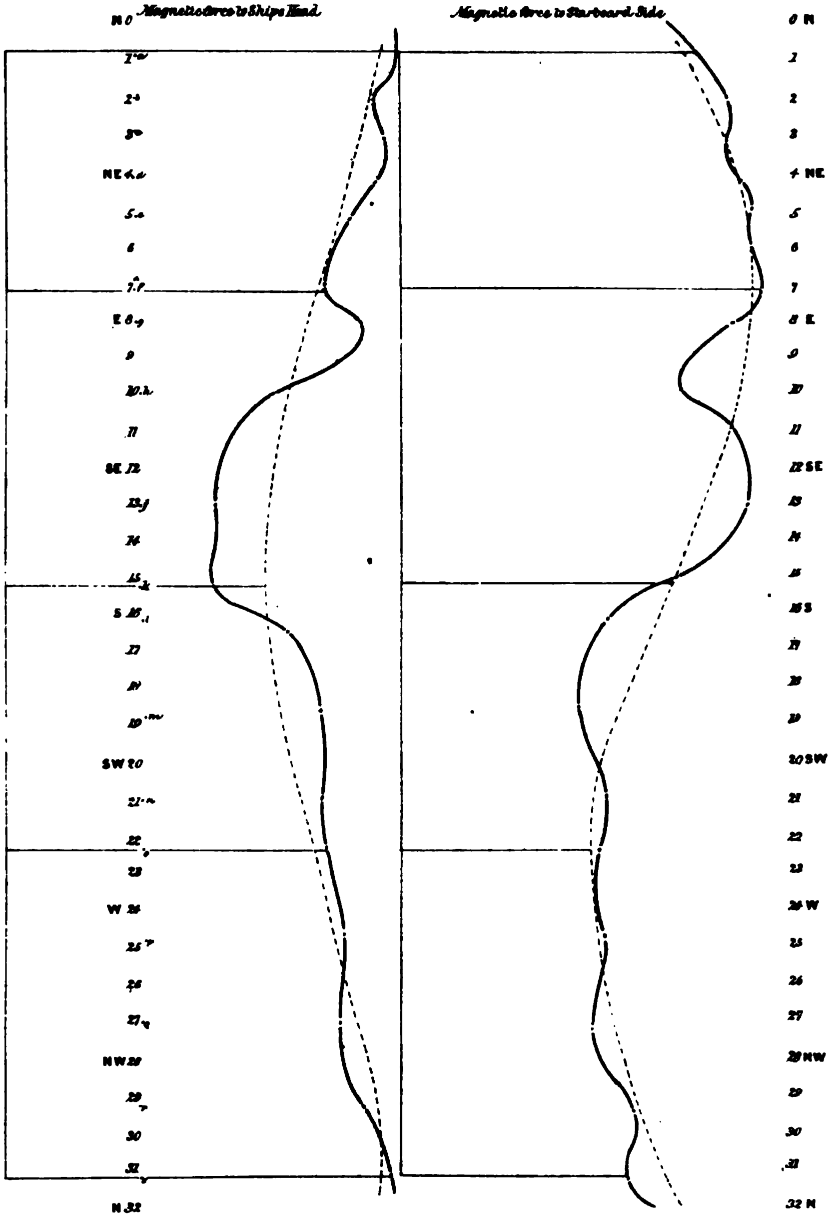
J. Bien, photo lith.



J. Bien, photo lith.

IRONSIDE

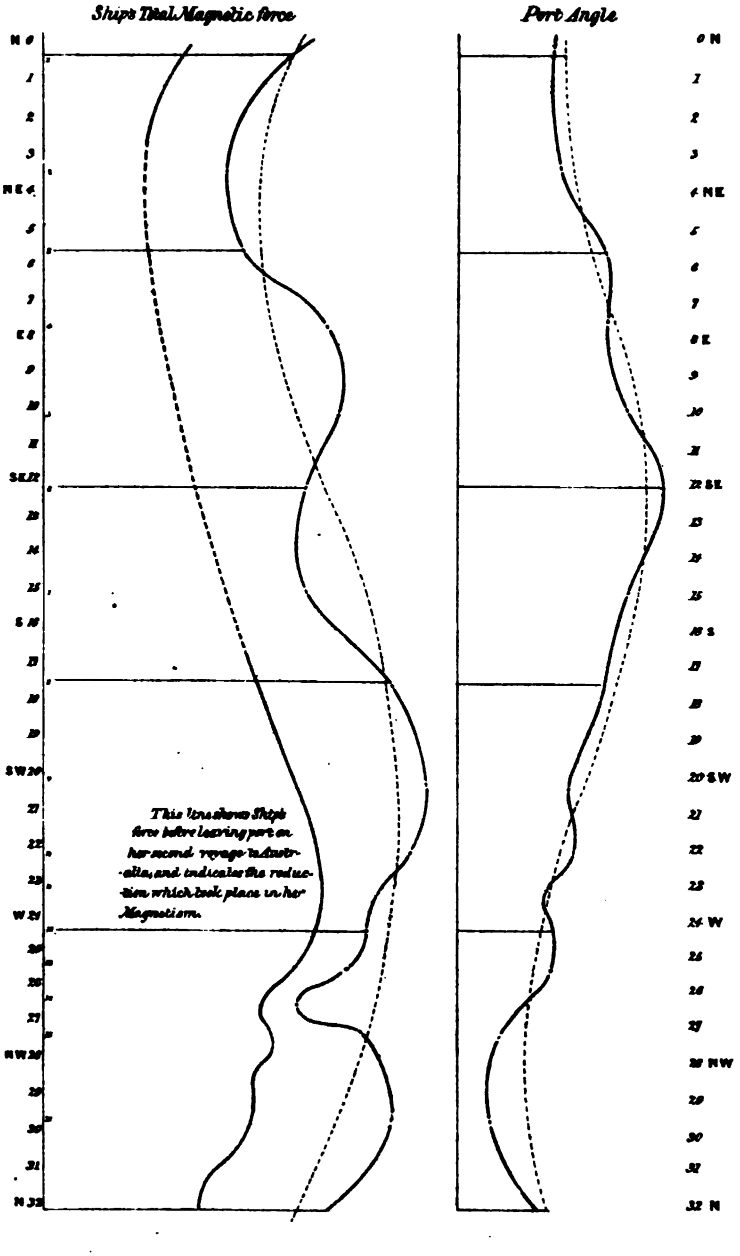
Mr Airy's Experiments.



J. Bien, photo lith

ROYAL CHARTER

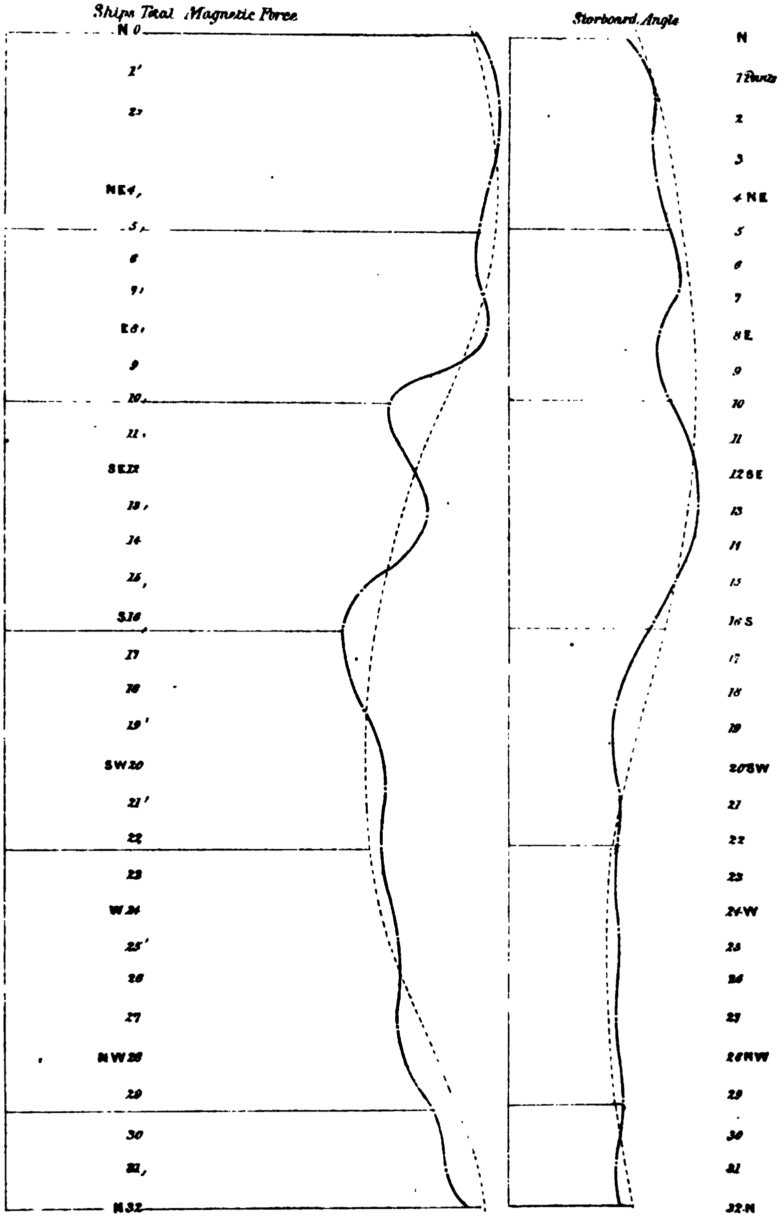
Experiments with Vibration Needle



J. Bien, photo lith.

IRONSIDE

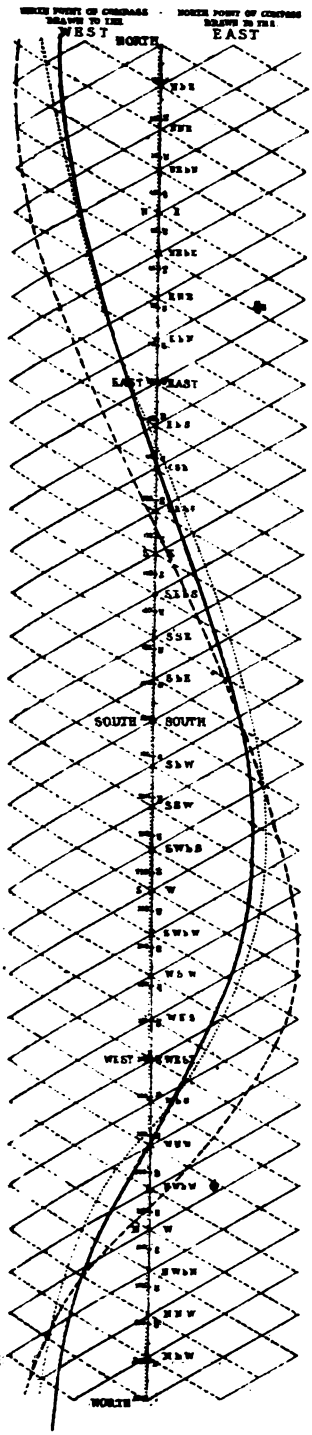
Mr. Airy's Experiments



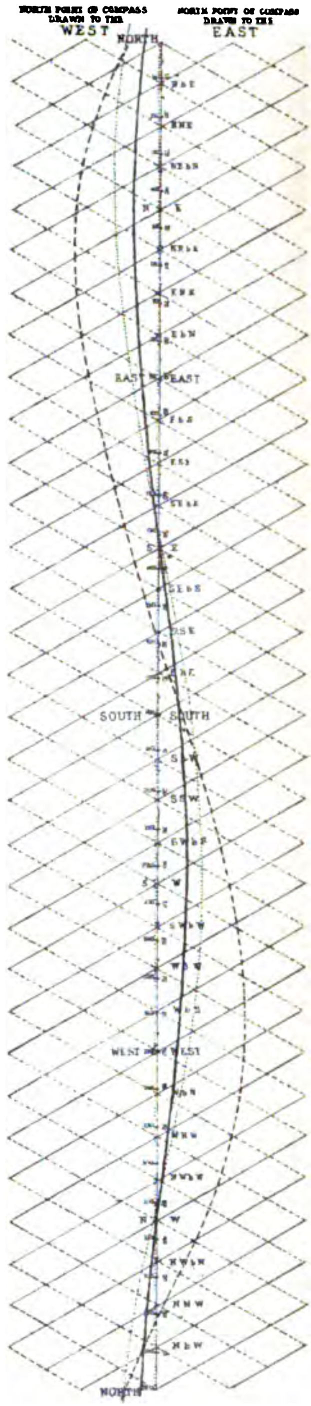
J. Bien, photo lith.

"ROYAL CHARTER"

No. 1.
Steering Compass
DIAGRAM



No. 11.
Companion Compass.
DIAGRAM



Nos. I. & II.—*Polar Deviations of Compensated Compasses.* No. *I.*—*Steering Compass.* No. *II.*—*Companion Compass.*

- - - - Curves—Approximate before leaving Liverpool.
.... Curves—Deviations observed at Melbourne.
——— Curves—Deviations on ship's return to Liverpool.

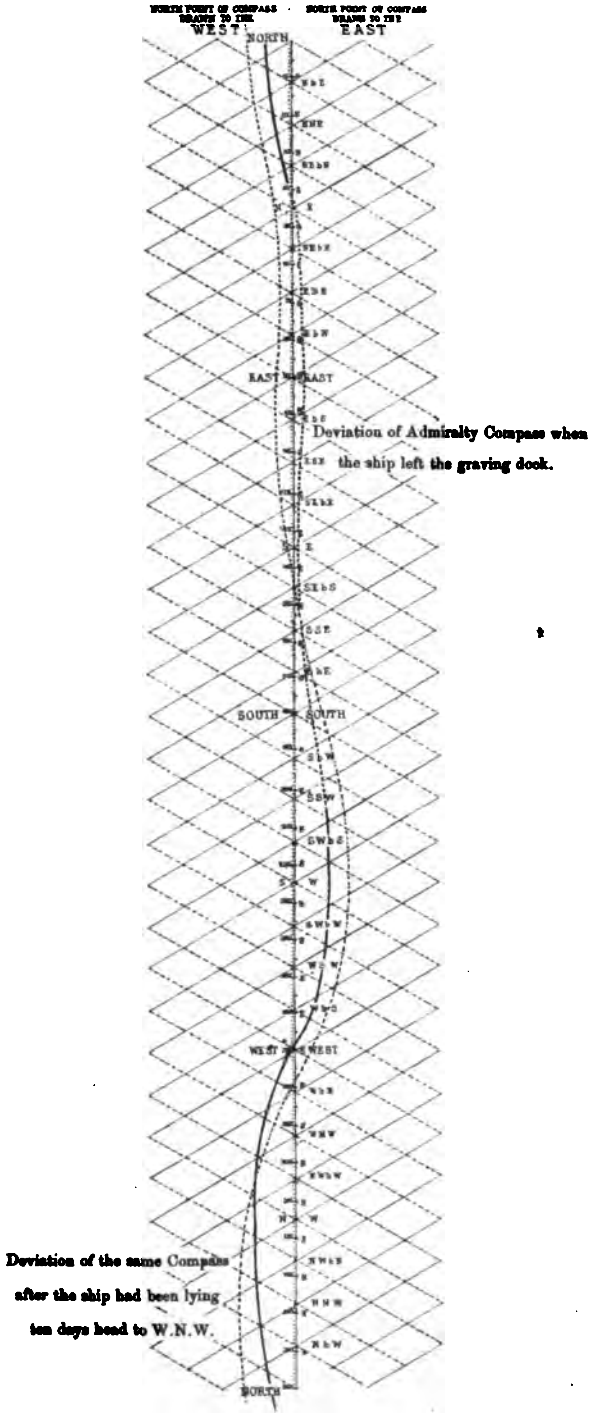
J. Bien, photo lith.

"ROYAL CHARTER"

Nº 111

Admiralty Compass

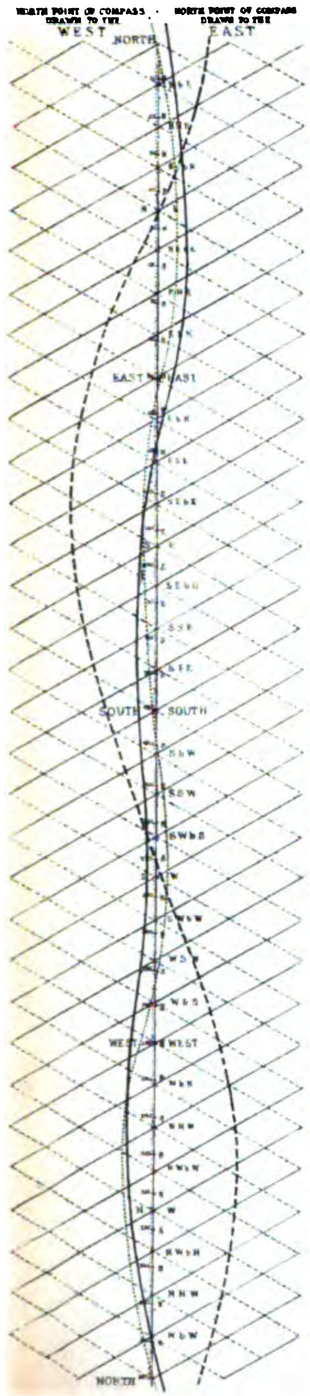
DIAGRAM



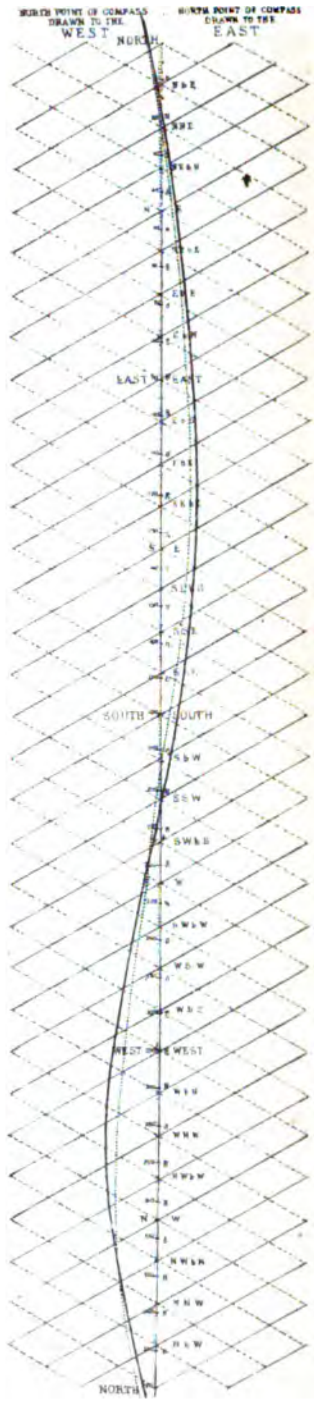
The dotted portions of the curves are interpolations.

S. S. BŒOTIA.

No. 1
Steering Compass.
DIAGRAM



No. 11
Mast Compass
DIAGRAM



No. 1.—*Curve of Deviations of Compensated Steering Compass, interpolated from three observations during voyage from Grimsby to Liverpool,* (-------- *Curve*) *indicating rapid change in ship's magnetism.*

——— Curve—Deviations of the same Compass, with the Magnets removed, from observations made immediately before the ship sailed on her first voyage to the Mediterranean.

.... Curve—Deviations of same Compass after the ship had traded to the Mediterranean for five months.

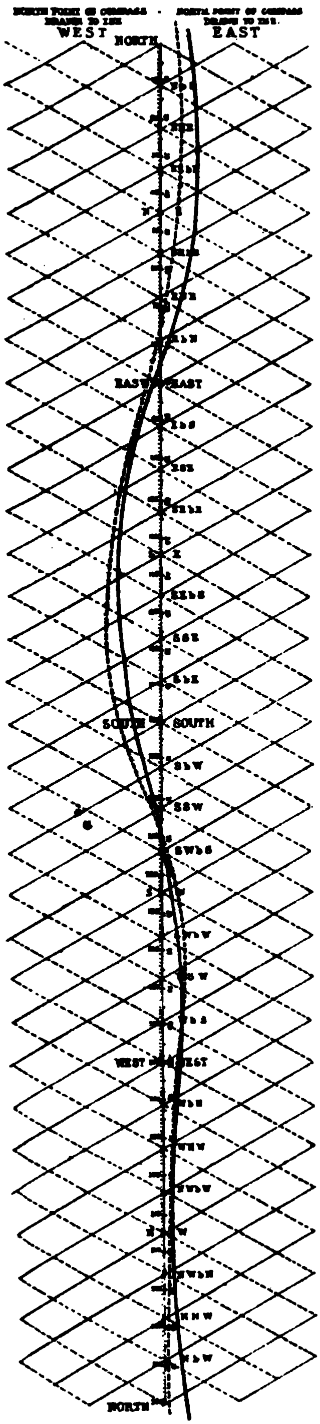
J. Bien, photo lith.

No. III

Fore Compass.

(Compensated)

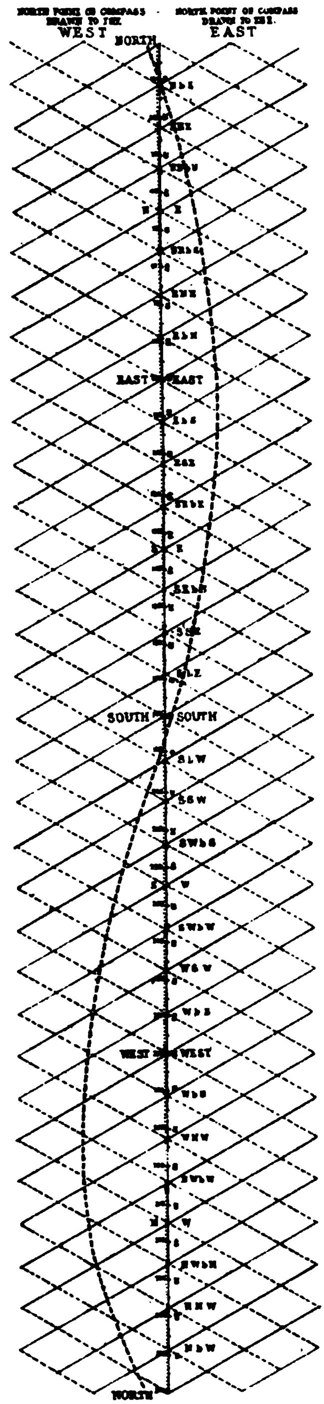
DIAGRAM



No. IV

Extra Compass.

DIAGRAM



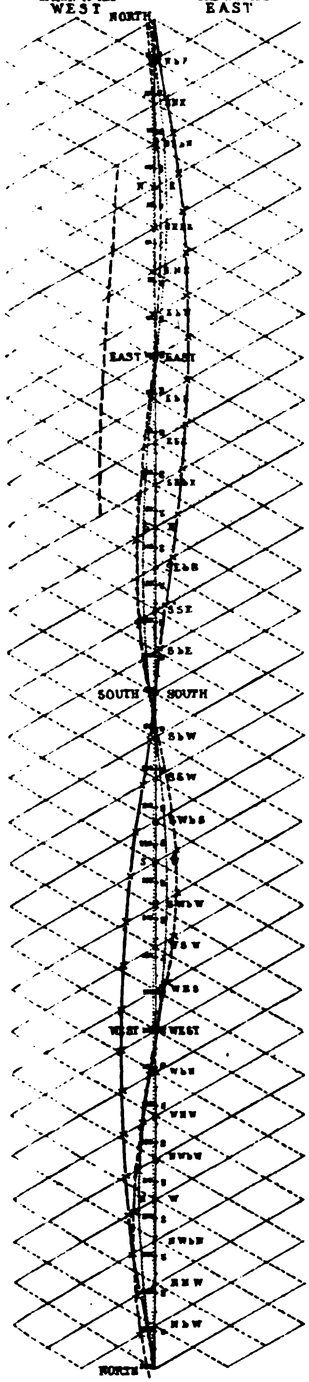
No. II. and No. III.—*Deviations observed at same times for Mast Compass, and for Compensated "Fore Compass."*

All indicate a change in the ship's magnetism.

No. IV.—*Deviation of Uncompensated Compass placed a few feet further forward than the Steering Compass, and higher from the deck, to show increased attraction toward ship's head, as the Compass is moved forwards in ships built with head more or less to the South.*

Nº I.
S.S. IONIA.
DIAGRAM

NORTH POINT OF COMPASS DRAWN TO THE WEST · NORTH POINT OF COMPASS DRAWN TO THE EAST



No. I.—*Deviations of Compasses of S.S. "Ionia," October, 1856.*

- - - - - - - -Curve - Steering Compass, compensated for polar deviation only.

Portion of - - - - - - - -Curve - Deviations of Steering Compass on voyage to Liverpool.

........Curve - Compass compensated for polar deviation only.

———Curve - Mast Compass; no compensation. It shows only an attraction towards the bow, and a small amount of plus quadrantal.

No. II.—*Deviations of Compasses of S.S. "St. Andrew."*

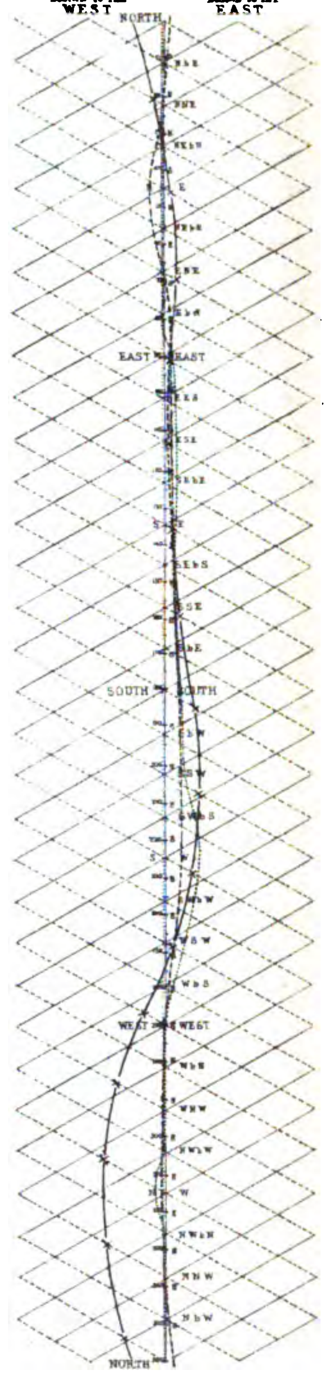
- - - -Line - Elevated Compass, not compensated.

......Line - Deviations of Steering Compass, as given in Deviation Table, August 29, 1856, after compensation by magnets only.

———Line - Deviations of Steering Compass, as observed by the Captain, off Oporto, November 23, 1856, from 16 azimuths of the sun. Variation allowed, 22° W.

Nº II.
S.S. "SAINT ANDREW."
DIAGRAM

NORTH POINT OF COMPASS DRAWN TO THE WEST · NORTH POINT OF COMPASS DRAWN TO THE EAST



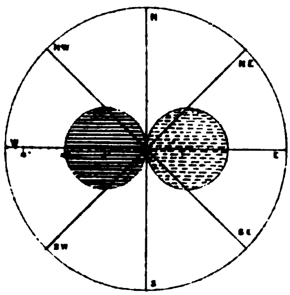
J. Bien photo lith

DIAGRAMS
OF
POLAR & QUADRANTAL DEVIATIONS.

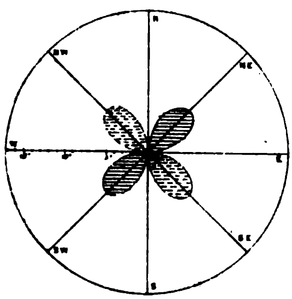
(Described on the preceding page)

The same deviations are exhibited on the following Plate. The numbers and descriptions correspond in each of them.

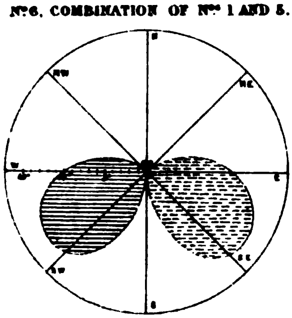
Nº 1, ATTRACTION TOWARDS SHIP'S STERN.



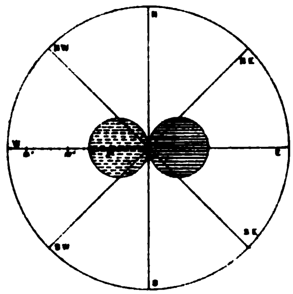
Nº 5. PLUS QUADRANTAL ATTRACTION.



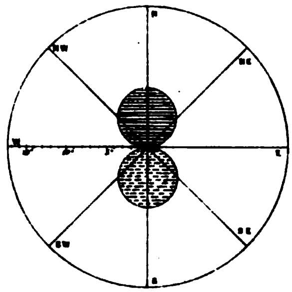
Nº 6. COMBINATION OF Nºs 1 AND 5.



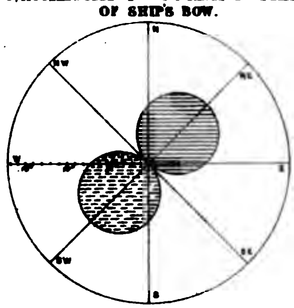
Nº 2. ATTRACTION TOWARDS SHIP'S BOW.



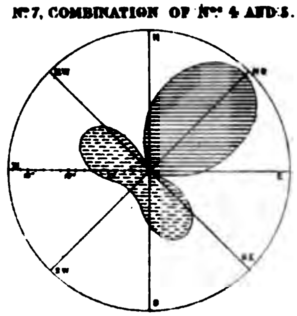
Nº 3. ATTRACTION TOWARDS STARBOARD SIDE.



Nº 4. ATTRACTION FOUR POINTS TO STARBOARD OF SHIP'S BOW.

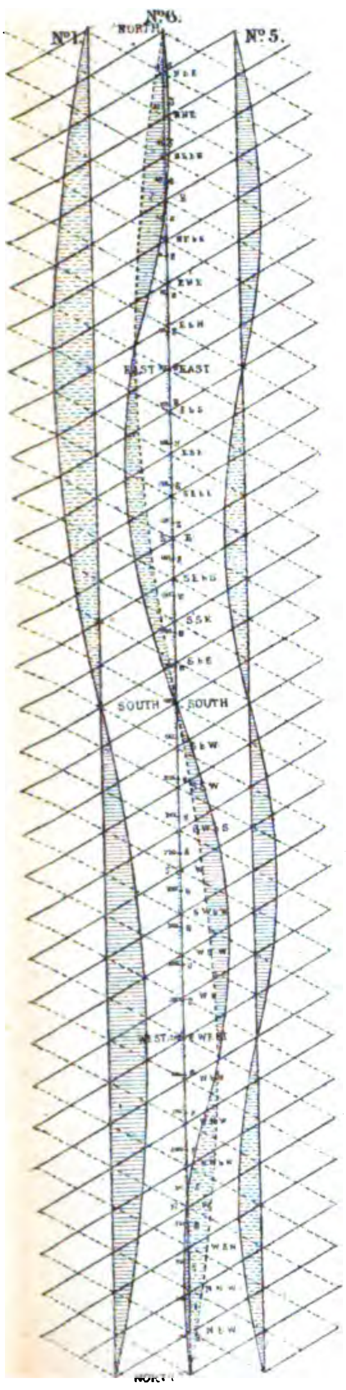


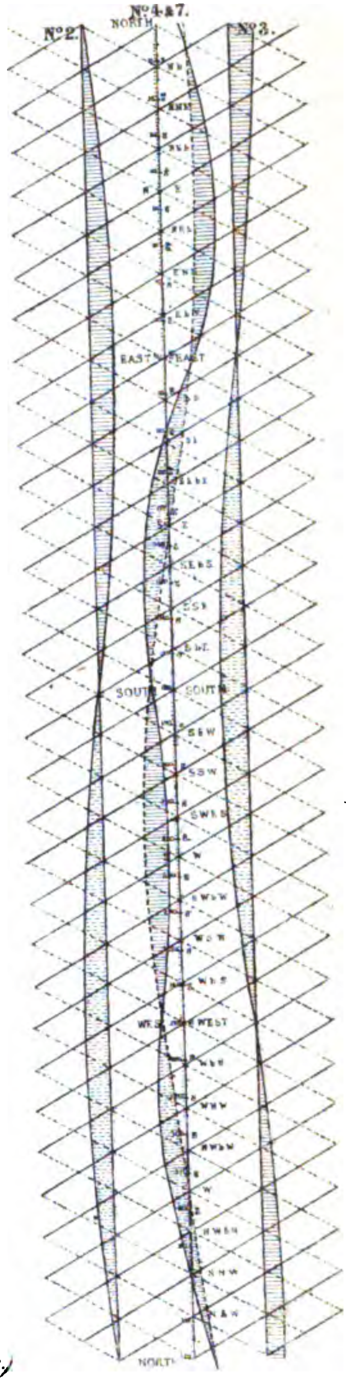
Nº 7. COMBINATION OF Nºs 4 AND 5.



J. Bien, photo lith.

DIAGRAM OF POLAR & QUADRANTAL DEVIATION.



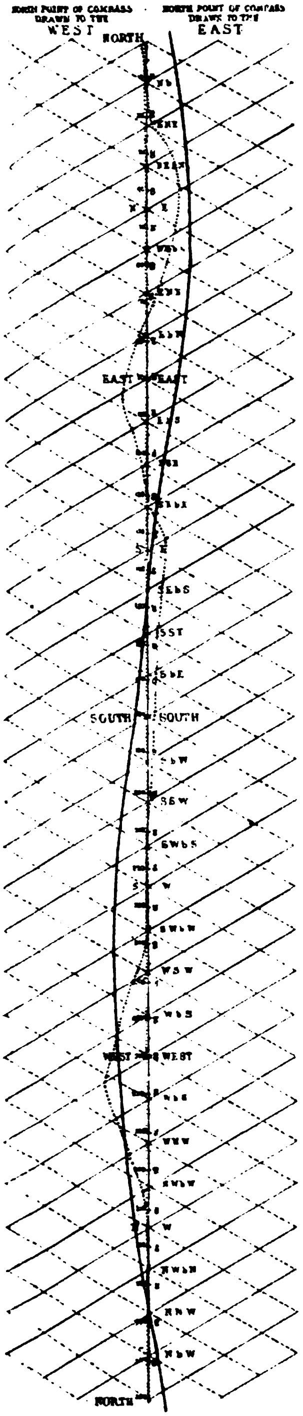


(See preceding Plate.)

Nº I.

MEXICANA.

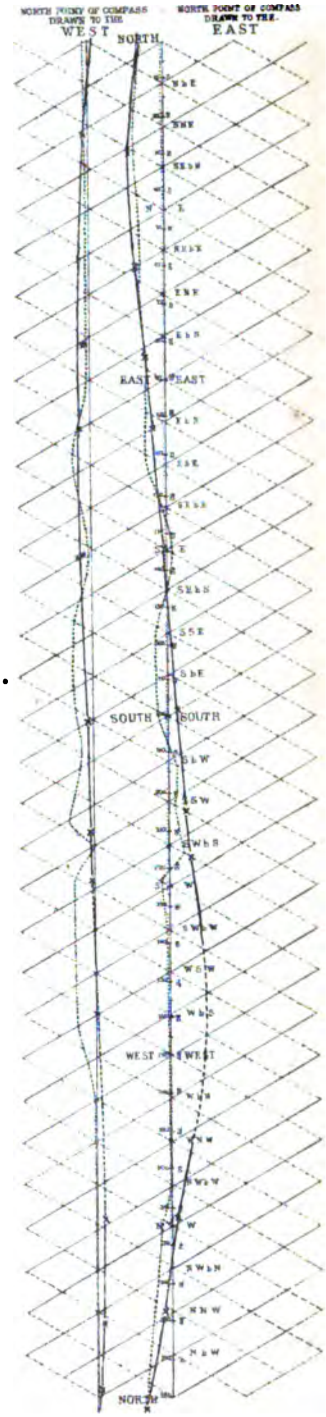
DIAGRAM



Nº II.

SAPPHO.

DIAGRAM



No. I.—"*Mexicana.*" *Compensated Steering Compass.*

........Curve - Deviations (improbable) as given by the Compass Adjuster before the ship left Scotland for Liverpool.

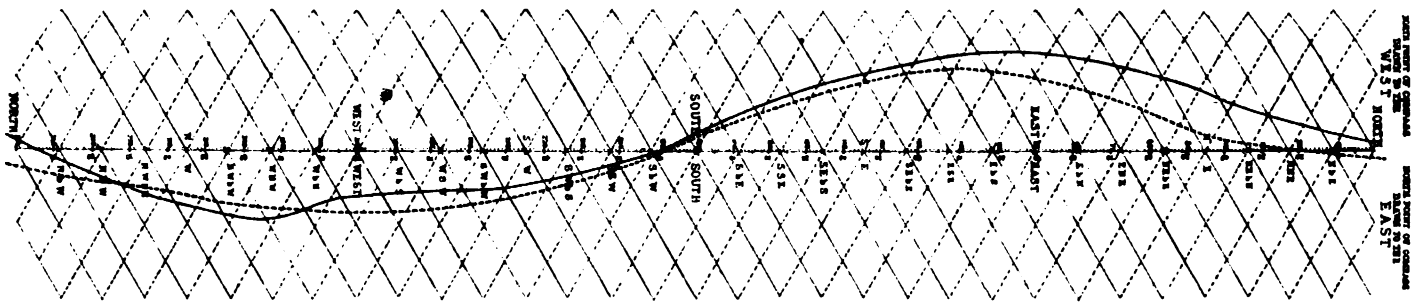
——Curve - Deviations of the same Compass as obtained in the River before the vessel sailed from Liverpool.

No. II.—"*Sappho.*" *Compensated Steering Compass and Mast Compass.*

........Curves show the Deviations of each as given by the Compass Adjuster. The peculiar flexures, corresponding to each other in both curves, indicate error in the Shore Compass.

——Curves indicate the Deviations of the same Compasses, at the same time, as obtained by azimuths of the sun. (There were no azimuth observations between S.W. and N.W. The dotted parts of the black curves are interpolations.)

J. Bien, photo lith.



No. 1.—*Ship "Prospero."*

———— Curve - Deviation curve of Bridge Compass at Bristol, before sailing for Liverpool. (Shows large index error.)

.... Curve - Deviations for the same Compass after ship's arrival at Liverpool, with index error corrected, showing decrease in ship's magnetism.

No. II.

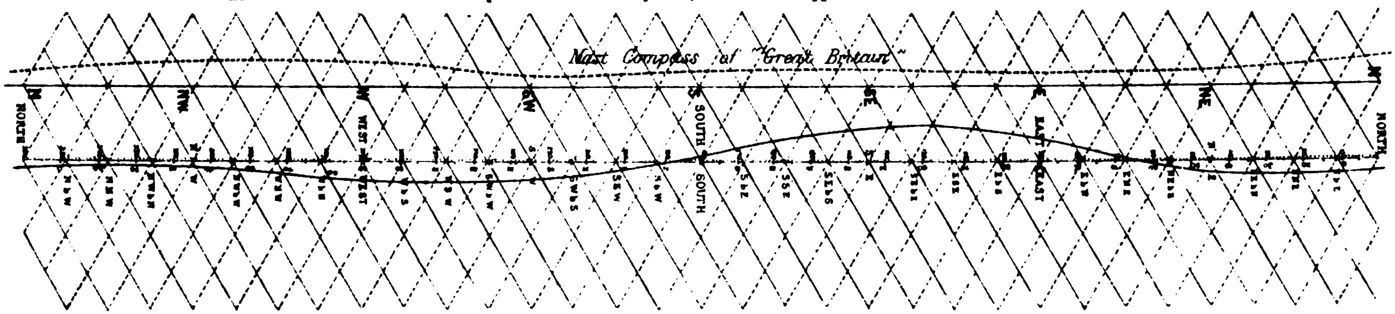
———— Curve - Deviation of Steering Compass of same ship, as observed at Liverpool, indicating uncompensated quadrantalmagnetism and reduction of ship's magnetism. (This Compass was compensated by Magnets at Bristol, but they were not disturbed at Liverpool.)

(During the voyage from Bristol to Liverpool, in the new ship, large deviations were observed. Two Captains were on board; one considered the errors to be due to the ship's attraction, the other to mechanical faults in the Compass. The latter stated, that on examination he found the pivot of one card three-quarters of an inch above the plane of the gimballs, and the card of the Companion Compass half an inch above, and that this gave rise to so much motion that it was almost impossible to say what the deviations were.)

.... Curve - Mast Compass of "Great Britain."

This curve shows very little real deviation, but a large index error, which occasions all the deviations to appear westerly.

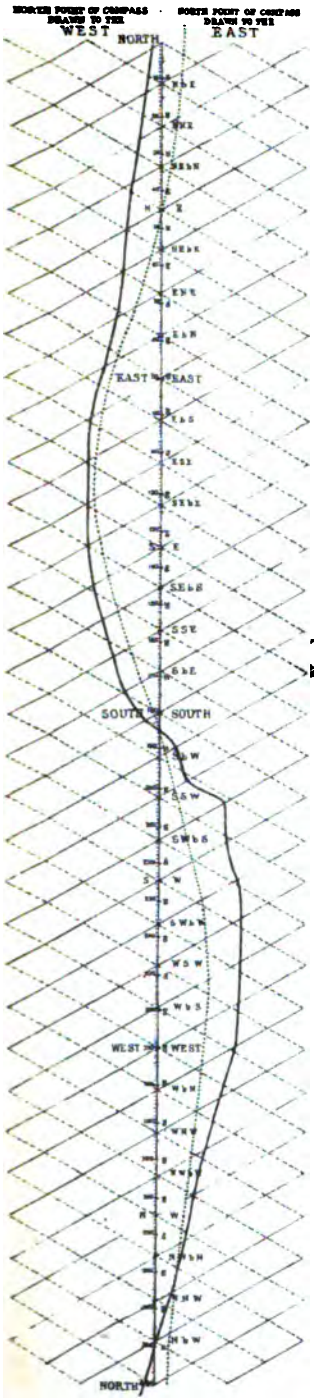
The lubber-line is seldom towards ship's head in Mast Compasses; in this case it appears to be about 4° too touch to starboard.



J. Bien, photo lith.

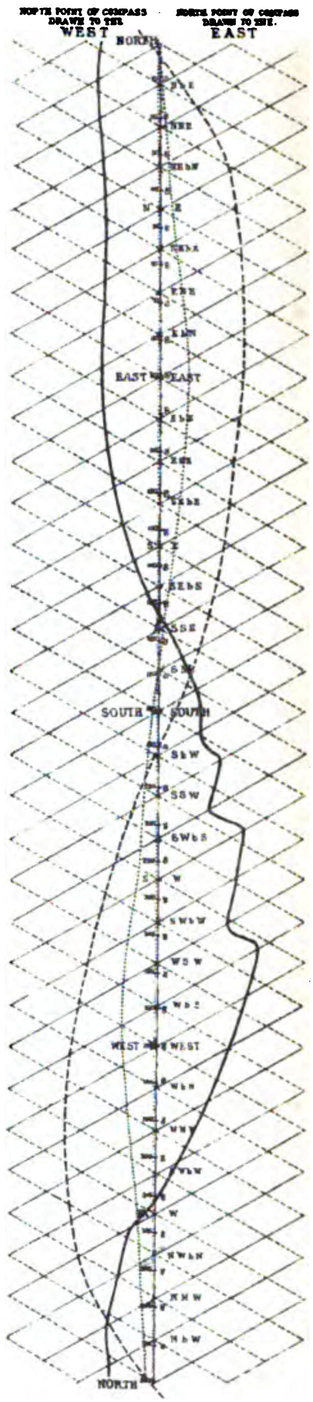
No. I.

DIAGRAM



No. II.

DIAGRAM



No. 1.

——— Curve - Deviations of Standard Compass of "City of Washington," September 15, 1855.

........Curve - Deviations of the same Compass, October 27, 1856.

(Both taken from deviation cards.)

They indicate a change in the ship's magnetism, as well fore and aft as transverse. That for 1855 also shows errors in the Shore Compass.

No. II. – Steamer "*Valparaiso*."

——— Curve - Deviations of Steering Compass, as taken from Adjuster's card.

........Curve - Mast Compass, and

- - - - Curve - Standard Compass, both showing attraction forward, instead of aft, as with the Steering Compass.

This ship sailed for W. coast of South America, without any adjustment for either Compass.

J. Bien, photo lith.

THIRD REPORT

FROM

THE LIVERPOOL COMPASS COMMITTEE

TO

THE BOARD OF TRADE.

1857–60.

To the Lords of the Committee of Privy Council for Trade:

The Liverpool Compass Committee have the honor to present the following as their third and final report on the magnetism of iron ships.

The four years which have passed since the second report was presented to your Lordships have afforded so many opportunities for acquiring further information, and have added so much to the experience of the committee on this subject, that they have thought it desirable to briefly review their former communications, and see how far they may now require modification, Having made this retrospection, the committee feel great satisfaction in reporting that it only remains for them to confirm their previous deductions, and to append the results of their more recent investigations.

The chief points already insisted upon are—

That the magnetism of iron ships is distributed according to precise and well determined laws.

That a definite magnetic character is impressed upon every iron ship while on the building slip, and is never afterwards entirely lost.

That a considerable reduction takes place in the magnetism of an iron ship on first changing her position after launching; but afterwards that any permanent change in its direction or amount is a slow and gradual process.

That this original magnetism of an iron ship is constantly subject to small fluctuations from change of position, arising from new magnetic inductions.

That the compass errors occasioned by the more permanent part of a ship's magnetism may be successfully compensated, and that this compensation equalizes the directive power of the compass needle on the several courses on which a ship may be placed.

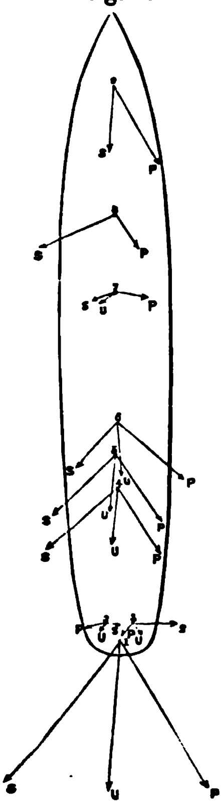
These deductions were founded on observations and experiments made in port.

The principal topics which remained for discussion and inquiry were, the effect of heeling on the compasses of iron ships, and the changes which occur on change of magnetic latitude, so far as these could be determined by the collation and discussion of observations made at sea by those captains of iron ships who had co-operated with the committee. So much difficulty attended the latter, arising from scantiness of material, as well as apparent discrepance in the results, that at the time the report for 1856 was completed, it was considered that the best if not the only mode of completing this part of the subject, would be to send the secretary one or two voyages by steamer to Alexandria, to make the neeessary experiments, this being the shortest voyage which would include the requisite magnetic conditions. It is believed, however, though these experiments are still desirable, that enough has now been determined to practically settle all those points which the Liverpool Compass Committee were expected to investigate.

In considering the compass deviations which arise from heeling in iron ships, it was early a subject of remark, that the evidence before the committee generally indicated an attraction of the north end of the compass needle, to the high or weather side of the ship, in whatever direction she listed, while the published experiments on this subject, made on board the "Bloodhound," by direction of the Admiralty, showed, on the contrary, a deviation of the needle towards the lee side, and of comparatively small amount. The reports of merchant captains were in consequence received with some degree of caution, until they eventually became so numerous and so consistent, as to demand the immediate action of the committee. It was decided, therefore, that the committee should defray the heavy expense of heeling and swinging a large iron ship, if the owners could be induced to lend one for the purpose. As the observations made by Captain Leitch, on board the steamship "City of Baltimore," referred to in the preceding report, showed that this ship would be a desirable one for the purpose, a deputation was instructed to wait on the managing owner, Mr. W. Inman, who at once placed this noble ship at the disposal of the committee, with the very liberal intimation that he would defray the whole of the attendant expenses. Arrangements were immediately made for swinging this ship, and the results proved most conclusively, not only the correctness of Captain Leitch's observations, but that the errors from heeling were so large as to very seriously affect the safe navigation of the ship when not allowed for. Thus, the azimuth compass of this vessel, which is placed about four feet above the deck house, nearly eleven feet above the deck, and about thirty feet before the mizzen mast, when the ship's head was placed north, correct magnetic, showed a deviation to the west of 7° 30';

when she was heeled 10° to starboard, the deviation was 25° 30′ to the west; and when she was heeled 10° to port, the deviation was 15° 3′ to the east; showing a difference of 41°, due to heeling alone, without in any way changing the direction of the ship's head; or an average change of 2° of deviation for each degree of heel! This was about the maximum change for the azimuth compass, for it was found that when the ship's head was east or west by compass, there was practically no change of deviation from heeling, and that the change gradually increased as the ship's head approached north or south by compass.

Fig. 4.



To obtain as much information as possible from this heeling experiment, the deviations of nine compasses were observed. They were placed in different parts of the ship, as indicated in the annexed diagram. Nos. 2, 3, and 7 were compensated in the manner originally directed by the Astronomer Royal, and did not show much change of deviation from heeling.

The arrow-pointed lines represented as proceeding from the compass stations, 1, 4, 5, 6, 8, 9, in the diagram, indicate the relative strength and direction of the ship's magnetism at these positions. The arrows at 2, 3, 7, show only the resultants of the ship's magnetic force, and that of the magnets placed to compensate it. The letters U, P, S, signify upright, port heel, and starboard heel respectively.

At all these stations except 2 and 3, the north end of the needle was drawn towards the high side of the ship as the ship heeled over. At stations 2 and 3, which are about six feet below the level of station 1, the north end of the needle went towards the low side of the ship.

The following table contains some further particulars of these experiments; the details are given in the Appendix:

10

STEAMSHIP "CITY OF BALTIMORE."

No.	Position of compass.	Deviations observed with ship's head north correct magnetic.			Change from heeling 10° to port to 10° to starboard.	Average change for each degree of heel.	Mean amount and direction of ship's horizontal force in terms of Earth's horizontal force.						Ship's vertical force, as obtained while ship's head was N. N. E. in terms of Earth's horizontal force at Liverpool.
							Port heel.		Upright.		Starboard heel.		
		Port heel.	Upright.	Starboard heel.			Force.	Starboard angle.	Force.	Starboard angle.	Force.	Starboard angle.	
		° ′	° ′	° ′	° ′	° ′		° ′		° ′		° ′	
1	Compass placed above the aft side of round-house	+66 40	—24 0	—67 0	133 40	6 41	.9417	149 50	.8394	186 33	.9942	219 26	† 2.332
2	Port-steering compass, compensated	— 6 0	— 6 0	0 0	6 0	0 18	.1355	256 58	.0452	217 41	.0711	96 35	......
3	Starboard-steering compass, compensated	0 0	+ 4 30	+ 9 30	9 30	0 29	.0895	226 58	.0831	130 19	.2254	90 35	......
4	Standard compass	+16 15	— 8 30	—28 0	44 15	2 13	.4034	144 9	.3052	191 49	.5278	230 58	1.437
5	Azimuth compass	+15 30	— 7 30	—25 30	41 0	2 3	.4099	144 4	.3348	190 31	.4984	227 6	1.375
6	Dipping needle compass	+22 30	— 0 45	—17 0	39 30	1 59	.4855	125 19	.2938	178 42	.3893	220 11	1.212
	Dipping needle compass with vertical magnet placed below	+12 30	......	—11 0	23 30	1 11	......	......	......	......	......	......	......
7	Fore compass compensated	+ 8 30	— 2 0	— 7 15	15 45	0 47	.1654	105 36	.0976	244 26	.1308	253 52	.503
8	Mr. Gray's azimuth compass*	? + 3 30	+11 30	? —28 0	31 30	1 35	.2420	145 28	.3006	126 28	.4482	246 0	......
9	Compass placed over the fore hatch	+24 0	......	+ 7 0	17 0	0 51	.5103	150 15	......	......	.3690	184 26	......

* This compass was shifted a few feet further aft when the ship was heeled, and there is some doubt as to whether it was the same height from the deck.
† This observation was made about three or four feet further forward on the round house than the position of the compass when the ship was swung.

An examination of the diagram, Plate 31, or of the last seven columns in this table, will immediately show that this steamer has a very strong attraction towards the stern for the north end of the compass needle; that the vertical attraction near the stern is so great as to be nearly equal to the earth's vertical magnetic force at Liverpool when the ship's head is N.N.E., and that it gradually decreases towards the bow; that the ship's magnetic force is so nearly in the line of the keel, that a heel of 10° is sufficient to throw it to port or to starboard. The experiments with the dipping-needle compass (see Appendix A) also show that the amount and direction of the ship's total force change with each change in her position. An attempt has been made to exhibit in the annexed diagram, Plate 31, the changes in the ship's horizontal magnetic force as the ship is swung round, upright, 10° heel to port, and 10° heel to starboard. The positions of the ship's head are indicated by the usual abbreviations.

The results of these experiments were thought so very remarkable, that the deputy chairman of this committee, who was then having a large iron ship built in Liverpool, with her head towards the east, determined that this vessel, the "Aphrodita," should also be heeled and swung before she went to sea. A short time afterwards, the owners of another large ship, the "Simla," then building on the opposite bank of the Mersey, with her head towards the west, consented to have her heeled for similar experiments.

Both these ships, like the "City of Baltimore," showed very large deviations from heeling, while the general direction of their magnetism corresponded with the opposite directions in which they were built; the chief attraction of the compass needle in the "Aphrodita" being towards the starboard side, and in the "Simla" towards the port side. But both ships corresponded with the "City of Baltimore," in attracting the north end of the compass needle to the high side when they were heeled over.

The following table exhibits the principal facts, and is arranged to correspond with the table already given for the "City of Baltimore," further discussion and detail being reserved for the Appendix:

"APHRODITA" AND "SIMLA."

No.	Position of the compass.	Deviations observed with ship's head north correct magnetic.			Change by heeling ship from 10° to port to 10° to starboard.	Average change in deviation from each degree of heel.	Mean amount and direction of ship's horizontal force in terms of the Earth's horizontal force at Liverpool.					
							Port heel.		Upright.		Starboard heel.	
		Port heel.	Upright.	Starboard heel.			Force.	Starboard angle.	Force.	Starboard angle.	Force.	Starboard angle.
	"APHRODITA."	° ′	° ′	° ′	° ′	° ′		° ′		° ′		° ′
1	Compass under companion	+36 40	+17 30	− 3 40	40 20	2 1	.7871	107 45	.3489	102 30	.1348	240 58
2	Compass near companion (in the ordinary position for the steering compass)	+51 40	+27 20	− 5 15	56 55	2 51	.8458	115 59	.5763	148 42	.4876	191 51
3	Admiralty standard compass	+29 15	+18 0	+ 5 20	23 55	1 12	.6030	103 37	.3690	124 18	.1757	158 9
4	Dipping-needle compass	+32 0	+21 30	+ 9 0	23 0	1 9	.6913	94 35	.4394	104 9	.2016	102 55
	"SIMLA."											
1	Steering compass	+ 2 45	−22 0	−38 30	41 15	2 4	.2346	186 59	.5331	245 26	.8383	254 20
2	Compass over companion	+ 3 0	−12 30	−30 0	33 0	1 39	.0416	102 6	.2910	267 15	.5748	267 49
3	Dipping-needle compass	− 8 30	−16 10	−24 30	16 0	0 48	.2724	283 54	.4597	278 59	.6416	276 50
4	Standard compasss	− 2 45	−10 20	−17 20	14 35	0 44	.0730	315 48	.2594	280 0	.4356	279 6
5	Forward compass	− 2 0	− 9 0	−16 0	14 0	0 42	.1078	345 56	.2639	295 45	.4381	287 20

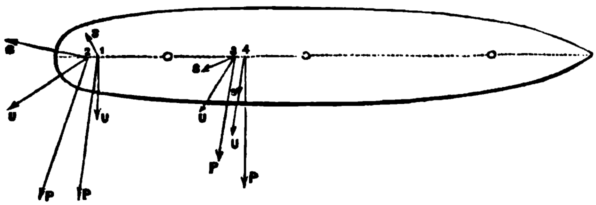
The relative amount and direction of the magnetic force of each ship at the stations of the several compasses will perhaps be best exhibited by the following diagrams:

Fig. 5.

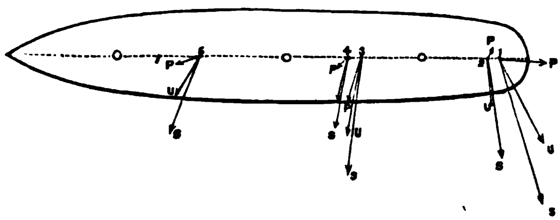
Diagrams to show amount and direction of ship's magnetic force, with ship upright, and with 10° *heel to port and starboard.*

P. Port. U. Upright. S. Starboard.

"APHRODITA," built Head East.



"SIMLA," built Head West.



Had the heeling experiments by the Compass Committee closed with these made upon the "Aphrodita," "Simla," and "City of Baltimore," there would undoubtedly have appeared some incongruity between them and the Admiralty experiments upon the "Bloodhound" and the "Recruit." For though it would be easy for one conversant with the magnetism of iron ships to indicate what distribution of a ship's magnetic force would to them account for the observed phenomena, it is felt that the majority of the commanders of iron ships could not be expected to possess this information, and that they may be excused for holding the opinion now prevalent among them, that there is something wayward and uncertain, not to say marvellous, in the deviations of the compass which arise from heeling. Fortunately, a fourth vessel of the same large class as the "Simla" and "Aphrodita," was afterwards heeled, at the request of the secretary, and proved, as it were, a connecting link between the two sets of experiments, the results obtained in this case demonstrating practically what had previously been suggested by theory. A few days before this ship, the "Slieve Donard," was swung, some preliminary experiments were made with the dipping-needle and vibration compass, to ascertain suitable positions for the compasses. These indicated so little vertical magnetic force in the after part of the vessel, compared with those made on board the other ships, that it was at once suspected that the "Slieve Donard" would show very small error from heeling, and that she could not have been built head nearly east, as had been supposed, from the known position of the building yard. On going to the yard, it was found that, owing to the great length of this ship, the ways on which she was built had been placed obliquely, so that the direction of her head while building was nearly three points south of east! The smallness of the observed dip was thus satisfactorily accounted for, and the inference which had already been drawn in respect to the deviations to be expected from heeling this ship was proportionately strengthened.

The following table, showing the principal results obtained on board the "Slieve Donard," is arranged so as to allow comparison with the preceding tables, further particulars being reserved for the Appendix:

"SLIEVE DONARD."

No.	Position of the compass.	Deviations observed with ship's head north correct magnetic.			Change by heeling ship from 10° to port to 10° to starboard.	Average change in deviation from each degree of heel.	Mean amount and direction of ship's horizontal force in terms of the Earth's horizontal force at Liverpool.					
							Port heel.		Upright.		Starboard heel.	
		Port heel.	Upright.	Starboard heel.			Force.	Starboard angle.	Force.	Starboard angle.	Force.	Starboard angle.
		° ′	° ′	° ′	° ′	° ′		° ′		° ′		° ′
1	Aftermost steering compass, compensated...	+ 7 30	+ 2 40	− 0 30	8 0	0 24	.0940	72 20	.0456	65 0	.0450	56 0
2	2d steering compass, compensated...............	− 8 10	− 7 0	− 0 45	2 25	0 7	.1138	267 50	.0760	253 30	.0475	265 20
3	Skylight compass, compensated.....................	− 3 30	− 0 30	+ 3 0	6 30	0 20	.0662	66 30	.0220	140 30	.0740	78 0
4	Mast compass	+ 4 0	+ 2 15	− 1 25	5 25	0 16	.1922	2 10	.2015	1 30	.1960	0 55
5	Port skylight compass	+ 7 20	+ 6 0	+ 4 0	3 20	0 10	.4150	17 45	.3960	19 15	.3780	14 40
	Port skylight compass, ship's head south	− 3 45	− 5 45	− 5 45	2 0	0 6	....	....	....	....	....	....
6	Starboard skylight compass............................	+15 20	+12 10	+13 20	2 0	0 6	.5160	45 30	.4730	39 0	.4830	44 30
7	Compass placed above after-hatch.................	+20 0	....	+21 0	1 0	0 3	....	....	.4630	35 15	....	....
8	Dipping-needle compass	+11 20	+10 50	+10 30	0 50	0 3	.5790	39 40	.5280	37 45	.4900	36 50
	Dipping-needle compass, ship's head south..	−26 30	−20 45	−16 25	10 5	0 30	....	....	....	....	....	....

To exhibit at one view and in the most unexceptionable manner the general effect of heeling on the compasses of iron ships, the annexed diagram has been prepared. Plate 32 shows graphically the deviations of the standard compasses of the six ships which have been experimented upon. The standard compasses are chosen because they were placed in carefully selected positions, free from the disturbance of particular masses of iron, and at least four feet above the deck; in the cases of the "Aphrodita," "Simla," and "City of Baltimore," from eleven to twelve feet above the deck. In each example the deviation curve, with ship upright, is shown in full line, with ship heeling to port in broken line, and with ship heeling to starboard in dotted line.*

An examination of the preceding diagrams, and the illustrations in Reports 1 and 2, showing the distribution of the magnetism of iron ships, as influenced by position while building, (see specially those of the "Bœotia," built with head southerly, and "City of Washington," built with head northerly, Plates 8 and 9, of Report II,) will readily show that there is a general consistency in the results. Thus, in ships built with their head more or less to the north, there is a strong magnetic attraction of the opposite name below the compasses in all the after part of the ship, the effect of which is to increase the deviations observed with the ship upright as the ship is heeled in one direction, and to decrease them when the ship is heeled in the opposite direction, the result being equivalent to an attraction of the north end of the compass needle to the high side of the ship. In ships built with head more or less to the south, as there will be the contrary magnetic attraction below the compass, the reverse effect from heeling is exhibited. It remains to be explained why the deviations from heeling in ships built head to south are so much smaller than in ships built head to north in these northern latitudes. The principal, but not the only cause of this, is believed to be the induced vertical magnetism of the deck beams, and other similarly placed pieces of iron, as the ship heels over. In this latitude the upper end of the beams instantly acquire southern polarity, and in combination with the natural south polarity of the after part of the vessels built head to north, jointly produce the deviation of the needle to the high side; but in ships built head to south there is only the difference instead of the sum of these two forces. This being the case, it is apparent that there may be some ships in which these two forces will cancel each other in this latitude, and that these ships must necessarily be built in north latitude, with their head somewhere between south and west and south and east. The "Slieve Donard" indicates more closely these limits for ships of her class built in this country, and places them near S.W. and S.W. by W., or S.E. and S.E.

* While this report was passing through the press, two other large iron ships have been swung with ten degrees heel to port and to starboard. The results will be given in the Appendix.

by E. Further, as these deviations from heeling, like ordinary deviations, are partly due to the more permanent and partly to the induced magnetism of the ship, it is evident they must change with change of magnetic latitude, and that in high south latitudes the reverse phenomena must be expected to obtain; namely, that ships built here, with head more or less to the north, will have comparatively small deviations from heeling in high south latitudes, and that ships built head to south will have larger deviations, and of the contrary name, to those exhibited in north latitude.

The *general* effects of heeling on the deviation of the compass in iron ships may be stated as follows:

1. The maximum deviations from heeling will occur in iron ships when they are upon or near northerly or southerly compass courses. They will decrease as the ship approaches easterly or westerly compass courses. There will practically be no deviation from heeling when ship's head by compass is east or west.

2. In ships built in this country, with their head towards any point between W.S.W. and E.S.E. by way of north, the north end of the compass needle deviates towards the high or weather side of the ship, and, other things being the same, to the greatest extent in ships built with head at or near north. In these ships, the deviation from heeling will increase as the ship attains greater north magnetic latitude, and will decrease as the ships go towards south magnetic latitude. In some cases the deviation from heeling in these ships may disappear in high south magnetic latitude, or even change its name.

3. In ships built with head between S.W. and S.E. by way of south, the deviation from heeling will usually be small in north magnetic latitude, and the north end of the needle will generally be attracted towards the low side of the ship. The deviation from heeling in these ships will increase as they approach south magnetic latitude.

4. In ships built in positions intermediate to those named in sections 2 and 3, the deviations will usually be small in ordinary north latitudes, and are not likely to be very large in ordinary south latitudes.

5. To test whether a ship's compasses will be affected by heeling or not, she should be listed over while her head is at or near north or south, both to port and to starboard, as in some cases there may be a moderately large deviation from heeling as the ship inclines in one direction, and very little, or even none, when the ship is heeled the opposite way. The trial should be made with head north, if the ship was built with head northerly, and with head south, if built with head southerly. This precaution will be most necessary when the compass is near the stern. The deviation from heeling on the intermediate points may be approximately found by multiplying the maximum deviation from heeling into the sine of the angular distance of the point in question from east or west.

6. An approximate idea of the extent to which a ship's compasses will

be affected by heeling may be obtained by dipping-needle and vibration experiments, without actually heeling or swinging a ship, by persons who have acquired previously some experience in these experiments and in the magnetism of iron ships; but until further data on this subject are accumulated, the most satisfactory course is to swing every new iron ship with a list to port and to starboard, as well as upon an even beam.

These remarks are intended to apply to uncompensated standard compasses, placed in the ordinary positions, and have relation only to the extra deviation which is caused by heeling. Other results are also possible, as, for example, in ships without iron deck beams. It is also possible for the deviation from heeling to be in the same direction, whether a ship inclines to port or starboard; but in any such case it is believed that the deviation from heeling in one direction, if not in both, must necessarily be very small in amount; so small that it could not practically affect the navigation of an iron ship.

The compasses in these experiments, which were compensated in the usual manner with magnets placed below the level of the card, have shown comparatively small errors from heeling. This effect was anticipated by the Astronomer Royal in his paper published in the Philosophical Transactions for 1839.

Further particulars of the heeling experiments by this committee are reserved for the Appendix, where will also be given the results of all the known experiments of this kind. The deviations from heeling observed on board the "Sharpshooter," were furnished by Mr. Evans, of the Admiralty Compass Department. This vessel is reported to have had no iron deck beams; but it will be seen that her quadrantal deviation is comparatively large; she affords, therefore, an apt illustration of the magnetism of the floors and bottom plates of a ship being conducted up the sides. This effect is also very apparent in experiments made on board the "Accrington," to which reference will presently be made.

Before leaving this part of the subject, the committee request attention to some of the extreme cases of deviation from heeling, as illustrating how rapidly the deviations increase in those quadrants in which the directive power of the compass needle is small.

Interesting as the various heeling experiments have proved to the committee, and conclusive as they are believed to be upon those points which practically affect the navigation of iron ships, it is felt that much more will be desired by those who have made the magnetism of iron ships a subject of scientific research, or who desire to introduce a mechanical corrective for this error. The Liverpool Compass Committee would gladly have done more towards the elucidation of those yet unsettled points to which reference has been made, and to those quantitative inquiries which the subject suggests; but their efforts have been limited by circumstances which those who are acquainted with the necessities and competitions of commerce will easily conceive. In no instance has the committee been enabled to carry out their programme in the mode intended. Even where individual shipowners, regardless of personal inconvenience and expense, have placed their ships at the temporary disposal of the committee, the impossibility in the crowded docks at Liverpool, of controlling the movements of other vessels, has rendered all attempts at very exact or complete experiments abortive. It is hoped, however, that the Board of Trade will use its influence in getting those parts of the Compass Inquiry completed which the Compass Committee have found beyond their power. The committee would specially express the desire that means may be found to leisurely and carefully swing some large iron ship, both upright and heeled to port and starboard, in both magnetic hemispheres. The following particulars of the magnetic force of the "Accrington," obtained while she was swung on an even beam, are the most complete which the committee can offer, and will illustrate the details which they consider desirable. Similar records for several carefully selected positions on board almost any iron ship, not on her first voyage, if obtained in both hemispheres, and with the ship heeled about 10° to port and starboard, would do more, it is conceived, to settle the yet moot points of the inquiry than any other course that could be imagined.

In examining, by means of the following table and the diagrams in Plates 33 and 34, the vertical, lateral, and longitudinal movement of the magnetism of the "Accrington," as her head is turned to the various points of the compass, it is thought the most sceptical must be convinced that an important proportion of the resultant magnetism is due to the Earth's induction, and must desire to obtain, in at least one instance, those complete experiments which can alone decide authoritatively how much of a ship's polar compass deviation is due to that magnetism which was, as it were, hammered into her while she was being built, and how much to the vertical induction from the Earth which belongs to the ship's geographical position at the time of the experiment.

"ACCRINGTON."

Birkenhead, Great Float, September, 1859.

(Vibrations of horizontal needle on shore, 20.23 per minute. Dip on shore, with weighted dipping needle at right angles to magnetic meridian, 45° 20′.)

Ship's head correct magnetic.	Ship's head by compass.	Deviation.	Vibrations of horizontal needle per minute.	Force in direction of needle.	Dip observed on board.	Ship's vertical force in terms of Earth's horizontal force.
° ′	° ′	° ′			° ′	
N. 1 5 W.	N. 14 40 E.	—15 45	18.75	.8590	49.22	.4176
N. 22 43 E.	N. 36 53 E.	—14 10	19.53	.9320		
N. 43 25 E.	N. 56 3 E.	—12 38	20.00	.9774	49 12	.3990
N. 72 13 E.	N. 82 49 E.	—10 36	20.87	1.0618		
N. 85 45 E.	S. 84 20 E.	— 9 55	21.82	1.1634		
S. 89 35 E.	S. 79 58 E.	— 9 37	21.00? (22.0)	1.0776 (1.1826)	48 37	.3350
S. 68 15 E.	S. 60 45 E.	— 7 30	22.40	1.2261		
S. 42 0 E.	S. 39 54 E.	— 2 6	22.98	1.2904	48 5	.2639
S. 22 0 E.	S. 25 13 E.	+ 3 13	23.23	1.3186		
S. 0 10 E.	S. 9 35 E.	+ 9 25	23.23	1.3186	48 10	.2866
S. 23 0 W.	S. 6 37 W.	+16 23	21.61	1.1411		
S. 44 0 W.	S. 23 2 W.	+20 58	20.38	1.0140	48 7	.2813
S. 67 30 W.	S. 45 10 W.	+22 20	18.54	.8399		
West.	S. 73 5 W.	+16 55	16.90	.6979	48 35	.3314
N. 63 30 W.	N. 69 0 W.	+ 2 30	16.22	.6268		
N. 45 0 W.	N. 35 22 W.	— 9 38				
N. 47 0 W.					48 45	.3495
N. 22 23 W.	N. 7 8 W.	—15 15	17.82	.7759		

Ship's head, correct magnetic.	Deviation.	Force in the direction of the needle.	Earth's horizontal force at Liverpool, taken as unity. Ship's horizontal force.	Ship's vertical force.	Ship's total force.	Starboard angle.	Dip.	Ship's head by compass.	Deviation.
	° ′					° ′	° ′		° ′
North.	—15 50	.8625	.291	.4125	.5052	234 45	35 12	North.	—15 26
N. by E.	—15 5	.8968	.270	.4151	.4956	229 45	33 4	N. by E.	—15 48
N. N. E.	—14 15	.9254	.250	.4150	.4850	223 45	31 4	N. N. E.	—15 1
N. E. by N.	—13 25	.9530	.233	.4100	.4712	218 5	29 37	N. E. by N.	—14 6
N. E.	—12 35	.9813	.216	.4010	.4550	213 15	28 19	N. E.	—13 11
N. E. by E.	—11 50	1.0140	.206	.3890	.4400	207 45	27 54	N. E. by E.	—12 18
E. N. E.	—11 3	1.0573	.200	.3745	.4246	208 30	28 6	E. N. E.	—11 28
E. by N.	—10 15	1.1118	.209	.3565	.4130	209 55	30 23	E. by N.	—10 38
East.	— 9 40	1.1746	.229	.3360	.4064	204 20	34 16	East.	— 9 51
E. by S.	— 8 55	1.1743	.250	.3190	.4060	209 35	38 5	E. by S.	— 9 14
E. S. E.	— 7 25	1.2266	.269	.3056	.4070	210 20	41 21	E. S. E.	— 8 16
S. E. by E.	— 5 25	1.2677	.286	.2935	.4100	211 30	44 13	S. E. by E.	— 6 24
S. E.	— 2 45	1.2975	.299	.2830	.4120	212 45	46 34	S. E.	— 3 18
S. E. by S.	+ 0 5	1.3129	.312	.2750	.4156	214 5	48 38	S. E. by S.	+ 0 34
S. S. E.	+ 3 5	1.3195	.326	.2700	.4236	216 5	50 22	S. S. E.	+ 4 34
S. by E.	+ 6 15	1.3097	.335	.2670	.4280	217 15	51 27	S. by E.	+ 9 14
South.	+ 9 35	1.2870	.345	.2650	.4350	218 45	52 28	South.	+14 19
S. by W.	+13 5	1.2442	.353	.2665	.4426	220 35	52 57	S. by W.	+18 24
S. S. W.	+16 20	1.1851	.359	.2690	.4486	225 0	53 9	S. S. W.	+21 19
S. W. by S.	+19 0	1.1081	.364	.2740	.4556	228 35	53 2	S. W. by S.	+22 52
S. W.	+21 10	1.0195	.370	.2810	.4640	232 5	52 47	S. W.	+22 39
S. W. by W.	+22 28	.9232	.379	.2885	.4764	234 50	52 43	S. W. by W.	+21 14
W. S. W.	+22 20	.8393	.389	.2984	.4900	237 0	52 33	W. S. W.	+18 54
W. by S.	+20 30	.7624	.390	.3090	.4990	237 25	51 37	W. by S.	+15 24
West.	+16 55	.7018	.387	.3220	.5025	237 55	50 14	West.	+11 22
W. by N.	+10 50	.6622	.375	.3355	.5026	239 15	48 11	W. by N.	+ 7 2
W. N. W.	+ 3 20	.6439	.365	.3485	.5036	241 10	46 19	W. N. W.	+ 2 22
N. W. by W.	— 3 55	.6512	.357	.3620	.5076	243 40	44 36	N. W. by W.	— 2 6
N. W.	— 9 40	.6773	.350	.3750	.5126	244 0	43 2	N. W.	— 6 6
N. W. by N.	—13 30	.7196	.342	.3875	.5164	243 5	41 26	N. W. by N.	— 9 48
N. N. W.	—15 18	.7733	.325	.3975	.5130	241 15	39 16	N. N. W.	—12 38
N. by W.	—16 0	.8225	.307	.4065	.5096	238 50	37 4	N. by W.	—14 26

The heeling experiments may be expected to afford approximate values for the sub-permanent and induced vertical magnetism of the several ships; but the attempt to estimate them has not proved satisfactory. (See Appendix.) The observations made on board the "City of Baltimore," with the dipping-needle compass, are perhaps the most trustworthy for this purpose. This ship's vertical force was large, and the means of the experiments give 1.054, 1.069, and 1.064, respectively, as the vertical force of the ship for heel to port, upright, and heel to starboard, in units of the Earth's horizontal force at Liverpool. If the whole of the ship's vertical force were sub-permanent, a heel of 10° should reduce its effect by .016; but taking the mean of the two results with the ship heeled, which will be sufficiently accurate for this estimate, the reduction amounts only to .010, indicating, on the supposition that there would be no change from a heel of 10° in the induced vertical magnetism, that the sub-permanent magnetism was $\frac{5}{8}$ of the whole observed, or .668 of the Earth's horizontal force at Liverpool.

At present the only direct experiments before the public upon the changes which occur in the vertical magnetism of an iron ship on change of geographical position, are those made by Dr. Scoresby during his voyage in the "Royal Charter." The particulars are given in the following table, which has been extracted from his posthumous volume describing this voyage, p. 270 :*

***Journal of a Voyage to Australia and round the World for Magnetical Research.* By the Rev. W. Scoresby, D.D., F.R.S., etc. Edited by Archibald Smith, Esq. M.A., F.R.S. London, 1 vol. 8vo. 1859. B. F. G.

"ROYAL CHARTER."

Outward passage.

Date.	Latitude.	Ship's head true magnetic.	Terrestial dip.	Station I.—Poop, 40 feet from stern.		Station II.—Poop, 100 feet from stern.		Station III. Standard, 181 feet from stern.	Station IV.—Forecastle, 273 feet from stern.		Station V. 284 feet from stern.	Ship's heeling.
				Starboard dip.	*Port dip.*	*Starboard dip.*	*Port dip.*	*Midships dip.*	*Starboard dip.*	*Port dip.*	*Midships dip.*	
	° ′	°	°	°	°	°	°	°	°	°	°	°
March 8	6 58 S.	S. 43 W.	10 N.	…	…	…	…	34½ N.	…	…	…	7 starboard.
11	16 46	11	3½ S.	…	…	…	…	16	…	…	…	7 starboard.
12	19 30	8 E.	10	…	…	15 inches abaft.		6¾	…	…	…	7½ starboard.
13	23 30	South	15	5¾ S.	4 N.	…	…	½	…	…	6 S.	9 starboard.
14	28 32	S. 5 E.	23	…	…	…	…	8½ S.	25½ S.	15½ S.	15¾	9 starboard.
	29 20 W.	…	…	…	…	…	…	…	…	…	…	…
15	32 29 S.	21	28½	16½	8½ S.	29 S.	25 S.	13½	…	…	…	…
	27 32 W.	…	…	…	…	…	…	…	…	…	…	…
17	36 15 S.	24	36	…	…	31½	35½	23½	33	41½	28	5 starboard.
19	41 13	47	44	27½	26	38½	53½	33	…	…	…	10 starboard.
22	42 9	47	50¼	33½	35½	41¾	59¾	43	…	…	…	4 port.
25	43 52	37	57¾	42¾	44½	53½	65¾	52	…	…	…	2 port.
28	45 49	…	62½	…	…	…	…	62	…	…	…	…
April 3	47 31	50	70½	63	70	67½	79½	70½	…	…	…	6 starboard.
11	44 24	82	73¾	68¾	78¾	…	…	70	…	…	…	…
12	44 7	E. 3 N.	73½	…	…	71½	87½	75½	72	85½	75½	1 port.
15	40 48	N. 10 E.	…	…	…	…	…	70½	…	…	…	6 starboard.
PORT PHILIP.												
April 21	37 52	…	…	…	…	…	…	66¾	73 1-6	69	68	…

"ROYAL CHARTER."

Homeward passage.

Date.	Latitude.	Ship's head true magnetic.	Terrestial dip.	Station I.—Poop, 40 feet from aft.		Station II.—Poop, 100 feet from aft.		Station III. Standard.	Station IV.—Forecastle.			Ship's heeling.
				Starboard dip.	*Port dip.*	*Starboard dip.*	*Port dip.*	*Mean dip.*	*Midships dip.*	*Starboard dip.*	*Port dip.*	
	° ′	°	°	°	°	°	°	°	°	°	°	°
May 30	50 45 S.	S. 5 E.	76 S.	72½ S.	72¾ S.	.....	.....	78½ S.	75¾ S.	76¾ S.	78¾ S.	7 starboard.
June 5	52 26	E. 17 N.	74½	70	82	.....	.....	77½	78¾	.....	.....	0
17	56 18	11	71	.....	.....	.....	.....	76¾	78½	74	89½	6 starboard.
July 2	48 45	N. 20 E.	48	26¼	29½	.....	.....	45½	64	61	66	1 starboard.
11	32 33	25	29½	2½ N.	10 N.	21¼ S.	29 S.	28	49	.....	.....	10 starboard.
14	22 52	7	16½	20	26¼	9 1-6 S.	4	14	39½	41	42	3 starboard.
17	13 28	18	0	34½	38½	15½ N.	7¾ N.	2¾ N.	21¼	19	24½	3 port.
21	0 36 N.	22	23½ N.	50	54	43	40	27½	12½ N.	15 N.	6 N.	4 port.
24	9 17	28	35	56¼	59½	52	53¼	35	29¾	.....	.....	0
29	18 38	25 W.	49	67¼	68¼	62¼	65¼	54½	52	.....	.....	0
Aug. 2	27 11	10 E.	58¼	72	73	71¼	72½	60¾	60¼	.....	.....	0
6	36 5	40	64½	75½	75¼	74¾	78	68¼	68¼	.....	.....	0

Vibration experiments were also tried by Dr. Scoresby, to ascertain the magnetic force in the direction of the dipping needle. Some of these are recorded in the volume, but without those details which are required to make them useful here. In consequence, only those observations for dip which were made on or near the magnetic equator, and those which show where the observed dip was zero, can be employed for roughly estimating the components of the ship's vertical magnetism.

At the station of the Admiralty compass, the four first observations show that the dip at the magnetic equator was about 20° 40′, indicating, if the Earth's magnetic force be taken as unity, and on the supposition that the force in the direction of the horizontal needle was the same as the Earth's on the magnetic meridian, a vertical magnetic force in the ship of .379, which, in terms of Earth's horizontal magnetic force at Liverpool, would be equal to .542, and with a heel of the ship of 10° would produce a deviation towards the high side of half a point of the compass. Five days afterwards, the observed dip is only 0° 30′, while the Earth's dip for the position is —15°. Multiplying Earth's total force here by sine 15° 30′, and reducing the product to the same terms as before, the ship's vertical force is .326, showing a change equal to —.216, which must be made up by a very small quantity due to difference in the Earth's horizontal force at the two stations, by a moderately large quantity being the ship's modulus at this station for vertical induction multiplied by sine of Earth's dip, and by a reduction in the ship's sub-permanent magnetism of probably about the same amount. If the change were due entirely to the ship's capacity at this station for vertical induction, it would indicate a co-efficient for induction of .285, which is much greater than is consistent with other cases to be alluded to in a later part of this report, while the supposed reduction is countenanced by the dip of 2° 45′, which was observed at this station on the magnetic equator on the homeward voyage, when the ships vertical magnetism is only .069. As this station was near the middle of the ship, the fore-and-aft inductive magnetism can have had very little influence on the observed dip, so that the sub-permanent magnetism must have undergone a very large reduction.

At the aftermost station, if the mean of the two observed dips be taken as the dip belonging to the middle of the deck at this place, the ship's vertical force here will be very nearly the same as that observed at the standard station, or .326, the estimate being subject, as before, to any errors arising from the supposition that the horizontal force in the direction of the needle was the same as that of the Earth in the magnetic meridian. On the homeward voyage, the needle in this position appears to have had no dip when the Earth's dip was —33°, and Earth's total force about .9, that at Liverpool being taken at 1.4. At the magnetic equator the observed mean dip will be 36° 25′, with the Earth's total force about .86. These give respectively .872 and 1.078 as the values of the ship's vertical magnetic force in terms of Earth's horizontal force at Liverpool. The latter value is sufficient to produce at Liverpool a deviation of 10° 48′ by the ship heeling 10° to port or starboard. The difference between these two values will be due, to some extent, to the difference of the Earth's horizontal induction at the two places of observation, but chiefly to the vertical induction indicated by the Earth's dip of —33°. Neglecting for a moment the smaller cause of difference, the co-efficient for the ship's inductive capacity will be .42. But as this position was near one end of the ship, the horizontal induction through the length of the ship may be expected to have an important influence on the ship's vertical force. Thus, with ship's head southerly on the outward voyage, the indicated vertical force is only .326, while on the homeward voyage, after the sub-permanent magnetism of the ship may be supposed to have undergone a reduction, it is more than three times as much. On the hypothesis that through the ship having been in nearly opposite directions, the observed values are the sum and difference of the two forces, the sub-permanent vertical magnetism of the ship at this station will be .702, and the vertical effect of the horizontal induction will be .376.

At the forecastle station no dip by observation will correspond with about 10° of south terrestrial dip on the outward voyage. On the homeward voyage, the observed dip at the magnetic equator was —21° 15′, and no observed dip will have occurred in about 15° of north geographical dip. At this station there is evidently a minus sub-permanent magnetism, and the same indication as at the stern of the influence of the horizontal induction through the length of the ship upon the observed vertical force. Here the ship's vertical force at the equator is .55, which, with a heel of 10° at Liverpool, would produce a deviation of the needle to the *low* side of the ship of 5° 30′; so that if compasses were placed at these two stations they would show a difference in the direction of the ship's head from heeling 10° of no less than 16°.

These are necessarily very rough approximations to the elements of the vertical magnetism of the "Royal Charter," but the committee were unwilling to pass over experiments which appear to have cost Dr. Scoresby much care and labor, and which are, it is believed, the only experiments of the kind which have yet been tried at sea on board an iron ship. They will at least serve to show what kind of observations will be requisite if another voyage of the kind should be undertaken; and that it will be essential to make complete vertical and corresponding horizontal force experiments at several stations on board the ship, and with her head as frequently as possible in opposite directions, before anything like a satisfactory estimate of the components of a ship's vertical magnetism, and the changes which occur during a sea voyage, can be obtained.

Before turning from these experiments to the compass logs of living navigators, the Compass Committee desire to record a passing tribute of respect to the enterprise and zeal of the late Dr. Scoresby, and to express a sympathy, which must be felt by all who have read the posthumous account of his voyage, in the intense interest with which he watches every indication of change in the magnetic condition of the "Royal Charter" on her outward trip, and the complete inversion of her inductive magnetism at Melbourne; the evident pleasure with which he again notes the first indication of northern induction near the stern of the ship on the homeward voyage, and its gradual progress towards the ship's bow as she gets further and further north, until he is able to show that the whole of the top sides of the ship have returned to their original magnetic condition.

It is hoped that the doctor's example will yet stimulate the intelligent captains of some of our large iron ships to fully study the subject of magnetism, and to make those quantitative and exact experiments which are still so much needed. How much they could accomplish with a little of the doctor's enthusiasm for his favorite science!

At the time the Compass Committee commenced their inquiry doubts were frequently expressed by persons who were thought to be well informed on the subject as to the correctness of the reports made by the captains of some iron ships, of the large deviations which they had experienced in the southern hemisphere; and this incredulity was certainly encouraged by some interested compass adjusters, as well as by some shipowners, who seemed to fear that iron ships would thereby acquire a bad name. Trustworthy evidence was, however, very soon produced to the committee of the extent of the deviations which arise from the change of geographical position. Two examples will be sufficient. The steering compass of a new iron ship, the "Harvest Home," built with her head to the eastward, was carefully adjusted by Mr. Gray, at Liverpool, before she proceeded to the East Indies, in 1855. The adjustment was made under the inspection of members of the committee, who were witness to the skill with which it was effected. On the arrival of this ship at Calcutta, the captain wrote to his owners as follows:

"My compass acted very well until I entered the 20th degree of south latitude, when the binnacle compass commenced to deviate considerably. I found the greatest amount of deviation in 39° south, and from 25° to 45° east longitude, the binnacle compass then being 7½ points out. Unfortunately, I had the standard compass broken to pieces with a heavy sea. I afterwards placed the azimuth compass on that part of the house where no deviation exists. It has ever since given me entire satisfaction."

The second example is from the log of the "Evangeline," on a similar voyage in 1855, and records the difference observed between the steering and standard compasses.

SHIP "EVANGELINE," (from Liverpool to Calcutta.)—Henry Fairlem, Commander..

Date.	Latitude.		Longitude.		Ship's head by standard compass.	Ship's head by steering compass.	Variation.	Deviation of binnacle compass, on the supposition that the standard was correct.
	By observation.	By dead reckon'g.	By chronometer.	By dead reckon'g.				
1855.	° ′	° ′	° ′	° ′	°	°	° ′	°
July 30	18 2 N.	18 4 N.	28 50 W.	29 13 W.	W. 45 S.	W. 45 S.		0
31	15 59	15 57	32 1	31 17	S.W.	S.W.		0
Aug. 1	13 15	13 14	33 32		S. S.W.	S. S.W.		0
3	9 17	9 19	34 7	33 39	South	South		0
4		8 38		33 57	S. by E.	S. by E.		0
9	5 42	5 46	19 40	19 42	W. ¼ N.	W. by N.		5¼ W.
17	5 2 S.	4 57 S.	27 55	27 34	W. 48 S.	W. 40 S.		8 W.
18	7 35	7 44	30 10	29 45	W. 48 S.	W. 40 S.		8 W.
23	21 21	21 18	31 30	31 20	S. 11 E.	S. 4 E.	7 30 W.	7 W.
26	24 33	24 25	29 40	29 25	S. 28 E.	S. 40 E.	10 0 W.	12 E.
27	27 7	27 9	26 45	27 1	S. 53 E.	S. 70 E.		17 E.
28	28 53	28 47	22 0	22 15			13 0 W.	
29	29 19		18 14		East	N.E. by E. ¼ E.		28 E.
30	27 55	27 55		14 54	N. 85 E.	N. 56 E.		29 E.
Sept. 2	32 46		14 31		S.E. ¼ S.	E. S. E.		28 E.
4	33 42	33 45	9 20	9 22	S. 50 E.	S. 74 E.		24 E.
6	35 50	35 55	4 11	3 57	S. 40 E.	S. 75 E.		35 E.
8		37 2		1 3	N. 45 E.		20 0 W.	
11	39 41	39 42	15 17 E.	15 26 E.	S. 55 30 E.	N. 80 E.		44 30 E.
15	39 10	39 14	26 55	26 59	S. 50 30 E.	N. 68 E.		61 30 E.
16		39 39		30 1	S. 50 E.	N. 78 E.		52 0 E.
17	39 33	39 39	32 7	31 44	S. 33 E.	N. 79 E.		68 0 E.
18	40 35	40 34	36 30	36 31	S. 45 E.	N. 79 E.		56 0 E.
20		40 21		46 47	S. 79 E.	N. 52 E.		49 0 E.
Oct. 2	30 2	30 5	76 40	76 43	N.E. by E.	N.E. by N. ¼ N.		25 30 E.
4	27 15	27 15	80 1	79 57	N. 69 E.	N. 58 E.		11 0 E.
6		20 59		81 28	N. 11 E.	N. 22 E.		11 0 W.
11	6 15	6 11	83 33	83 50	N. by E.	N. by E.		0
20	10 49 N.	10 53 N.	89 27	89 18	North	North		0
24	17 10	17 12	88 48	88 32	N. by E.	N. by E.		0

These and similar records were sufficient to show that extreme changes occurred in high south latitude, and when the ship was on easterly and westerly courses, clearly proving that the change was in the fore-and-aft magnetism of the ship, and chiefly due to inductive magnetism. An almost total absence, however, of recorded azimuths or amplitudes, made many of these logs very nearly worthless for the purpose of this investigation. The mode of navigating many iron ships may be described by the following quotation from the journal of Dr. Scoresby's voyage in the "Royal Charter:"

"The captains of ships proceeding from Australia to the eastward appear generally to be guided in their allowances on the dead reckoning by the agreement or differences discovered from day to day betwixt the positions of the ship, derived from suppositious allowances for compass errors, and the positions indicated by celestial observations. If they find themselves considerably to the southward of their reckoning on any particular day, they allow more easterly variation or deviation proportionally, or the converse. This practice, when the sun can be regularly seen, and whilst the course lies wide of any land or rocks, does very well; but when, as is not unfrequently the case, celestial observations may not be attainable for days together, or when the ship's course may lie pretty nearly in the direction of land, and especially when a change of wind may oblige a change in the course, and so in the ship's deviation, a reliance upon such inverse processes may obviously prove not only very embarrassing, but in heavy weather, with fog or darkness, not a little hazardous."

The advocates of this "inverse process," which scarcely deserves the name of navigation, have no doubt been forced to adopt it, to some extent, through the absence of proper variation charts.

With the strongest desire to make every log contribute something towards our instruction on the compass changes which are observed at sea, very little progress was possible, until such records as those kept by Captain Dalison, of the "Advance," Captain S. Nickels, of the "Astræa," and a few others of nearly equal merit, were placed at the disposal of the committee. Abstracts of some of these logs are given in the Appendix, as they form the basis on which much of this report must rest, and it is believed they may yet be of further service to those who desire to investigate the magnetic changes of iron ships. They may serve too as models for the information and guidance of the young navigator. The usual practice with these, as with other careful commanders of iron ships, has been to keep a daily record of the ship's head by each compass, and by frequent azimuths and amplitudes to ascertain the total error of the standard compass. It will be seen that they also, as opportunities occur, partially swing the ship, and thus obtain the error on adjacent courses, or upon those which are likely to be soon required. As the total error includes both variation and deviation, additional columns have been added to the logs to show these separately. The data for variation have usually been corrected, as far as possible, by the aid of General Sabine's magnetic contributions to the Philosophical Transactions, for copies of which, as well as other works on magnetism, the committee are indebted to this gentleman. More recently the variation has been conveniently obtained from the variation chart by Mr. Evans, published by the Admiralty.* Any discrepancies in the variation are usually so small, compared with the errors of observation at sea, that strict accuracy in this matter, or in the columns inserted to show the relative vertical and horizontal force of the earth, need not be insisted upon.

The logs will be chiefly employed here to ascertain the proportion which exists in the different ships between their sub-permanent and inductive magnetism, with a view to the practical application of the results to the permanent correction of the compasses of iron ships, and

* This very admirable variation chart of the world will do much towards enabling the captains of iron ships to ascertain what portion of the observed compass error is due to deviation and what to variation, as well as to ascertain how far the former is affected by heeling, which is almost impossible by the "inverse process."

more especially to the correction of the steering compass in its ordinary position.

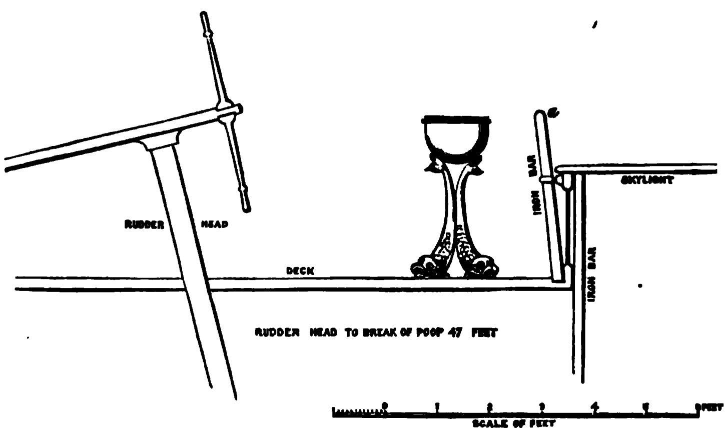
The theory on which the examination has been made is the most simple which could be adopted, and is believed to be sufficiently accurate for the purpose. In fact, the results obtained will indicate of themselves the extent to which other considerations should be introduced. The theory adopted is, that the deviations observed when the ship is upon or near to the cardinal points of the compass will give very approximate values for the ship's fore-and-aft and transverse magnetism; that where observations for deviation are made on several points near to the cardinal points, a curve drawn as nearly as possible through a projection of these deviations to the cardinal point will satisfactorily represent an observation taken on the cardinal point; that the deviation observed will be partly due to permanent and partly to induced magnetism; that the part due to the former will vary in the inverse ratio of the earth's horizontal force at the places of observation, and that the part due to the latter will vary as the tangent of the corresponding dip.

To facilitate reference, a portion of Mr. Evans's chart of variation has been introduced, with the addition of lines of equal magnetic dip and of equal horizontal force. The data for relative values of the Earth's horizontal force at the different stations have been taken from the *Atlas des Erdmagnatismus von Gauss und Weber:* Leipsig, 1840.

"ADVANCE."—Captain DALISON.

This iron ship is of about 600 tons register, and was built in Liverpool, with her head a few degrees to the south of east. Her steering and standard compasses were both compensated; but after she had been at sea a few days, her commander, observing that the compasses did not

Fig. 6.



agree with each other, removed the magnets altogether from the standard compass, but did not interfere with the compensation of the steering compass. In south magnetic latitude the difference between the compasses increased, until it was sometimes four and five points, and on one occasion in 62° south dip, a difference of about eight points is recorded. The annexed sketch shows the position of the steering compass with regard to the rudder-head, &c. The azimuth compass was placed about midway between the steering compass and the break of the poop, which is 47 feet from the front of the stern-post. At the break of the poop is and iron bulk-head, reaching to the poop-deck. On her first outward trip part of her cargo consisted of 220 tons of bar, sheet, and hoop iron.

The following table contains the analysis of the chief observations on the first voyage:

OUTWARD.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ by Earth's horizontal force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head in terms of Earth's horizontal force at each position.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force towards ship's starboard side in terms of Earth's horizontal force at each position.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head in terms of Earth's horizontal force at each position.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force towards ship's starboard side in terms of Earth's horizontal force at each position.
1	53 30 N.	3 0 W.	° ′ 70 0	2.75	1.0	Probably 0°.	0	Probably 0°	0	....	....	....	....
2	4 16 S.	22 23 W.	15 0	.2679	.55	About 15° 0′	.2588	2° 0′	.0349	(*)	....	10 45	.1865
3	19 40 S.	22 2 W.	—11 0	.1944	.595	About 15° 0′	.2588	....	....	....	....	....	....
4	23 10 S.	21 33 W.	—16 0	.2867	.6	....	....	....	....	....	....	13 40	.2363
5	27 16 S.	11 48 W.	—27 0	.5095	.65	About 32° 0′	.5299	....	....	....	....	17 0	.2924
6	32 0 S.	58 0 E.	—62 0	1.8807	.83	53 0	.7986	About 5° or 6°	.0872 / .1045	....	....	26 0	.4384
7	20 27 S.	65 27 E.	—53 30	1.3270	.73	....	....	About 3° or 4°	.0523 / .0698	....	....	14 0	.2419
8	11 7 S.	67 51 E.	—41 0	.8691	.63	....	....	About 3° or 4°	.0523 / .0698	....	....	9 30	.1650

HOMEWARD.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ by Earth's horizontal force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head in terms of Earth's horizontal force at each position.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force towards ship's starboard side in terms of Earth's horizontal force at each position.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head in terms of Earth's horizontal force at each position.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force towards ship's starboard side in terms of Earth's horizontal force at each position.
9	6 30 N.	84 30 E.	— 6 0	.1051	.48	About 20° 0′	.3420	About 1 30	.0262	Very small	....	8 0	.1392
10	8 0 S.	83 30 E.	—34 0	.6745	.55	26 30	.4462	....	....	....	....	....	....
11	32 30 S.	35 0 E.	—57 30	1.5697	.82	42 0	.6691	Probably —2 30	—.0436	—1 30	—.0262	....	....
12	16 40 S.	4 30 W.	—17 0	.3057	.61	....	....	—2 30	—.0436	....	....	9 0	.1564
13	0 0	19 0 W.	20 0	.3640	.55	....	....	—6 0	—.1045	....	....	7 0	.1219
14	18 0 N.	30 0 W.	50 30	1.2131	.62	7 0	.1219	—2 15	—.0393	4 0	.0698	9 30	.1650
15	27 0 N.	32 30 W.	60 0	1.7321	.72	....	....	0 0	....	....	....	12 30	.2164

* Probably very small +

This table affords the following equations for the steering compass, in which x is the co-efficient for ship's vertical induction, and y is the ship's permanent magnetism towards the head:

Number of observation.	Equations for steering compas, arranged in order of Earth's dip.	Values for x and y on voyage outward.		Values for x and y on voyage homeward.	
		x	y	x	
1	$-2.75\ x+y=0$	....	....	....	....
14	$-1.2131\ x+.62\ y=.1219$	....	....	.2478	.6815
2	$-\ .2679\ x+.55\ y=$ (about) $.2588$	.2079	.5717	....	....
9	$.1051\ x+.48\ y=.3827$	....	....	.2400	.6600
3	$.1944\ x+.59\ y=$ (about) $.2588$	.1425	.3919	....	....
5	$.5095\ x+.65\ y=$ (about) $.5299$	.2307	.6344	....	....
10	$.6745\ x+.55\ y=.4462$	....	....	.2040	.5610
11	$1.5697\ x+.82\ y=.6691$	....	....	.1749	.4810
6	$1.8807\ x+.83\ y=.7986$	.1894	.5209	....	....
	Means	.1916	.5297	.2167	.5959

Taking the mean of means, the co-efficient for the inductive capacity of the ship at the station of the steering compass, appears to be equal to .2046 of Earth's horizontal force at Liverpool, and the ship's permanent magnetism, including that of the compensating magnets, .5628 of the same unit. The permanent magnetism of the ship is probably alone about .4.

The standard compass during this voyage shows only a very small change in the ship's fore-and-aft magnetism. The deviations from the transverse magnetism vary from 7° to 26°; a slight consideration of the table is sufficient to show that nearly the whole is due to permanent magnetism. Had a transverse magnet been applied to this compass at Liverpool, sufficient to have produced a minus deviation of 20°, it would have been slightly under-compensated during the first part of the outward voyage, and, through a reduction in the ship's transverse magnetism, would have been slightly over-compensated on the homeward voyage, and the maximum polar deviation would probably have never exceeded half a point.

The standard compass on the second voyage of this ship was placed further forward, so as to be between the mizzen and main masts, and immediately over the break of the poop, about 47 feet from the rudder head, and above an iron bulk-head. It was seven feet four inches above the poop deck, and eleven feet two inches above the main deck; a position in which the deviations were found to be very small.

The magnets at the steering compass were not moved. Whether they had decreased in power, as seems probable, is not known, nor whether there was any deviation observed in port.

"ADVANCE."—SECOND VOYAGE, 1856–'57. Captain DALISON.

OUTWARD.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's hor. force at station ÷ Earth's hor. force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head in terms of Earth's hor. force at each position.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force to ship's starboard side in terms of Earth's hor. force at each position.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head in terms of Earth's hor. force at each position.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force to ship's starboard side in terms of Earth's hor. force at each position.
			° ′			° ′		° ′		° ′		° ′	
1	41 24 N.	12 41 W.	65 30	2.1943	.84	8 0	.1392	....	....	—1 40	....	2 50	....
2	31 0	20 40	61 0	1.8040	.73	12 50	.2221	About — 4 0	....	....	....	....	....
3	29 30	21 46	60 0	1.7321	.72	....	....	....	....	—0 20	....	7 45	....
4	26 29	23 5	57 0	1.5399	.68	10 30	.1822	....	....	....	....	....	....
5	19 37	26 30	51 30	1.2572	.58	About 9 30	.1650	About 0 45	....	About —0 45	....	5·45	....
6	0 28	27 30	23 0	.3907	.55	12 0	.2079	....	....	1 5	....	....	....
7	6 36 S.	30 50	16 0	....	.55	....	....	— 0 24	....	....	....	3 36	....
8	14 12	32 7	1 0	.0175	.56	16 15	.2798	About — 3 45	....	1 15	....	About 5 30	....
9	21 0	29 0 W.	—12 0	.2126	.57	Head E 15 20 Head W. 20 20 Mean 17 50	.3062	2 20	....	—1 30	....	9 0	....
10	41 4	20 2 E.	—56 30	1.5108	.78	40 51	.6541	....	....	....	....	....	....
11	40 5	31 31	—60 0	1.7321	.81	50 0	.7660	....	....	2 10	....	....	....
12	38 48	57 0 E.	—65 0	2.1445	.84	50 0	.7660	About — 5 0	....	10 0	....	....	....
13	28 48	72 58	—61 0	....	.76	....	....	About — 5 0	....	....	....	7 30	....
14	23 1	73 14	—56 0	....	.71	....	....	About — 4 0	....	....	....	4 22	....
15	17 0	72 52	—51 0	....	.67	....	....	About — 4 0	....	....	....	3 8	....
16	8 20	73 49	—35 0	....	.59	....	....	— 1 30	....	....	....	5 45	....
17	5 17	74 15	—29 0	....	.56	....	....	— 1 30	....	....	....	5 0	....
18	2 22	74 36	—25 0	....	.53	....	....	About — 1 30	....	....	....	5 49	....
19	0 11 S.	75 7 E.	—20 0	....	.52	....	....	About — 1 30	....	....	....	4 34	....

HOMEWARD.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's hor. force at station ÷ Earth's hor. force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head in terms of Earth's hor. force at each position.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force to ship's starboard side in terms of Earth's hor. force at each position.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head in terms of Earth's hor. force at each position.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force to ship's starboard side in terms of Earth's hor. force at each position.
20	7 11 N.	79 25 E.	— 6 0	....	.47	....	....	About — 2 0	....	....	....	3 29	....
21	6 36 S.	91 36	—27 30	.5206	.51	21 40	.3692	— 0 40	....	1 0	....	2 39	....
22	8 0	87 0	—32 45	.6432	.53	34 40 ? 24 40	.4173	....	....	1 15	....	....	....
23	19 11	63 12	—52 30	1.3032	.72	37 0	.6018	....	....	Abo't 3 0	....	....	....
24	19 58 S.	60 22 E.	—53 0	....	.74	....	....	....	....	3 14	....	....	....

"ADVANCE."—SECOND VOYAGE—Continued.

AFTER STAYING A MONTH AT ST. LOUIS.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's horizontal force at station + Earth's horizontal force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head in terms of Earth's horizontal force at each position.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force to ship's starboard side in terms of Earth's hor. force at each position.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head in terms of Earth's horizontal force at each position.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force to ship's starboard side in terms of Earth's hor. force at each position.
			° ′			° ′		° ′		° ′		° ′	
25	20 20 S.	56 43 E.	−53 0	1.3270	.76	30 15	.5913	....	....	3 3	....	....	....
26	27 38	45 37	−57 30	1.5697	.82	About 30 0	.6293	....	....	3 21	....	....	....
27	29 12	42 8	−57 30	1.5697	.83	About 37 40	.6111	....	....	1 40	....	....	....
28	34 8	26 3	−57 0	1.5399	.80	About 40 0	.6428	....	....	1 53	....	....	....
29	34 33	18 14	−52 30	....	.77	....	....	− 6 30	....	1 47	....	2 30	....
30	30 57	13 8	−49 0	....	.74	....	....	− 4 5	....	....	....	3 0	....
31	23 20	3 38 E.	−33 0	.6494	.66	About 27 0	.4540	− 6 42	....	1 40	....	0 58	....
32	10 30	11 15 W.	− 2 0	....	.58	....	....	− 4 0	....	....	....	3 0	....
33	6 58	14 32	5 30	....	.57	....	....	{ − 1 0 − 5 20 }	....	0 40	....	5 30	....
34	5 15 S.	12 20	9 0	.1584	.57	About 18 30	.3173	− 1 30	....	1 24	....	5 50	....
35	18 59 N.	30 35	51 30	....	.62	....	....	− 3 18	....	....	....	3 50	....
36	25 22	32 57	58 0	....	.70	(*)	(*)	+ 0 33	....	....	....	8 45	....
37	32 0	33 23	64 0	2.0503	.78	(†)	(†)	− 1 35	....	....	....	9 20	....
38	33 39	33 23	65 30	2.1943	.82	About 6 0	.1045	− 0 52	....	Abo't 0 56	....	8 8	....
39	36 2 N.	31 46 W.	67 0	2.3559	.88	1 50	.0320	....	....	−4 0	....	....	....

* Wind E., force 6. † Wind E.S.E., force 3.

This table affords the following equations for the steering compass. x and y represent, as before, ship's capacity for vertical induction, and ship's permanent magnetism towards the head. On the outward voyage, the cargo consisted, in part, of 260 tons of bar, hoop, and sheet iron:

No. of observation.	Equations for steering compass arranged in order of Earth's magnetic dip.	Values for x and y on voyage outward. x	Values for x and y on voyage outward. y	Values for x and y on voyage homeward. x	Values for x and y on voyage homeward. y
Mean of 39 and 38.	$-2.2753\,x + .85\,y = .0683$. (For combination with other equations for the homeward voyage)........	....	....	....	....
Mean of 1, 2, and 4.	$-1.8461\,x + .75\,y = .1812$. (For combinations with other equations for the outward voyage)........	....	....	....	....
5	$-1.2572\,x + .58\,y =$ (about) .1651........	.1465	.6022	....	....
6	$-\ .3907\,x + .55\,y = .2079$........	.0779	.4333	....	....
34	$-\ .1584\,x + .57\,y = .3173$........	....	....	.1986	.6118
8	$.0175\,x + .56\,y = .2789$........	.1055	.5013	....	....
9	$.2126\,x + .57\,y = .3062$........	.1043	.4983	....	....
21	$.5206\,x + .51\,y = .3692$........	....	....	.1741	.5462
22	$.6432\,x + .53\,y = .4173$........	....	....	.1817	.5669
31	$.6494\,x + .66\,y = .4540$........	....	....	.1659	.5246
23	$1.3032\,x + .72\,y = .6018$........	....	....	.1684	.5310
25	$1.3270\,x + .76\,y = .5913$........	....	....	.1578	.5025
10	$1.5106\,x + .78\,y = .6541$........	.1357	.5757	....	....
28	$1.5399\,x + .8\,y = .6428$........	....	....	.1572	.5011
26	$1.5697\,x + .82\,y = .6293$........	....	....	.1497	.4809

EQUATIONS—Continued.

No. of observation.	Equations for steering compass arranged in order of Earth's magnetic dip.	Values for x and y on voyage outward.		Values for x and y on voyage homeward.	
		x	y	x	y
27	$1.5697\,x + .83\,y = .6111$	....	....	.1436	.4647
11	$1.7321\,x + .81\,y = .7660$	.1531	.6183	....	....
12	$2.1445\,x + .84\,y = .7660$	.1339	.5701	....	....
	Means	.1224	.5427	.1663	.5255

In May, 1857, immediately before the "Advance" proceeded on her third voyage, an upright bar of iron, about 8 feet long, 2½ inches wide, and 1 inch thick, was fixed at the back of the cabin, and before the compass, as shown in the sketch, Fig. 6. There was no opportunity of testing beforehand what strength the bar should be. On trial, as the ship was passing from the dock into the river, with her head for a few moments at west, it was found much too weak for the purpose intended. The fore-and-aft magnets had to be shifted a little further from the compass. The effect of these alterations will be seen in the discussion of the observations made on the third voyage.

The cargo on the third outward voyage consisted, in part, of 350 tons of rod, hoop, and bar iron, and machinery.

"ADVANCE."—THIRD VOYAGE, 1857–'60.)

OUTWARD.

No. of observation.	Date.	Latitude.	Longitude.	Terrestrial dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ Earth's horizontal force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head, &c.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force to ship's starboard side, &c.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head, &c.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force to ship's starboard side, &c.
	1857.			° ′			° ′		° ′		° ′		° ′	
1	May 12	53 30 N.	3 0 W.	70 0	2.75	1.0	0	....	0	......	....	......	....	......
2	June 3	36 28	12 12	62 30	1.9210	.76	2 16 / 3 20 better	.0523	....	......	—5 0	......	....	......
3	17	9 41 N.	27 56	....	....	.57	....	....	—2 30	......	About —2 30	......	4 0	......
4	July 10	28 9 S.	34 27	— 4 30	.0787	.59	12 20	.2079	1 30	......	—4 30	......	8 45	......
5	23	41 40	1 12 W.	—47 30	1.0913	.71	17 30	.3007	....	......	....	......	....	......
6	25	41 8	6 0 E.	—51 0	1.2349	.74	22 31	.3830	....	......	....	......	....	......
7	31	40 59	23 27	—57 40	1.5798	.78	27 36	.4633	....	......	....	......	....	......
8	Aug. 6	39 23	35 37	—61 0	1.8040	.82	43 0	.6820	....	......	....	......	About 6 20	......
9	20	30 34	81 39	....	....	.72	....	....	About —5 0	......	....	......	About 1 0	......
10	22	25 44 S.	82 5	....	....	.69	....	....	—0 15	......	....	......	3 40	......
11	Sept. 8	15 0 N.	84 8	....	....	.45	....	....	—1 0	......	....	......	4 0	......
12	9	18 31 N.	85 4 E.	17 30	.3153	.45	About 4 40	.0814	....	......	....	......	....	......

"ADVANCE."—THIRD VOYAGE, 1856–'57—Continued.

CALCUTTA TO HONG KONG, ETC.

No. of observation.	Date.	Latitude.	Longitude.	Terrestrial dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ Earth's horizontal force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head, &c.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force to ship's starboard side, &c.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head, &c.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force to ship's starboard side, &c.
	1857.			° ′			° ′		° ′		° ′		° ′	
13	Oct. 31	17 31 N.	90 12 F.	16 0	.2867	.44	8 0	.1392	+4 0	......	—0 40	......	6 45	......
14	Nov. 21	0 49	108 0	......	......	.46	......	......	0 55	......	......	......	4 40	......
	1858.													
15	Feb. 2	5 20	105 54	— 5 0	.0875	.45	10 12	.1771	......	......	About —2 48	......	......	......
16	April 15	15 43	96 5	......	......	.45	......	......	—0 15	......	......	......	4 15	——
17	May 14	4 52	105 18	— 5 0	.0875	.45	17 50*	.3062	0 50	......	About —1 30	......	4 0	......
18	27	19 13	114 29	......	......	.46	......	......	—0 40	......	......	......	4 20	......
	1859.													
19	Feb. 6	9 13	97 23	......	......	.45	......	......	—3 8	......	......	......	4 8	......
20	Aug. 11	10·47	94 37	— 5 0	.0875	.45	11 0	.1908	......	......	......	......	......	......
21	Sept. 2	3 30 N.	85 35	—12 0	.2126	.47	About 20 0	.3420	......	......	......	......	......	......
22	8	0 40 S.	83 15	......	......	.50	......	......	—3 7	......	......	......	......	......
23	17	8 32	76 13	—35 0	.7002	.58	20 41	.3530	......	......	......	......	......	......
24	19	8 52	70 12	—37 30	.7673	.6	21 40	.3692	......	......	......	......	......	......
25	22	4 52	64 35	......	......	.58	......	......	—2 28	......	About —1 30	......	2 40	......
26	23	3 15	64 31	—28 0	.5317	.57	About 18 0	.3090	—2 0	......	0	......	3 30	......
27	24	1 46 S.	64 20	......	......	.55	......	......	—5 0	......	......	......	1 40	......
28	26	0 48 N.	66 13 E.	—20 0	.3640	.53	14 0	.2419	—3 37	......	—0 20	......	1 30	......

FROM BOMBAY HOMEWARD.

No. of observation.	Date.	Latitude.	Longitude.	Terrestrial dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ Earth's horizontal force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head, &c.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force to ship's starboard side, &c.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head, &c.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force to ship's starboard side, &c.
29	Dec. 15	4 4 N.	63 55 E.	—15 0	.2679	.52	14 0	.2419	......	......	—2 10	......	......	......
30	30	8 17 S.	65 8	—37 0	.7536	.61	About 19 30	.3338	......	......	......	......	2 0	......
	1860.													
31	Jan. 2	9 35	65 47	—38 0	.7813	.61	{ Head W., 19 40; Head E., 18 0 }	.3256	—3 0	...	{ Head W., —2 0; Head E., —0 40 }	...	3 0	......
32	13	19 12	51 29	52 0	1.2799	.76	25 45	.4368	—2 16	......	0 8	......	4 0	......
33	27	31 59	34 4 E.	......	......	.81	......	......	......	......	—0 20	......	......	......
34	Feb. 28	1 19 S.	21 18 W.	......	......	.56	......	......	—6 0	......	......	......	0 35	......
35	April 4	38 23 N.	28 35 W.	67 15	2.3847	.9	9 10	.1593	1 5	......	—4 30	......	3 40	......

* Single observation.

The last table affords the following equations for the steering compass:

Number of observation.	Equations for the steering compass arranged in the order of the Earth's magnetic dip.	Values for x and y on voyage outward.		Values for x and y in the East Indies.		Values for x and y on voyage homeward.	
		x	y	x	y	x	y
1	$-2.75\,x + y = 0$. (For combination with other equations for the outward voyage)						
35	$-2.3847\,x + .9\,y = .1593$. (For combination with other equations for observations in the East Indies and on the homeward voyage)						
2	$-1.921\,x + .76\,y = .0523$	.3095	.8511				
12	$-\ .3153\,x + .45\,y = .0814$	.0883	.2428				
13	$-\ .2867\,x + .44\,y = .1392$	.1508	.4177				
15, 17, 20	$.45\,y = .2162$			.1145	.4804		
4	$.0787\,x + .59\,y = .2079$	.1222	.3361				
21	$.2126\,x + .47\,y = .3420$			.1775	.6473		
29	$.2679\,x + .52\,y = .2419$					.0911	.4183
28	$.3640\,x + .53\,y = .2419$			.0837	.3989		
26	$.5317\,x + .57\,y = .3090$			.1019	.4469		
23, 24	$.7338\,x + .59\,y = .3611$			.1117	.4743		
30, 31	$.7675\,x + .61\,y = .3297$					.0930	.4235
5	$1.0913\,x + .71\,y = .3007$	.1471	.4045				
6	$1.2349\,x + .74\,y = .3830$	.1171	.3221				
32	$1.2799\,x + .76\,y = .4368$					.0918	.4245
7	$1.5798\,x + .78\,y = .4633$	.1244	.3421				
8	$1.8040\,x + .82\,y = .6820$	.1705	.4689				
	Means	.1537	.4232	.1179	.4895	.0920	.4221

The mean values for the three voyages will be, respectively, for x, —.2041, —.1443, —.1212, and for y, .5628, .5341, .4449. The difference between the mean values on the second and third voyages, both for x and y, correspond very well together, and with the known effect of the bar, which was introduced before the steering compass after the second voyage.

On the return of the "Advance" to Liverpool, after her third voyage, she lay in dock with her head to the north, so that there was no opportunity of obtaining the fore-and-aft error of this compass; but the fore-and-aft magnets were taken on shore, and placed in the same relative position as when on board with a trial compass, when they were found to produce an error of 10°. As the north end of these magnets was towards the ship's stern, they would assist in producing the observed y; the ship's permanent magnetism to the head will therefore be $.4449 - .1736 = .2713$, or sufficient to produce at Liverpool a deviation of 15° 45′.

On the supposition that when the fore-and-aft magnets were in place, there was no error in Liverpool with ship's head east or west, x or the co-efficient for vertical induction will be .1618, which is much greater than the mean values obtained on the two last voyages. If .1212, the mean value for the third voyage, be accepted, there would be on the ship's return to Liverpool an error represented by $-2.75 \times .1212 + .4449 = .1116$, which is equal to a deviation towards the ship's head of

6° 25′. A mean between these two extreme suppositions, or —.1367 for the co-efficient for vertical induction, and .2713 for the permanent magnetism towards the ship's head, will, it is thought, be a very close approximation to the magnetic elements of this ship for the station of the steering compass.

There seems little doubt that a vertical bar of soft iron introduced before this compass, so as to produce at Liverpool a deviation towards the ship's head of 15° 45′, and a permanent magnet placed on the deck with the north pole towards the bow, so as to neutralize the deviation caused by the bar, would satisfactorily correct this compass for all latitudes.*

This discussion does not afford any satisfactory data for expressing an opinion on the effect of the iron carried as cargo on each of the outward voyages.

The sea errors of the standard compass of the "Advance," on the second and third voyages, were so small as scarcely to require any attempt at artificial correction. A transverse magnet with its north end to starboard, sufficient to produce at Liverpool a deviation of 7°, would certainly be sufficient for all practical purposes. The residual errors and the errors from heeling would then be too small to give the navigator any anxiety, when unable for a day or two to make any observations for the correction of the compass.

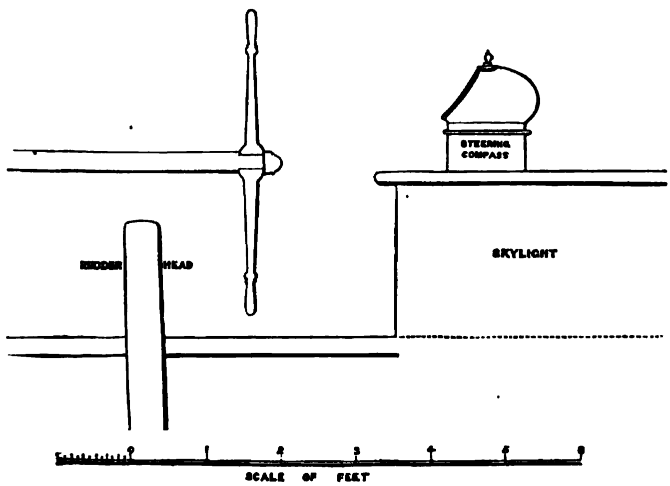
"ASTRÆA."—Captain S. NICKELS.

The "Astræa," is a three-masted schooner, of about 400 tons, and was built on the Clyde with her head to the west of south, in the spring of 1856. Her first voyage was to the West Indies (see second report of Compass Committee;) since then she has made several voyages to the island of Mauritius and to Calcutta. Captain Nickels, at the request of the committee, has repeatedly swung his ship at sea, and the details he has furnished (most of which are given in the Appendix,) present one of the most complete records which have yet been received of the changes which occur in the magnetism of iron ships. This vessel is a good type of iron, ships built in this country with her head in a southerly direction. Her steering compass is placed over the cabin skylight, as shown in the accompanying sketch. According to the deviation table given by the compass adjuster before leaving the Clyde, the steering compass had a deviation of 2½° degrees west when ship's head was east, and no error with her head at west. The attraction to port was rather over-compensated by a transverse magnet, the table showing no error

* See some further particulars respecting this compass, with letter from Captain Dalison, in the Appendix, showing effect of the short iron bar marked *a* in the sketch, Fig. 6.

with ship's head north, and with ship's head south a deviation of 4° west. As the deviations on the card are all westerly, there is evidently an index error of some sort. After allowing for this, the resultant attraction to starboard may be taken as 1°. When examined in Liverpool after her return from the West Indies, it was about 15½°, showing a considerable reduction in the ship's magnetism. On removing the transverse magnet, the attraction to starboard was — 8½°. Supposing the magnet to have retained its power, the original attraction to starboard will be represented by a deviation of about —23°. There was also found an attraction towads the head of —8½°, indicating a reduction of the same extent in the ship's fore-and-aft magnetism. On her return to Liverpool from the Mauritius, the deviation towards the bow had increased to 11°. The deviations of this compass rapidly increased as the ship went south, especially when her head was east or west; and the captain observing that the magnet caused an increase of deviation on some other courses, removed it from the compass altogether. Besides the steering compass, there was a standard compass placed near the mizzen mast, but it does not appear to have acted well. The deviations of the standard compass are reported to have been frequently of the opposite name to those of the steering compass, so that in the southern hemisphere there was sometimes a difference of several points between them; thus, on 11th October a difference of 8½ points is recorded, and on the 18th of the same month, in latitude 40° S. and longitude 33° E., a difference of 10 points.

Fig. 7.



Observations made in latitude 24° 32′ S. longitude 28° 42′ W., and in lat. 37° 32′ S., longitude 12° 30′ W., afford, in conjunction with an observation made at Liverpool, the following equations for estimating pretty approximately the elements of this ship's fore-and-aft magnetism on the first southern voyage, at the station of the steering compass, in terms of Earth's force at Liverpool:

$$-2.75\ x + \ \ y = -.1908$$
$$.3153\ x + 6\ y = .3746 \text{ or } x = .2488,\ y = .4934$$
$$.7813\ x + 65\ y = .5050 \quad x = .2448,\ y = .4824$$

or a mean $x = .2468$ and a mean $y = .4879$; x representing, as before, the co-efficient for vertical induction, and y the ship's permanent magnetism.

These forces in latitude 40° south longitude 40° east, would give an attraction towards the head equal to .8695 of the Earth's horizontal force, or a maximum deviation of 60° 24′, which quite confirms the extreme deviations which Captain Nickels has recorded for this compass, as well as the assertions which have been so frequently made by the commanders of other iron ships, namely, that in certain places and positions of the ship their steering compass has been found to be entirely destitute of directive power. This would of course occur when the ship's force and Earth's force were nearly the same, and acting in opposite directions.

The following table is obtained from the second voyage to the Mauritius and the first to Calcutta. (See Appendix M.)

STEERING COMPASS OF THE "ASTRÆA."—Captain S. NICKELS, 1857, 1858, 1859.

OUTWARD VOYAGE TO MAURITIUS.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's hor. force at station ÷ Earth's hor. force at Liverpool.	Deviation towards ship's head.	Force towards ship's head in terms of Earth's hor. force at each station.	Deviation to ship's starboard side.	Force to ship's starboard side in terms of Earth's hor. force at each station.
	° ′	° ′	° ′			° ′		° ′	
1	30 42 N.	18 17 W.	60 0	1.7321	.72	1.0	.0175	—8.15	—.1435
2	19 46 N.	24 11 W.	50 30	1.2131	.615	4.10	.0727	—6.44	—.1172
3	3 36 N.	16 23 W.	30 0	.5774	.55	9.26	.1639	....	....
4	28 8 S.	24 50 W.	—24 0	.4452	.62	18.40 (about)	.3201	....	....
5	34 0 S.	2 45 E.	—44 0	.9657	.715	25.0 (about)	.4226	....	....
6	38 47 S.	22 16 E.	—56 30	1.5108	.79	41.30	.6626	....	....
7	38 51 S.	40 0 E.	—59 0	1.6643	.835	45.30	.7133	....	....
8	23 13 S.	59 9 E.	—56 30	1.5108	.78	....	....	—5.24	—.0941

HOMEWARD VOYAGE.

9	22 32 S.	55 7 E.	—55 0	1.4281	.78	36.0	.5878	....	....
10	17 27 S.	5 24 W.	—30 30	.5890	.62	18.0 (about)	.3090	....	....
11	15 42 S.	7 27 W.	—13 0	.2309	.6	....	....	—6.30	—.1132
12	2 26 S.	27 9 W.	20 0	.3640	.54	....	....	—7.6	—.1236
13	15 30 N.	39 35 W.	46 30	1.0538	.59	6.32	.1138	....	....

STEERING COMPASS OF THE "ASTRÆA"—Continued.

OUTWARD VOYAGE TO CALCUTTA.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's hor. force at station + Earth's hor. force at Liverpool.	Deviation towards ship's head.	Force towards ship's head in terms of Earth's hor. force at each station.	Deviation to ship's starboard side.	Force to ship's starboard side in terms of Earth's hor. force at each station.
	° ′	° ′	° ′			° ′		° ′	
14	45 0 N.	12 45 W.	67 20	2.3945	.9	—4.15	—.0741	—8.38	—.1501
15	9 19 S.	32 7	10 0	.1763	.555	8.30	.1478	—4.28	—.0779
16	15 52	32 52	0	0	.554	11.45	.2036	....	....
17	27 12	30 22	—21 0	.3839	.6	14.30 (about)	.2504	+1.0	.0175
18	2 5 S.	83 36 W.	—22 0	.4040	.51	14.30 (about)	.2504	....	....

HOMEWARD VOYAGE.

19	18 58 S.	57 26 E.	—53 0	1.3270	.75	30.30	.5075	....	....
20	31 45 S.	30 36 E.	—56 0	1.4826	.81	37.20	.6065	....	....

The change in the deviation to starboard may be attributed chiefly to change in Earth's horizontal force, except No. 17, which does not accord with the others, and perhaps is caused by heeling. The transverse magnetism of the ship appears to be almost wholly permanent. The following are the equations for the "Astræa's" fore-and-aft magnetic elements, arranged in the order of the Earth's dip:

No. of observation.	Equations.	Mauritius voyage.				Calcutta voyage.			
		Outward.		Homeward.		Outward.		Homeward.	
		x	y	x	y	x	y	x	y
14	$-2.3945\,x + .9\,y = -.0741$					1.2127	3.1441		
1	$-1.7321\,x + .72\,y = .0175$	.6247	1.53						
2	$-1.2131\,x + .615\,y = .0727$	.3972	.9014						
13	$-1.0538\,x + .59\,y = .1138$			.3982	.9042				
3	$-.5774\,x + .55\,y = .1639$	.2875	.5988						
15	$-.1763\,x + .555\,y = .1478$					.1879	.3261		
16	$.554\,y = .2036$					.2030	.3675		
17	$.3839\,x + .6\,y = .2504$ (about)					.1794	.3026		
18	$.4040\,x + .51\,y = .2504$ (about)					.1924	.3384		
4	$.4452\,x + .62\,y = .3201$ (about)	.2039	.3699						
10	$.5890\,x + .62\,y = .3090$ (about)			.1862	.3213				
5	$.9657\,x + .715\,y = .4226$ (about)	.1906	.3334						
19	$1.3270\,x + .75\,y = .5075$							.1919	.3369
9	$1.4281\,x + .78\,y = .5878$			.2061	.3760				
20	$1.4826\,x + .81\,y = .6065$							.2051	.3732
6	$1.5108\,x + .79\,y = .6626$	.2208	.4264						
7	$1.6643\,x + .835\,y = .7133$	.2204	.4153						
	$-2.75\,x + y = -.1908$.*								
	Means	.3064	.6536	.2635	.5338	.3951	.8957	.1985	.3551
	Means of the observations lying below No. 3, and above No. 6.	.1973	.3517	.1962	.3487	.1907	.3336	.1985	.3551

* The last equation has been used in combination with all the others.

It is evident from this and the preceding tables, that a portion of the ship's changing magnetism does not change immediately on change of magnetic latitude, or that a portion of the magnetism treated as permanent is only so under certain conditions. The fluctuations in the value of the more permanent part of the magnetism of the "Advance" are smaller than in the "Astræa," even when, in the latter ship, only the observations made in the southern hemisphere are compared with those made in Liverpool; but in both cases the fluctuations are within limits which make compensation by fixed magnets and an ordinary bar of vertical iron in all probability practically efficient. If the vertical bar proposed to be placed before the compass descended to the keel, and formed part of the structure of the ship, it seems pretty certain that the changes in its magnetism would correspond so closely with the changes occurring in the stern-post and other iron aft of the steering compass, that the fluctuations alluded to would altogether disappear.

As there are reasons for supposing that these fluctuations attain their maximum in ships built head to the south, the following table has been prepared, to afford a comparison between the observed deviations of the steering compass of the "Astræa" and the calculated deviations which would be produced by a bar of perfectly soft iron and a fixed permanent magnet. The table is prepared for three values of x and y. First from values obtained from the five equations, Nos. 15, 16, 17, 18, and 4, in conjunction with the five equations, Nos. 10, 5, 19, 9, and 20, which include outward and homeward observations for both voyages, and give $x = .207$ $y = .3359$; next, for the values of x and y, observed on the magnetic equator and Liverpool; and lastly, for $x = .2$ $y = .4$ of Earth's horizontal force at Liverpool. It will be seen that the greatest difference in the last two columns between the observed and the calculated deviations in only one instance is so much as half a point of the compass, the range of error being within 3° 56′ and — 5° 40′, while, without compensation, the fore-and-aft magnetic error is so much as four points, and the range of error five points.

No. of observation.	Dip.	Observed deviation.	$x = -.207$. $y = .3359$. Calculated deviation.	Difference. Outward voyages.	Difference. Homeward voyages.	$x = -.203$. $y = .3675$. Calculated deviation.	Difference. Outward voyages.	Difference. Homeward voyages.	$x = -2$. $y = .4$. Calculated deviation.	Difference. Outward voyages.	Difference. Homeward voyages.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
At Liverpool..	70 0	—11 0	—13 30	—2 30	....	—11 0	0 0	....	— 8 41	2 19	....
14..................	67 20	— 4 15	—11 9	—6 54	....	— 8 56	— 4 41	....	— 6 50	— 2 35	....
1..................	60 0	1 0	— 6 42	—7 42	....	— 5 2	— 6 2	....	— 3 21	— 4 21	....
2..................	50 30	4 10	— 2 33	—6 43	....	— 1 10	— 5 20	....	0 12	— 3 58	....
13..................	46 30	6 32	— 1 9	....	—7 41	0 10	....	— 6 22	0 52	....	—5 40
3..................	30 0	9 26	3 44	—5 42	....	4 52	— 4 34	....	6 0	— 3 26	....

TABLE—*Continued.*

No. of observation.	Dip.	Observed deviation.	$x=-.207.\ y=.3359.$ Calculated deviation.	Difference. Outward voyages.	Difference. Homeward voyages.	$x=-.203.\ y=.3675.$ Calculated deviation.	Difference. Outward voyages.	Difference. Homeward voyages.	$x=-.2\ \ y=.4.$ Calculated deviation.	Difference. Outward voyages.	Difference. Homeward voyages.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
15	10 0	8 30	8 37	0 7	....	9 41	1 11	....	10 46	2 16	....
16	0 0	11 45	10 43	—1 2	....	11 45	0 0	....	12 49	1 4	....
17	—21 0	14 30	16 9	1 39	....	17 22	2 52	....	18 28	3 58	....
18	—22 0	14 30	14 46	0 16	....	15 38	1 8	....	16 33	2 3	....
4	—24 0	18 40	17 31	—1 9	....	18 37	— 0 3	....	19 42	1 2	....
10	—30 30	18 0	19 17	....	1 17	20 20	....	2 20	21 27	....	3 27
5	—44 0	25 0	26 7	1 6	....	27 44	2 44	....	28 30	3 30	....
19	—53 0	30 30	31 47	....	1 17	33 2	....	2 32	34 26	....	3 56
9	—55 0	36 0	33 53	....	—2 7	35 25	....	— 0 35	36 42	....	0 42
20	—56 0	37 20	35 23	....	—1 57	36 46	....	— 0 34	38 21	....	1 1
6	—56 30	41 30	34 37	—6 53	....	36 40	— 4 50	....	38 10	— 3 20	....
7	—59 0	45 30	38 41	—6 49	....	39 42	— 5 48	....	41 49	— 3 49	....

As before remarked, this table is constructed on the supposition that the compensating bar is of perfectly soft iron, and the compensating magnet quite permanent. In practice, the compensation would probably be more perfect than would be possible with these conditions. In the case of the "Astræa," compensation might be effected at Liverpool in this way: Place a fore-and-aft magnet so as to increase the attraction towards the stern by .36 of the Earth's horizontal force at Liverpool; then place a vertical bar of iron, of suitable size, (the size might vary according to circumstances, say from 8 feet long by 2 inches in diameter to 4 feet long by 3 inches in diameter,) and prepared so as to be free from retained magnetism, and with the end most susceptible to northern induction upwards. The upper end of the bar should be an inch or two above the level of the compass card, and at such a distance as to compensate all error, with the ship's head at east or west correct magnetic; on hammering the bar throughout its length, it would probably acquire enough magnetism to produce a deviation towards the bow of 6°; remove the bar a little further forward, so as to reduce this deviation to 3°. and permanently secure the bar in that position; then permanently secure the fore-and-aft magnet a little nearer to the compass, so as to compensate the remaining deviation of 3°, and this adjustment would be complete.

A modification of the compensation which has now been suggested, was successfully introduced into the ship to which attention is next directed.

"APHRODITA."—Captain Hugh Stewart.

This ship has already been noticed in treating of the effect of heeling on the compasses of iron ships. She is of 1,601 tons register, and more than 2,000 tons burthen. About 1,000 tons of iron were employed in her construction. The compass log for this ship during her first voyage to Calcutta and back is given in the Appendix. The standard compass is a very superior instrument, similar to those supplied to the Admiralty; and Captain Stewart states that he has only given those observations which he thought most worthy of dependence. A sketch is annexed, Plate 35, to show the position of the steering compasses with respect to the wheel and the compensating bar.* The Admiralty compass is fixed about thirteen feet above the deck, between the mizzen and main masts. The lower masts and the yards of this vessel are all made of iron or steel.

As this ship was not partially swung at intervals while at sea, like the "Advance and the "Astræa," there are not the same facilities for ascertaining the deviations on the cardinal points. The following table has, in consequence, been arranged differently to those which preceded it. Observations made near the cardinal points are selected, and the difference columns show the difference between these and the observations made in Liverpool with the ship's head in the same direction.

* Ordinary compass cards could not have been used in the positions selected for the steering compasses of this ship. Vertical compasses were therefore employed. In these the card is usually represented by a thin steel hoop on which the points of the compass are painted. Very great care is required in selecting compasses of this kind, as they frequently have a large index error. On one occasion, the secretary found on board an iron ship, about to go to sea with emigrants, two of these compasses which differed from each other so much as 18½°. On taking them on shore to be tested, one was found to have a — index error of 5°, and the other a + error of 13½°.

"APHRODITA."—Captain Hugh Stewart.

First voyage from Liverpool to Calcutta and back.

OUTWARD VOYAGE.

Number.	Latitude.	Longitude.	Magnetic dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ Earth's horizontal force at Liverpool.	Heel.—P, port; S, starboard.	Ship's head correct magnetic.	Standard compass. Approximate change in the deviation towards ship's head.	Standard compass. Approximate change in the deviation towards ship's starboard side.	Compass under the companion. Approximate change in the deviation towards ship's head.	Compass under the companion. Approximate change in the deviation towards ship's starboard side.	Compass over the companion. Approximate change in the deviation towards ship's head.	Compass over the companion. Approximate change in the deviation towards ship's starboard side.
	° ′	° ′	° ′			°	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	16 50 S.	25 34 W.	— 3 0	.0524	.58	1 S.	S. 12 30 E.	....	2 30	....	4 30	....	3 30
2	23 37	25 17 W.	—13 0	.2309	.60	0	S. 76 30 W.	8 15	....	3 15	....	16 15	....
3	36 34	57 50 E.	—64 0	2.0503	.83	0	N. 82 0 E.	1 0	....	4 0	....	16 0	....
4	19 46 S.	77 1	—53 0	1.3270	.68	6 P.	N. 9 0 W.	....	8 45	....	0 15	....	4 45
5	20 50 N.	88 32	22 0	.4040	.45	3 P.	W. 5 0 N.	3 30	....	5 0	....	3 0	....
6	21 8 N.	88 9 E.	22 0	.4040	.45	0	N. 8 0 E.	....	9 30	....	2 15	....	1 0
							HOMEWARD VOYAGE.						
7	16 52 N.	89 51 E.	14 30	.2586	.44	7 S.	S. 3 0 E.	....	10 40	....	6 0	....	6 45
8	13 56 N.	89 52	12 0	.2126	.46	3 S.	S. 4 45 W.	....	10 15	....	6 25	....	6 0
9	8 36 S.	88 53	—34 0	.6745	.53	10 P.	S. 1 20 E.	....	12 0	....	7 20	....	7 50
10	29 0	56 8	—60 0	1.7321	.82	0	S. 85 30 W.	0 45	....	5 45	....	15 15	....
11	30 36	45 35	—58 30	1.6319	.83	0	N. 83 0	2 0	....	5 50	....	18 45	....
12	31 11	43 41	—58 30	1.6319	.83	14 S.	N. 83 30	2 30	....	5 20	....	20 15	....
13	32 36	31 21	—57 0	1.5399	.81	15 S.	S. 80 15	0 45	....	5 25	....	19 0	....
14	21 3 S.	0 43 E.	—28 0	.5317	.65	0	N. 8 15	....	14 0	....	6 40	....	7 20
15	14 13 N.	29 32 W.	46 30	1.0538	.59	18 P.	N. 4 5	....	9 50	....	9 20	....	10 40
16	18 17	32 38	51 0	1.2349	.61	18 P.	N. 1 45	....	7 55	....	12 50	....	12 0
17	19 44	33 20	53 0	1.3270	.62	16 P.	N. 1 55 W.	....	8 5	....	8 40	....	8 50
18	25 50	35 56	59 0	1.6643	.70	12 P.	N. 0 15 E.	....	5 55	....	13 30	....	12 0
19	27 11	36 34	60 30	1.7675	.73	14 P.	N. 4 45	....	1 40	....	13 40	....	16 0
20	45 31	24 16	70 0	2.7475	1.03	8 S.	N. 89 45	3 30	....	10 10	....	0 30	....
21	51 22 N.	8 29 W.	70 0	2.7475	1.00	0	S. 87 15 E.	7 30	....	0 15	....	8 30	....

At Liverpool, at the station of the standard compass, the deviation to ship's head was — 9° 35′, and to starboard side + 17° 32′.

Observations Nos. 3, and 10, and 11, afford suitable equations for comparison with those representing the ship's fore-and-aft magnetic force at Liverpool, at the stations of each of the three compasses.

For the standard compasses they are—

For Liverpool $-2.75\ x + \ \ y = .1665$

" Obs. 3, $2.0503\ x + .83\ y = .1837$, or $x = .0105$, $y = .1954$

" Obs. 10 & 11, $1.682\ x + .825\ y = .1902$, or $x = .0134$, $y = .2032$

or a mean $x = .012$ and a mean $y = .1993$

For the compass under the companion they are—

For Liverpool, $-2.75\ x + \quad y = -.0442$

" Obs. 3 $\quad 2.0503x + .83\ y = \quad .1132$, or $x = .0346$, $y = .0509$

" Obs. 10 & 11 $\quad 1.682\ x + .825\ y = \quad .0727$, or $x = .0276$, $y = .0319$

or a mean $x = .0311$ and a mean $y = .0414$

For the compass placed over the companion they are—

For Liverpool, $-2.75\ x + \quad y = -.0958$

" Obs. 3, $\quad 2.053\ x + .83\ y = \quad .1908$, or $x = .0624$, $y = 0757$

" Obs. 10 & 111 $\quad .682\ x + .825\ y = \quad .2079$, or $x = .0726$, $y = .1039$

or a mean $x = .0675$ and a mean $y = .0898$

The values obtained for the compass under the companion show that the compensation is very nearly perfect, and that it would probably be quite so for all latitudes, if the magnet were placed an inch or so further from the compass, and the upright bar were placed about two inches nearer. The "Aphrodita" has since made a second voyage to Calcutta, and the captain, in a letter to the owners, states, that in running down her easting in the southern hemisphere, this compass has never been more than half a point in error.

The elements of this ship's fore-and-aft magnetim at the station of the standard compass does not differ much in quantity from those of the screw steam transports, "Assistance" and "Adventure," which were also built at Liverpool, in as nearly as possible the same direction as the "Aphrodita." The difference in sign is no doubt due to the standard compasses of the two steamers being placed very much nearer to the stern than the standard of the "Aphrodita."

The following equations are obtained from deviation tables for these vessels, which were furnished to the committee by Mr. F. J. Evans, of the Admiralty Compass Department. Both ships were swung at Portsmouth, in May, 1857, and again in Canton river, in the spring of 1858.

The "Assistance" at Portsmouth, gives—

$$-2.4751\ x + \quad y = \quad -.1619$$

And near Canton—

$$-\ .5774\ x + .47\ y = \quad -.0704, \quad \text{or } x = .0097,\ y = -.1379.$$

The "Adventure" at Portsmouth, gives—

$$-2.4751\ x + \quad y = \quad -.1691;$$

And near Canton—

$$.5774\ x + \quad y = \quad -.07005, \text{ or } x = .0161,\ y = -.1293.$$

These results are very similar, and show great permanency in the magnetism of both ships. The transverse magnetism of the ships was also similarly permanent, so that the difference in the tables for Portsmouth and Canton is almost entirely due to the difference in the Earth's directive power at the two places.

Observations made on board the Turkish iron paddle-wheel steam frigate "Feid Gehadd" show a similar degree of permanency in the fore-and-aft magnetism of this ship at the station selected for the standard compass, which is immediately before the mizzen mast, and about seven feet above the deck. The equations are—

For Alexandria, $-\ .7265\,x + .53\,y = -\ .1161.$

For Liverpool, $-2.75\quad x + \quad y = -\ .1994$ or $x = .0143, y = -\ .2387$

The next ship to which attention is directed is also a screw steamer, and is the only merchant steamer for which returns suitable for the present part of the inquiry have been obtained. It is a subject of surprise as well as regret to the committee to have to make this announcement. Among so many intelligent captains of iron steamers as sail from the port of Liverpool, it might be reasonably supposed that several would have been ready to furnish the committee with tables of deviation obtained at Malta, or Alexandria, at New York, Portland, or the St. Lawrence, for comparison with the deviations observed in the Mersey. But, so far as the committee are aware, such tables do not exist The information these tables would give might be expected to be as serviceable in the navigation of the ship as they would be interesting to the committee. It might be supposed, too, that to swing an iron ship before leaving a distant port, when she has to pass rocks and headlands, where fogs are at times prevalent, would be necessary for any navigation which did not deserve Dr. Scoresby's designation of an "inverse process;" but this cannot be the case, as, with the exception of an occasional mishap, the navigation of our iron steamers must be considered eminently successful. Unnecessary detention in port or loss of time on the voyage cannot be urged as the reason, as, in a steamer, under favorable circumstances, the requisite observations could be made in an hour, or even in half that time.

STEAMSHIP "BŒOTIA"—Captain HARAM.

This vessel was swung by Captain Haram, at Malta, in July, 1857, and the observations then made with the deviation tables furnished to her on the 12th of the same month, before leaving Liverpool, afford the following equations of this ship's fore-and-aft magnetism:

Steering compass in the usual position:

At Liverpool $-\ 2.75\quad x + \quad y = -\ .4067.$

At Malta $-\ 1.2799\,x + .63y = -\ .1994$, or $x = .1255, y = -\ .0615$

Mast compass, about 16 feet above the deck on the front of the mizzen-mast:

At Liverpool $-\ 2.75\quad x + \quad y = \ .0262.$

At Malta $-\ 1.2799\,x + .63y = \ .0895$, or $x = 1.614, y = \ .4698.$

Fore compass, in fore part of forward deck-house, about six feet six inches above the deck.

At Liverpool $-2.75\ x + \quad y = \ .0198.$
At Malta $\quad -1.2799\,x + .63\,y = \ .1045$, or $x = .2033,\ y = .5789.$

On the return of this ship to Liverpool, and in consequence of the change in the deviations reported by Captain Haram, a vertical iron bar was introduced before the steering compass, sufficiently near to compensate about two-thirds of the inductive magnetism of iron aft of the compass, the remaining polar deviation being compensated in the usual manner. The quadrantal error, which averaged about 8° on the four-point courses, was, as nearly as possible, corrected by two cast-iron cylinders with rounded ends, each being 12 inches long, by rather more than 3 inches in diameter. After this, the steering compass acted so much better than before, that from that time (1857) to the present, it is believed no alteration of any kind has been made or required.

"SIMLA."—Captain W. WILLIAMS.

This ship is of 1,444 tons register, and has already been referred to in this report, when treating of the effect of heeling on the compasses of iron ships. In the Appendix are inserted numerous extracts from the log kept by Captain Williams, during the first voyage of this ship to Calcutta and back; also, many interesting notes which he made on the second outward voyage to the same port, when there were on board upwards of 2,000 tons of iron in the form of machinery, railway plant, &c.

The following selections have been made as suitable for comparison with the records which have been taken from other logs:

FIRST VOYAGE OUTWARD TO CALCUTTA.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ by Earth's horizontal force at Liverpool.	Steering compass.				Standard compass.			
						Deviation towards ship's head.	Force to ship's head in terms of Earth's horizontal force at each station.	Deviation towards ship's starboard side.	Force to ship's starboard side in terms of Earth's hor. force at each station.	Deviation towards ship's head.	Force to ship's head in terms of Earth's horizontal force at each station.	Deviation towards ship's starboard side.	Force to ship's starboard side in terms of Earth's hor. force at each station.
	° ′	° ′	° ′			° ′		° ′		° ′		° ′	
1	At Liverpool.*		70 0	2.75	1.00	—12 48	—.2215	—29 0	....	2 35	....	—14 48	....
	At Liverpool.†		....	....	....	Prob'ly 0 0	....	Prob'ly 0 0					
2	13 0 N.	28 0 W.	45 0	1.00	.59	....	....	....	....	About 0 0	....	— 8 0	....
3	5 45 N.	30 44	35 0	.7002	.555	....	....	....	....	0 0	....	— 7 20	....
4	0 0	31 0	25 0	.4663	.55	....	....	....	....	App'ers	....	— 7 20	....
5	28 0 S.	29 0 W.	—22 0	.4040	.6	11 0	.1908	— 0 30	....	....	....	— 7 20	....
6	35 3	82 17 E.	—65 30	2.1943	.74	16 30	.2841	— 5 0	....	....	....	....	....
7	0 31 S.	92 40 E.	—17 30	.3153	.485	— 5 0	....	— 1 15	....	—1 0	....	— 3 45	....

* Before compensation. † After compensation.

"SIMLA"—Continued.

FROM CALCUTTA TO DEMERARA.

No. of observation.	Latitude.	Longitude.	Dip.	Nat. tan. dip.	Earth's horizontal force at station ÷ by Earth's horizontal force at Liverpool.	Steering compass. Deviation towards ship's head.	Steering compass. Force to ship's head in terms of Earth's horizontal force at each station.	Steering compass. Deviation towards ship's starboard side.	Steering compass. Force to ship's starboard side in terms of Earth's hor. force at each station.	Standard compass. Deviation towards ship's head.	Standard compass. Force to ship's head in terms of Earth's horizontal force at each station.	Standard compass. Deviation towards ship's starboard side.	Standard compass. Force to ship's starboard side in terms of Earth's hor. force at each station.
	° ′	° ′	° ′			° ′		° ′		° ′		° ′	
8	3 24 N.	86 13 E.	—11 0	.1944	.48	....	....	....	....	1 35	....	— 5 30	....
9	29 12 S.	39 11 E.	—57 0	1.5399	.82	....	....	....	....	....	....	—10 0	....
10	20 20	0 29 W.	—27 30	.5206	.65	....	....	....	....	....	....	— 8 56	....
11	14 23	8 42	—11 0	.1944	.59	....	....	....	....	....	....	— 9 52	....
12	0 30 S.	41 10	27 30	.5206	.53	....	....	....	....	1 0	....	—10 0	....
13	7 6 N.	52 50 W.	38 0	.7813	.53	....	....	....	....	2 15	....	....	....
DEMERARA TO LIVERPOOL.													
14	47 21 N.	22 3 W.	70 30	2.8239	1.06	....	....	....	....	—1 0	....	— 6 30	....
LIVERPOOL TOWARDS CALCUTTA, (SECOND VOYAGE.)													
15	50 4 N.	8 28 W.	69 15	2.6395	.98	— 8 0	—.1392	— 5 53	....	—0 11	....	—11 50	....
16	29 19 S.	27 7 W.	—25 0	.4663	.61	....	....	....	....	+1 38	....	— 6 15	....
17	32 20 S.	76 15 E.	—63 0	1.9626	.75	+ 7 0	.1219	....	....	1 38	....	— 6 15	....
18	3 10 N.	83 32 E.	—12 30	.2217	.48	+ 1 30	.0262	— 0 30	....	—0 12	....	— 2 10	....

On the first outward voyage, in latitude 35° south, the deviations of the steering compass were observed by comparison with the standard compass, which was then found to have only very small error. The attraction of 16° 30′ to the bow is very probably correct, but the deviation of —5° to starboard is too small by the amount of deviation due at this time to the standard. On reversing the fore-and-aft magnet at this place, the deviations towards the head was cancelled, so that its effect was equal to a deviation of 8°, or .1392 of Earth's horizontal force at the station or to .1881 of Earth's horizontal force at Liverpool. As the position of the compensating magnet appears to have been again altered, the observations made on the homeward voyage with this compass have been omitted. The observations made on the second outward voyage may, however, be compared with each other, as it is recorded that the magnet retained the same position during this voyage. Observations 1, 5 and 6, give the following equations for the steering compass:

$$-2.75\,x + y = -.2215,$$
$$.404\,x + .6\,y = .1908, \quad \text{or } x = .0929,\ y = .2555,$$
$$2.1943\,x + .74\,y = .2840, \quad \text{or } x = .0672,\ y = .1847,$$
$$\text{or a mean } x = .08 \text{ and a mean } y = .2201.$$

Deducting .1881 for the effect of the magnet, there remains .032 as the permanent magnetism due to the ship.

For the second outward voyages there are the following equations, Nos. 15, 17, and 18:

$$-2.6395\,x + .98\,y = -.1392,$$
$$1.9626\,x + .75\,y = .1219, \quad \text{or } x = .0573,\ y = .0125,$$
$$.2217\,x + .48\,y = .0262, \quad \text{or } x = .0623,\ y = .0258,$$
$$\text{giving a mean } x = .0598, \text{ and a mean } y = .0191.$$

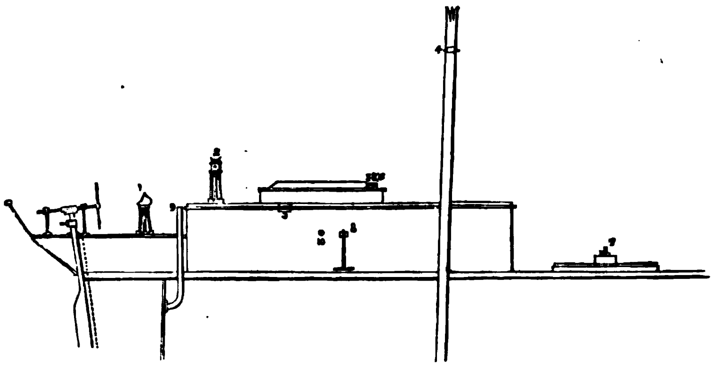
The change in the fore-and-aft magnetism of the ship at the station of the standard compass is exceedingly small. The observations on the outward voyages show, that the transverse magnetism is chiefly sub-permanent, and, as was the case in the "Royal Charter," that it undergoes a considerable reduction in high south latitudes, while the ship's head is in a direction opposite to that in which the ship was built, and readily returns again towards its old condition on the ship's head being placed in a favorable direction.

"SLIEVE DONARD."—Captain Thompson.

This ship is of the largest class, and registers about 1,500 tons. Like the "Simla" and "Aphrodita," she was also the subject of experiments on the effect of heeling previous to her first voyage. The following observations are selected from the compass-log kept by Captain Thompson, a copy of which appears in the Appendix. Towards the conclusion of the voyage, all the compasses show signs of being out of order, and the recorded deviations cannot be received with confidence. The captain, however, states, that a few days before making the Channel, on his return, he took the precaution to put new pivots and agates in place of the old ones; and it will be seen that the latest observations differ very much from those which immediately precede them, and accord more closely with the original deviations with ship's head to the eastward. An attempt was made to compensate the fore-and-aft magnetism at the station of the steering compass, by a vertical bar of iron, as in the "Aphrodita;" but it will be observed that this ship, like the "Astræa," requires that the apparent attraction towards the stern at Liverpool should be very considerably over-compensated.

"SLIEVE DONARD."

Fig. 8.



1. Steering compass.
2. Second steering compass with vertical card.
3. Skylight or tell-tale compass.
4. Mast compass.

} Four compasses belonging to the ship.

5. Compass placed port side of skylight.
6. Compass placed starboard side of skylight.
7. Compass placed over hatchway.
8. Dipping-needle compass.

} Four experimental compasses.

9. Vertical iron bar riveted to the iron bulkhead below.
10. Position of the dipping-needle compass on first experiment.

First voyage.

LIVERPOOL TO BOMBAY.

No. of observation.	Date.	Latitude.	Longitude.	Dip.	Nat.tan. dip.	Earth's hor. force at each station ÷ Earth's hor. force at Liverpool.	Steering compass. Deviation towards the ship's head.	Steering compass. Force to ship's head in terms of Earth's hor. force at each station.
	1859.	° '	° '	° '			° '	
1..........	Feb.25	At Liverpool	....	70 0	2,75	1.0	0 0	....
2..........	May 1	7 8 S.........	31 10 W.....	15 0	.2679	.55	10 0	.1736
3..........	7	17 27 S.........	36 10 W.....	— 3 0	.0524	.56	23 15	.3947
4..........	25	36 57 S.........	1 45 E.....	—46 0	1.0855	.72	43 45	.6915
5..........	June 2	40 48 S.........	31 8 E.....	—60 0	1.7321	.81	About 78° 0'	.9781
ADEN TO BOMBAY.								
6..........	Aug.28	12 20 N.........	45 14 E.....	0 0	.0	.50	18 45	.3214
BOMBAY TO LIVERPOOL.								
7..........	Dec.19	12 2 N.........	60 0 E.....	— 4 0	.0699	.49	23 0	.3907
8..........	25	3 58 N.........	48 35 E.....	—16 0	.2867	.55	26 30	.4462
	1860.							
9..........	Jan. 1	11 26 S.........	42 5 E.....	—41 0	.8693	.68	47 0	.7314
10..........	8	24 0 S.........	36 30 E.....	—53 0	1.3270	.78	67 0	.9205

These give the following equations for the components of the ship's headward force. They are arranged in the order of the Earth's dip:

No. of observation.	Dip.	Equations.	Outward voyage.		Homeward voyage.	
			x	y	x	y
	°					
1	70	$-2.75\,x + y = 0$				
2	15	$-\,.2679\,x + .55\,y = .1736$	.1418	.3900		
6	0	$.5\,y = .3214$	.2337	.6428		
3	3	$.0524\,x + .56\,y = .3947$	.2478	.6815		
7	4	$.0699\,x + .49\,y = .3907$			.2756	.7579
8	16	$.2867\,x + .55\,y = .4462$			.2480	.6820
9	41	$.8693\,x + .68\,y = .7314$			.2670	.7343
4	46	$1.0355\,x + .72\,y = .6915$	.2293	.6306		
10	53	$1.327\,x + .78\,y = .9205$			.2651	.7290
5	60	$1.7321\,x + .81\,y = .9781$	.2470	.6793		
		Means, omitting No. 2	.2395	.6586	.2639	.7258

The mean of means will give .2517 as the co-efficient for the ship's fore-and-aft vertical induction, and .6922 for the ship's permanent magnetism towards the bow, plus the effect of the compensating magnet. Estimating the effect of the magnet as = .1305, the ship's permanent magnetism will be .5617, a much larger amount than is exhibited by either of the ships which have been examined, but not more, when compared with the "Astræa," than might have been expected from the large size of the "Slieve Donard," and the direction in which she was built. The same considerations lead to the expectation that in a ship like the "Great Eastern," which is so very much larger, and built with her head much nearer to the south, an enormous amount of magnetism would be unmasked on a voyage which would take her into high south magnetic latitudes.

Before the "Slieve Donard" sailed on her second voyage, the steering compass was placed much nearer the vertical compensating bar; and a permanent magnet was introduced, so as to produce a compensation more in accordance with the magnetic condition of this ship, as inferred from the observations at sea recorded by Captain Thompson.*

"SWARTHMORE."—Captain LEDBITTER.

This ship, of about 1,400 tons register, was iron framed and plated to the main-deck, with wooden sides and spar-deck above. The standard compass was placed before the mizzen mast, and about 4 feet 6 inches above the spar-deck. The deviation tables for the compasses of this ship, as obtained by Mr. Wiggins, in the East India Docks, London, in May, 1853, indicate that she was built with her head very near magnetic

* Since this was written, the "Slieve Donard" has returned to Liverpool from her second voyage, and the captain reports that the steering compass never differed more than half a point from the deviation table which he received in Liverpool before sailing.

north. The observations made at sea by Captain Ledbitter are the more valuable on this account, as none of the other ships from which compass records have been received were built in this direction.

The first voyage of the "Swarthmore" was to Bombay. A reduction in the deviations of the standard compass is soon apparent, but the reduction is very little more than would be due to the great directive power of the Earth. The difference between the three compasses for which a record was kept, the standard, steering, and fore compasses, never exceeds 5° on the courses steered, until after the ship makes more than 30° of south latitude, and this accordance continues, with little exception, until the ship has rounded the Cape of Good Hope, and is put upon more northerly courses.

The following equations appears to be the be best which can be obtained from the records of the first voyage, for the ship's fore-and-aft magnetism.

Standard Compass.

In north latitude, dip 68°. $-2.475\ x - \ y = -.2501,$

In south latitude, dip —60°. $1.7321\ x - 8\ y = -.1478.$

or $x = .0140,\ y = -.2152.$

Steering Compass.

In north latitude, dip 68°. $-2.4751\ x + \ y = 0.$

In south latitude, dip — 60°. $1.7321\ x -,\ .8\ y = -.0349.$

The equatiou for the steering compass are evidently incongruous. The occurrence of a minus co-efficient for the permanent magnetism is only to be accounted for on the supposition that a very great reduction has taken place in the compensating magnets, or that they have been removed altogether.

Before the "Swarthmore" proceeded on her second voyage, she underwent a number of alterations, during which she lay for some time with her head to the south. The spar deck was removed, and the standard compass was placed above a deck-house, not far from its first position. The steering compass was adjusted by a magnet, and stated to be without error on the cardinal points. The fore compass was also adjusted, and stated to be without error on these points, except a westerly deviation of 1° 30′ when the ship's head was north correct magnetic.

This voyage gives the following equations for the station of the standard compass:

Outward.

1. Lat. 53° 30′ N. Long. 3° 0′ W. dip 70. $-2.75\ x - \ y = -.1219.$
2. " 29 14 S. " 26 41 W. " —25. $.4663\ x - .62\ y = -.0828,$
   or $x = .0033,\ y = -.1310.$
3. " 36 21 S. " 59 56 E. " —65. $2.1445\ x - .83\ y = -.0262,$
   or $x = .0169,\ y = -.0754.$

Homeward.

4. Lat. 30° 7′ S.	Long. 42° 5′ E.	dip —58.	$1.6003x—.83$	$y=—.0828$,	
				or $x=.0047$, $y=—.1088$.	
5. " 19 59 N.	" 30 30 W.	" 41.	$.8693x—.57$,	$y=—.0698$,	
				or $x=.0005$, $y=—.1233$.	
6. " Irish Sea		" 70.	$—2.75\,x—$	$y=—.1219$.	

Giving a mean $x=.0063$ and a mean $y=—.1096$.

Better values will perhaps be obtained by omitting No. 3, when the mean x will be equal to .0028 and the mean y equal to— .121. A small difference in the estimate of the Earth's horizontal force would cancel out x altogether.

In the log for this ship, under date November 26, 1855, occur the following particulars relating to the steering compass, the ship's head at the time being south 87° east correct magnetic. On removing the magnet from the steering compass, it read north 84° east, instead of north 62° east, as before. On reversing the direction of the magnet, and elevating it 9 inches above its position, the compass then read south 78° east, ship's head correct magnetic at the time being south 86° east. Except that the magnet was afterwards shifted from the starboard to port side of the compass, no change in its position is recorded. On December 24, in south dip 65°, the ship was swung, the deviations of the steering compass being obtained by comparison with the standard compass, as the sun was not visible. After making an allowance for the deviations of the standard compass, there remains an attraction to the ship's head indicated by a deviation of 19° 45′.

These appear to be the most satisfactory data which the log affords for ascertaining the co-efficients for the magnetism of the "Swarthmore" at the station of this compass.

With ship's head by compass north 62° east, there would be a proportion of the + quadrantal deviation in the observed error of 31°; but as the deviation arising from the attraction to the ship's head would be reduced here in the ratio of sine 62° to 1, these corrections may be considered as compensatory, and the force to head be fairly assumed as = sine 31° = .515. Calling the force due to polar magnetism after the removal of the magnet = sine 8° = .1392, and deducting this from .515. there remains .3758 equal force of the magnet at this place, and dividing by .62, to bring it into terms of Earth's horizontal force at Liverpool, it becomes .6061, or equal to a deviation of 37° 18′. Again, with dip — 65°, and the factor for horizontal force .83 the headward force will be sine $19° + \frac{\text{sine } 8° \times .83}{.62} = .3379 + .1863 = .5242$. Then, as the headward magnetism of the ship was exactly compensated by the magnet at Liverpool, there will be the three following equations for obtaining the components of the ship's magnetism at this station:

$$-2.75\,x + y = -.6061,$$
$$.4663\,x + y = .1392, \text{ or } x = .2372,\ y = .0462,$$
$$2.5837\,x + y = .5242, \text{ or } x = .2321,\ y = .0322,$$
$$\text{or a mean } x = .2347 \text{ and a mean } y = .0392.$$

or a permanent magnetism headward sufficient to produce at Liverpool a deviation of 2° 15′ only, and an induced magnetism capable of producing a deviation of — 40° 12′.

During the summer of 1856, before the third voyage, additional rows of stringer-plates were added to the main and to the lower decks, and an additional row of fore-and-aft plates were fixed in the 'twixt decks on each side of this ship. For a considerable period during the repairs the ship lay with her head to the west. The effect of this can be seen in the recorded deviations. The ship does not appear to have been swung before leaving Liverpool on this voyage.

Through the whole of 1857, in different parts of the East Indies, so far as can be ascertained from the log, the deviation of the standard compass towards the head appears to vary from 0° to — 2°, and back to a small plus quantity. In February, 1858, when there are observations on three successive days with ship's head east, in latitude 45° 30′ south, longitude 141° 40′ east, dip — 73° 30′ the deviations were 1° 20′, 1° 20′, and 2° 30′ respectively, or a mean deviation of 1° 43′. At this time the steering compass showed deviations varying from 36° to 40°. A few days afterwards, the captain remarks, "our steering compass has become so exceedingly sluggish, that I have removed the magnet entirely from its vicinity." In May, of the same year, during the voyage from Sourabaya to Madras, the standard compass again shows a deviation to the head of about — 2°. The record of the voyage extends to December, 1858, but the fore-and-aft magnetism of the ship at the station of the standard compass shows very little change, although in this part of the voyage the dip varies from — 58° to 65°.

The observations for the following equations were separated by long intervals of time and extreme range of dip:

Lat. 40° 0′ N.	Long. 15° 0′ W.	dip 65°	$-2.1445x - .84\ y = -.1736,$	
" 42 17 S.	" 79 41 E.	dip —68°	$2.4751x - .78\ y = 0,$	or $x = .0361, y = -.1146.$
" 45 30 S.	" 141 40 E.	dip —72° 30′	$3.1716x - .71\ y = .03,$	or $x = .0354, y = -.1163,$

or a mean $x = .0358$, and a mean $y = -.1155$, a very close approximation to the results obtained on the second voyage.

The compass logs on which the preceding discussion is founded, and from which large extracts will be given in the Appendix, are the most complete which have been presented to the committee. They are the more valuable, as containing the records of observations made by practical men, unbiassed by any magnetic theory. To Captain Dalison, of the "Advance," Captain S. Nickels, of the "Astræa," and Captain Ledbitter, of the "Swarthmore," the thanks of the committee are specially due for compass records continued during several years. The logs which are now kept by Captain Williams, of the "Simla,"* and the commanders of some other iron ships, will also, if continued for a few years, be equally valuable. The acknowledgments of the committee are also due to the captains of the following sailing ships and steamers, for the loan of their logs, and to several of them for frequent personal assistance, in conducting experiments on board of their ships. To Captain Reid, of the "Sarah Palmer," Captain T. Patching, formerly of the "Lady of the Lakes," Captain Stewart, of the "Aphrodita," Captain Williams, of the "Simla," Captain Thompson, of the "Slieve Donard," Captain Carmichael, formerly of the "Fusilier," Captain Robertson, formerly of the "Sappho," Captain Carlyle, formerly of the "Startled Fawn," Captain Fairlem, of the "Evangeline," Captain Leitch, of the "City of Baltimore" steamship, Captain Haram, formerly of the "Bœotia" steamship, Captain Ballantine, formerly of the "Canadian" steamship, Captain Parkes, formerly of the "Laconia" steamship, Captain Bonfellow, formerly of the "Ionia" steamship, Captain Grange, formerly of the "Indian" steamship, Captain Boyce, formerly of the "Royal Charter," Captain Grey, of the "Great Britain," &c.

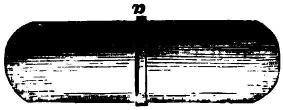
So early as 1856, an examination of several logs had convinced the secretary that a large portion of the errors of the steering compass in iron ships was due to vertical induction, and could be in a great measure compensated by a vertical bar placed immediately before the binnacle. In December, of that year, he made a special report on the subject to this committee, recommending that a vertical iron bar should be introduced in new iron ships while they were building, at such a distance before the usual position of the steering compass as to compensate the greater part of the attraction of the stern-post and other vertical iron immediately aft the compass. At that time, however, it was thought desirable to wait until further information had been collected, and until some experiments had been made, before any specific recommendations of this kind were put forward by the committee. The experiments which have since been tried, when taken in conjunction with the discussion of the observations made at sea in different ships and in various

* Since this was written, Captain Williams has presented to the committee the copy of a most interesting compass log which he kept during a second voyage to Calcutta, in the "Simla," in which the effect of the changing vertical magnetism on the polar deviation and especially on the change in variation from heeling under varying northern and southern magnetic dip, is very clearly illustrated. See Appendix M.

magnetic latitudes, now enable this committee to strongly recommend this suggestion to the consideration of iron shipbuilders, and also to point out to them to what extent magnets must be introduced in particular cases, in combination with the vertical iron, so as to insure, even on first voyage, comparative freedom from those large errors which are experienced in high south latitudes, and, as a consequence, that extreme sluggishness of the compass now so frequently complained of. Vertical bars have now been introduced into fifteen ships, in each case with more or less success, as recorded in Appendix H. In five of these only have the bars been riveted to the framework of the vessel, and in these, not until the building of the ship was completed. In the others, the bars were necessarily short, so as not to interfere with the cabin fittings. In no instance has the effect of the iron bar been in excess; on the contrary, it has been found that either a larger bar, or the placing of the compass nearer to the bar, would have been an improvement. If the bar were fixed while the vessel was building, so as to be subject to the same concussions as the sternposts, &c., the compensation may be expected to be more perfect. Perhaps the most remarkable result of this part of the investigation is the abundant proof it affords that in one class of ships the vertical bar in this latitude must be placed so near the compass as to produce an excess of deviation towards the bow. The "Advance," the "Astræa," and especially the "Slieve Donard," are instances of this class, and would, respectively, require an attraction to the bow from the vertical iron, equal to .2656, .3408, and .5085 of the Earth's horizontal force at Liverpool.

A number of experiments have also been made on the compensation of that portion of the magnetism of iron ships which produces quadrantal deviation, by the use of cast-iron, instead of the boxes of iron chain which have for many years been employed for this purpose. Before placing any cast-iron correctors on board ship, a number of trials were made with cast-iron cylinders, to ascertain whether they would retain any magnetism. Cylinders of two sizes were employed, one nine inches long by three inches in diameter, the other size twelve inches long by about three and a quarter inches in diameter, the ends of each being made globular, as represented in the accompanying sketch.

Fig. 9.



At first, a small collar (*a*) was cast upon them, to keep them from slipping from the brackets on which they are supported, but this was afterwards found to be unnecessary. These experimental cylinders were cast from the best No. 1 iron, and were submitted to blows while held in the direction of the Earth's magnetic force; and they were also kept for a considerable time in this direction, to ascertain whether they would retain any of the induced magnetism due to the position, and were found to be perfectly free from any permanent magnetism. Other cylinders were cast in the line of magnetic dip, and allowed to go cold in this direction, but did not retain any magnetism from this treatment. These trials appeared conclusive as to the suitability of cast-iron for correcting the deviation arising from horizontal induction. It should be mentioned, however, that some specimens of cast-iron, said to be best No. 1, have since been seen, which held a small portion of permanent magnetism, but not so much as to interfere with their use for correctors. The nine-inch cylinders are suitable for correcting quadrantal deviation not exceeding 5°, and the 12-inch cylinders for deviations not exceeding 8°. The quadrantal correctors tend to increase the directive power of the compass to which they are applied, but they should not be placed nearer than 1.25 lengths of the compass needle from the centre of the card. When the distance exceeds this proportion, the compensation is usually sufficiently correct for practical purposes. The use of very large cards with correspondingly long needles is adverse to good compensation; and it is worthy of remark, that length of needle and other circumstances being the same, compensation of the quadrantal deviation is more perfect with a double needle-card having only one needle. The diagrams in Plate 36, and the following tables, will illustrate the deviations produced by the quadrantal correctors, when applied to cards having one, two, and four needles. The four-needle card experimented with, was one of the Admiralty standard compass cards.

The dotted curves in the diagrams are calculated curves, or curves representing the deviations which would have been produced had the compass needle been extremely small in comparison with the distance of the correctors. Tables with the results of the experiments are given in Appendix K, also some specimens of the quadrantal deviations observed on board ship, after the polar deviations have been more or less completely compensated by the application of magnets. It will be observed that some of these deviations are very large in amount, and that they are usually greater in two quadrants than in the two adjacent ones. This inequality in the deviations in the different quadrants might be considered as due to the difference in the directive power of the compass needle in the different positions of the ship, if it were not also found in cases in which the directive power must have been very nearly equalized by polar compensation with magnets. It seems probable, therefore, that the difference alluded to may, to some extent, be occasioned by a greater susceptibility in the iron of the ship to magnetic induction in one direction rather than in another.

On the supposition that the horizontal inductive force acts in the direction of and in proportion to the resultant of the Earth's and the ship's polar magnetic force, (see diagram, Plate 45, and tables in Appendix L,) the quadrantal deviations must necessarily be dissimilar in the different

16

quadrants. Thus, with a polar magnetism due to ship equal to .379 of Earth's horizontal force at a starboard angle of 257°, and a capacity for horizontal induction in transverse iron equal to .209, the deviations in the several quadrants will be as follows:

1st quadrant.		2d quadrant.		3d quadrant.		4th quadrant.	
Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.
	° '		° '		° '		° '
North	0 0	East	0 0	South	0 0	West	0 0
N. by E.	2 30	E. by S.	—3 10	S. by W.	3 8	W. by N.	—1 28
N. N. E.	5 40	E. S. E.	—5 55	S. S. W.	5 12	W. N. W.	—2 42
N. E. by N.	7 30	S. E. by E.	—7 58	S. W. by S.	5 50	N. W. by W.	—3 40
N. E.	8 25	S. E.	—8 58	S. W.	5 25	N. W.	—4 20
N. E. by E.	7 40	S. E. by S.	—8 10	S. W. by W.	4 32	N. W. by N.	—4 22
E. N. E.	5 55	S. S. E.	—6 25	W. S. W.	3 10	N. N. W.	—4 5
E. by N.	3 10	S. by E.	—3 40	W. by S.	1 33	N. by W.	—2 38

The deviations on the four-point courses are, respectively, 8° 25′, —8° 58′, 5° 25′, and — 4° 20′, or a mean co-effieient for quadrantal deviation of 6° 47′.

It will be seen also, on the supposition just enunciated, that, as the polar magnetism of the ship becomes less, whether by change of dip or by gradual loss of sub-permanent magnetism, so would the discordance in the values of the quadrantal deviation in the several quadrants decrease.

The following additional remarks on quadrantal deviation are offered as the result of observations made by the committee:

1. Quadrantal deviation may be large in amount in a small ship, and small in a large ship, and the reverse.

2. Generally, it is larger in amount in the middle of a large ship than in positions nearer to the ends.

3. It decreases rapidly as the compass is raised above the deck, and at a certain height above, it may change from plus to minus.

4. In the usual positions for a compass the quadrantal deviation is almost invariably plus, but it may be minus in a compass placed over a hatchway or skylight, or on the bridge between the paddles of a paddle-wheel steamer, or, as before stated, at some height above the deck, as on a mast. Plus quadrantal deviation is so generally observed because the compass is relatively so much nearer to the transverse than to the fore-and-aft iron of the ship; to the sides than to the ends of the ship It is, in fact, the amount by which the Earth's magnetic induction in the transverse iron of the ship exceeds the induction in the fore-and-aft iron, as felt at the station of the compass. It is the difference or resultant of two mutually opposing forces, which may exist in different proportions in ships of the same size, and which must necessarily vary as the relative distance of the compass from these forces is changed.

The committee, however, would not countenance the supposition that any complete explanation has yet been given why the quadrantal deviation is so much greater in some ships than in others, or why it should be so much greater in some quadrants of the compass than in the adjacent ones in the same vessel. Neither would they have it supposed that the quadrantal deviation can be taken as a measure of the susceptibility of the ship for magnetic induction, except in ships of precisely the same size and construction; much less that it affords any indication of the capacity of the ship for sub-permanent magnetism, as it is believed that these two qual ities exist together in different proportions in different kinds of iron. It would also be premature to suppose, that either susceptibility to induction or capacity for retaining magnetism may be taken as an index to quality of the iron. Specimens of very good iron have been found to possess both qualities largely.

It has been long known that iron and some other metals undergo a molecular change in the course of time, and become more crystalline and less able to bear concussion, and that this condition may be hastened by vibration. Mr. Airy, in his first paper on the magnetism of iron ships, alludes to the possibility of this change being accompanied by a corresponding change in the ship's magnetism, and urges this as a reason for keeping a sufficient register of the magnetic condition, and the circumstances attending the building of all iron ships. The particulars which the committee have been able to collect on some branches of the subject since 1855, will, it is believed, afford an appropriate commentary on this recommendation. They will at least serve as an index to the mass of information which would now have been available, had the complete records, as proposed, been commenced in the year the paper appeared, 1839.

The attention of the committee has necessarily been drawn to the question of the quality of iron, as affecting the magnetism of the ship; but their experience is not sufficiently generalized for publication, even if this part of the subject were free from the difficulty which always exists when the property of other persons has to be commented upon. The following extract is taken from the paper now alluded to:

"It is believed by practical men that the state of malleable iron changes from time only. If this be certain, and the notion just mentioned be plausible, (that permanent magnetism in iron depends on an artificial arrangement of the particles of the metal,) it seems sufficiently probable that the independent magnetism of the ship will change with time. This consideration enforces strongly the necessity for periodical examination, as suggested above. Such examination may possibly have an advantage beyond the correction of the compass for the time. An important change in the magnetism may indicate an important alteration in the quality of the iron, and may serve as a warning to be cautious of trusting to the strength of the ship in critical circumstances."

Changes in the magnetism of new iron ships, and change from keeping a ship for some time in one position, while undergoing repair, and from concussion, were adverted to in the last report, and some examples were also given. The following examples are selected from cases which have been observed since:

The "Aphrodita," built head to east, was kept, after launching, with her head as much as possible in the opposite direction. When nearly ready for sea, she was swung, and the deviation towards the starboard side of the ship, by the Admiralty standard compass, amounted to 17° 45′. She was then put into graving-dock, and remained for some time with her head about south 75° east; on being swung after this, the deviation to the starboard side was found to have increased to 21° 30′, showing an increase of 3° 45′ by keeping her head to the eastward. After remaining a few days longer with her head eastwardly, she was removed into the river. While going out of dock she came into violent collision with the pier, her head at the time being rather to the south of west. On again swinging her before she sailed on her first voyage, the deviation to starboard was found to be reduced to 17° 52′. This was in 1858. In November, 1860, after making two voyages to Calcutta, she was refitted in graving-dock, with her head north 75° west, and then lay for a short time with her head to the north. On swinging her after this, the attraction to starboard was found to be only 2° 13′. The deviations towards the stern on these four occasions, were, respectively, 12° 5′, 10° 7′, 9° 30′, and 4° 10.

The ship "Sarah Palmer" was built in Warrington, in 1855, of Staffordshire iron, and with her head about east south-east. The standard compass was placed above a deck-house between the main and fore-masts, and was about twelve feet above the deck. The deviation here was towards the head and to the starboard side. After a voyage to Calcutta, the ship was re-swung, and the deviations were found to be very nearly the same as at first. The deck-house was afterwards removed, and the standard compass was then placed between the main and mizzen-masts, but about the same height above the deck. In this position, the deviation towards the starboard side was nearly the same as at the first station, but the fore-and-aft attraction was towards the stern instead of towards the bow. The deviations here were equally as permanent as at the first position. During the summer of the present year, however, she underwent a thorough refit, while in graving-dock, with her head to the westward, and a doubling, consisting of two rows of plates, was added to each bilge. On swinging her when she was again ready for sea, it was found that the magnetism retained by the port side of the ship was sufficient to completely cancel the old deviation of the needle towards the starboard side, which in 1858, was 6° 30′.

Both of these ships were built of iron of superior quality, though of different retentive power for magnetism. The reduction in the transverse magnetism of one ship appears to have been gradual, but to have nearly disappeared after two voyages to Calcutta. The other appears to have retained much of her original magnetism during eight voyages to Calcutta, but it disappears through the hammering and concussion she received while in graving-dock, with her head in the opposite direction to that in which she was built.

A notable instance of an iron ship being fitted for sea in nearly the same position as that in which she was built, and showing changes in the deviations of her compasses immediately she is removed from this position, is affordsd by the "Great Eastern" steamer.

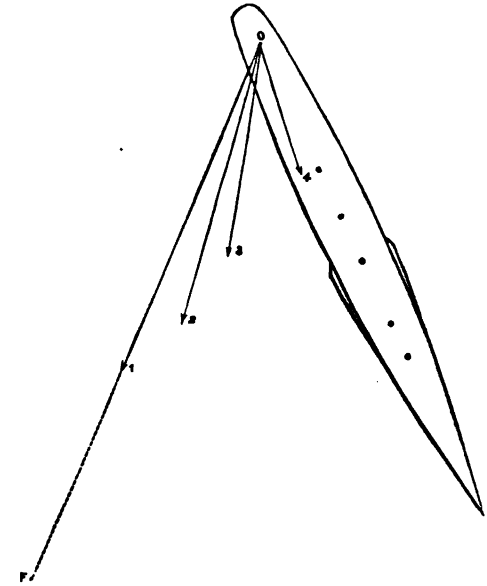
It was thought desirable by this committee, on account of the size of the "Great Eastern," and the enormous quantity of iron used in her construction, that some record should be made of the magnetic elements of this immense vessel. The secretary was therefore instructed to make as many experiments for this purpose as circumstances would permit. The details of these experiments are reserved for the Appendix. Here it will be sufficient to mention the general results. Most of the observations were made jointly by the secretary and Mr. Evans, of the Admiralty Compass Department, to whom the committee are much indebted for his able and zealous assistance in this as well as in other departments of the Compass Inquiry. The committee have also to thank the directors and other gentlemen connected with this ship for the facilities which they afforded for these experiments.

As was anticipated from the previous experiments of this committee, the deviations observed in the Thames did not correspond with those made the same day at the Nore. Those observed two days afterwards at Portland showed a more decided change, both in the amount and direction of this ship's magnetism. A still further change in amount and direction is exhibited by the observations made about six weeks afterwards at Holyhead, and a yet greater change was observed by Mr. Evans at Southampton, about eight months later.

The annexed diagram represents the relative change in the direction and amount of the magnetism of this ship while in the Thames, at Portland, at Holyhead, and at Southampton. The vertical line shows the direction and mean relative amount of the Earth's horizontal force at these stations. The ship is represented in the direction in which she was built. It will be observed that the magnetic axis of the ship tends more and more towards the vertical plane which passes through her keel.

"GREAT EASTERN."

Fig. 10.



1. Relative direction and amount of the ship's horizontal force at the station of the Admiralty Standard Compass, 7th September, 1859, in the Thames.
2. Do., do., 12th September, at Portland.
3. Do. do. 23d September, at Holyhead.
4. Do. do. 15th Jnne, 1860, at Southampton.

The Earths' horizontal magnetic force at the time being equal to the line O F.

That the magnetism of this ship has undergone a further change during her voyage to and from America can admit of no doubt. It must, however, be remembered that these changes, though very decided, afford little support to the assertions which have sometimes been made of *sudden* changes in the deviations of a ship's compass while at sea. It must also be remembered that these changes occurred in a new ship, one fitted while lying in the same direction as that in which she was built, and one built in a direction which is specially subject to changes of this kind. (See particulars respecting the "Bœotia" and "Ionia," in Report II.) The northern polarity of the vertical iron near the stern of iron ships built with their head more or less to the south in this magnetic latitude is in constant opposition to the vertical induction of the Earth in this hemisphere.

Towards the close of their last report, this committee ventured to suggest, for the consideration of the Board of Trade, a mode by which it was thought a great deal of information could easily be collected on the present system of compass correction and compass management in iron ships. It is believed that this part of the subject still requires examination.

The views of the committee have, however, been so ably expressed by one of the highest authorities on the magnetism of iron ships, that they prefer on this occasion to quote the following passage from Mr. Archibald Smith's introduction to Dr. Scoresby's journal of his voyage in the "Royal Charter:"

"The Board of Trade has lately directed the attention of the mercantile marine to this subject in its publications, (deviations of the compass,) but it has not yet taken up the subject in that systematic and continuous way to which the report of the Liverpool Compass Committee points as desirable. That this might be done with great advantage, and with little more expense than that incurred by the Liverpool Compass Committee during its present existence, does not admit of doubt. Whatever difference of opinion may be entertained as to applying correctors to the steering compasses of iron ships, it can hardly admit of question that every iron ship should have at least one compass removed as much as possible from the influence of iron, and not corrected by magnets, and should be swung at the beginning and end of every voyage of any length, and the deviation of the uncorrected and corrected compasses (if any) observed. *No man is competent to command an iron ship who is not competent to make these observations;* and if these observations were transmitted to the Board of Trade, and systematically reduced, and discussed and published, most valuable results would certainly be obtained. It may be added that the observations so made would furnish a test of the care, skill, and good faith of the captain who made the observations, as the process of reduction shows almost infallibly the genuineness and correctness of the observations."

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 of 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, before alluded to, the correct direction of the ship's head is usually very approximately ascertained. What is chiefly required in 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 that 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 connexion 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 twelve months; and in a third case, the agate cup in which the pivot rested had been filled with brickdust, 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 brickdust had made a hole completely through the agate. In the last instance, the 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.

The cases quoted refer to steering compasses, which are said to receive less attention in some ships, in consequence of the courses being set by a standard compass, and because an officer is always placed, in well-regulated ships, to see that the course by the standard compass is strictly kept; but the standard compass itself is not free from the same source of error, and more especially a standard mast compass, as mast compasses are often placed in a position not easily accessible, and where they are seldom examined until something connected with them goes conspicuously wrong.

While these causes of error are prevalent, there will constantly be reports of deviation from "the attraction of the land," of "compass disturbance from fog," of "unusual aberration," of "indraught," and the other unfounded or imaginary pretexts which are now put forward when an iron ship gets stranded.

In some cases shipowners instruct the nautical instrument maker to examine the ship's compasses after each voyage. The compasses are then collected, and taken to the workshop, but not always with the desired result, as the committee have witnessed instances (where the instruments have probably been put into the hands of apprentices or unskilful workmen,) of the compasses coming back to the ship with the needles on the card placed with their poles in opposite directions; with the pivots longer or shorter than they should be, so that the point of suspension of the card is no longer in the plane of the gimballs; with the needles and cap fixed on the wrong face of the card, so that the east and west points of the card were reversed. The best and almost the only remedy for these and the other errors belonging to the compasses of an iron ship must, it is believed, chiefly depend on the care and attention of the master, on his knowledge of the principles of magnetism, and on those mechanical properties on which good compass action depend, and especially on his personal attention to those little mechanical but important details which are so essential to the satisfactory working of this instrument.*

Another matter of some practical importance which has been brought under the consideration of this committee, is the proper time for swinging iron ships, and more particularly for steamers, such as those which trade regularly to the Baltic, to the Mediterranean, or to America, and what amount of dependence the captain should place in the deviation table which is or ought to be supplied to him by the compass adjuster. There appears sufficient reason for requiring that a new iron sailing ship or steamer should be swung immediately before each of the first two or three voyages; that all iron vessels should be swung immediately before the first voyage following any considerable amount of repair; whenever a change has been made in the position of the standard compass; when there is a change of captain, unless the new captain had charge of the vessel during the preceding voyage as chief officer.

Swinging at any other time may, it is thought, be left to the discretion of the captain. A new captain is often not completely master of his position. He wishes before going to sea in a strange ship to be satisfied as to the deviations of her compasses, but fears that his motives or his competency may be suspected, if he advises what, under the present system, involves some expense, in addition to the delay of a tide or two in getting the ship to sea. He perhaps ventures to allude to the subject, and is at once told that the former captain had sailed her without requiring that she should be swung, and that there was never "any difficulty" with her compasses. The new captain is thus put on his mettle; he makes inqui-

* These remarks apply to the compasses of wooden ships quite as much as to those of ships built of iron; and captains of wooden ships often report large compass errors which can only be attributed to similar mechanical causes.

ries of others how they manage, and resolves to use the utmost caution in clearing the Channel. If the weather is favorable, he does it without difficulty, and all goes well. The captain has gained experience, and the owners have saved expense and gained despatch. But, on the other side, if the weather is thick and unfavorable, how unsatisfactory and full of anxiety is the position of the captain. He has no means of discovering his error until he is actually in danger; and in the event of a casualty, with whom rests the responsibility?

It must not, however, be forgotten, that the utility of swinging ship is chiefly confined to assisting the captain in first clearing his port and the neighboring channels in case of thick weather, and ought not to supersede his making observations for himself whenever he has the opportunity; in short, that the deviations observed in port when the ship is upright and at rest, should always be considered subordinate to observations made at sea under various degrees of heel of the ship, and in steamers with the addition of the vibration of the screw. These observations are by far the most important, but they must be taken in connexion with all the collateral circumstances.

It has been noticed that strandings have often occurred with steamers on the first voyage after being swung; and it is known that many captains, after making two or three voyages, have a great repugnance to any change being made in the compensation of their compasses. They submit to the ship being swung when the appointed time comes round, but perhaps make no use of the deviation card which is then obtained. By practice, they have found for themselves what error must be allowed on the different courses incident to the voyage; and if the compensating magnets had been removed, they would have had to relearn their courses again. The word "error" is advisedly used here, as it is not compass deviation, properly so called, which they ascertain, but the resultant error from all the causes which have affected the ship's course on the particular trials from which the deduction has been made. Change the circumstances, and the course is no longer made correctly. The course steered is selected as being the mean result of many trials; the causes which operated in each to produce the observed issue were perhaps never estimated, and, as a consequence, there is always a probability of a deviation from the intended course through some of the conditions having been changed. By much care and attention, and frequently through good fortune, accidents from the causes now alluded to are not numerous; but when they do occur, they are of so fearful a nature as to challenge public attention and inquiry. Unfortunately, in cases where compass deviations are supposed to have in part occasioned the casualty, too little has been known of the subject to elicit to what extent they have been in fault, or how a recurrence of the accident might be prevented. In a screw steamer, when under sail, seven distinct causes may have conspired to produce the course which has been "made good," namely—

1. Set tide or current.
2. Set of the screw.
3. Leeway.
4. Good or bad steerage.
5. Variation of the compass.
6. Deviation of the compass.
7. Extra deviation from the heeling of the ship.

Again, the influence of some of these causes varies with the time occupied on the course; others vary in proportion to the distance gone over; but until the captain of the screw steamer is able to estimate how much each cause is likely to affect the course which is to be steered, and the limits within which his estimate is likely to be erroneous, he must ever be subject to much uncertainty as to the result. The experiments on the effect of heeling on the compasses of iron ships recorded in this Report, the evidence on the same subject afforded by the logs given in the Appendix, and the concurrent testimony of commanders of screw steamers of undoubted ability, all show how important an element this is in shaping a course, and more especially on courses like those between Cape Sable and Cape Race, the coast of Spain, and the entrance to the English or Irish Channels, and many others. It is most essential, then, that the captains and officers of iron ships should be well informed on this subject. Where so many imperfectly ascertained elements combine to produce a result, there will always be occasion for care and forethought; and the information which the committee urge as so necessary does not dispense with the utmost care, but rather seeks to assist by giving it proper direction. The managing owner of a number of iron ships once remarked: "Compasses in iron ships never are and never will be correct, and I do not want the compasses of my ships to be so. I forbid my captains to suppose it possible, as they would then become careless." The recommendation of this committee requires the same caution, while it shows on which side danger is to be apprehended. The well-informed captain can thus proceed with confidence, under circumstances in which the equally cautious but ignorant captain would have to lie-to or proceed slowly; or, on the other hand, in cases where information on the effect of heeling would counsel a change of course, the ignorant captain might go blindly forward into danger.

The committee have pleasure in including in the Appendix to this Report, two letters which they have received from Mr. Thomas Bennet, compass adjuster, Cork, which contain many remarks on compass adjustment and swinging ship that appear well worthy of careful consideration, and not less so because, to some small extent, the experience of Mr. Bennett does not accord with that of this committee. In many important particulars, however, they will be found to confirm the observations made in this and the preceding Report.

Before concluding this Report, it appears desirable that some explanation should be given of the delay which has occurred in its presentation. It is due to this committee, as well as to the secretary, Mr. Rundell, to explain, that in the spring of 1857 it was determined to dissolve the committee at midsummer, and Mr. Rundell was permitted to anticipate its dissolution by accepting another situation, on condition that he should prepare a final Report for the committee by the close of that year. But the heeling experiments made on board the "City of Baltimore," towards the end of 1857, showed that a most important part of the compass investigation would be left very incomplete, if the Report were closed at the time intended. It was therefore thought advisable to leave the matter entirely to the discretion of the secretary. The preparation of the Report has thus depended on his leisure hours, and the time that could be spared from other duties, and for the last three and a half years has been altogether an honorary task. The delay occasioned in this way has, however, enabled the Liverpool Compass Committee to present to your Lordships a much larger collection of facts and experiments than could at first have been reasonably hoped for, and to practically develop the subject of this inquiry to an extent which it is believed must materially influence the navigation and compass management of iron ships.

THOMAS BROCKLEBANK,
Chairman.

LIVERPOOL, *February* 13, 1861.

APPENDIX.

APPENDIX A.

Experiments to ascertain the effects of heeling on the compasses of the steamship "City of Baltimore," June 8 *and* 9, 1857.

Arrangements were made by the Compass Committee to conduct these experiments in the Wellington Basin, Liverpool, this dock being specially adapted for swinging ship, but at the appointed time it was found that the ship had been placed in the Huskisson Dock, in which was a number of iron steamers, some of them so close as to affect, it was feared, the accuracy of the results. As no notice of the change had been given, and time pressed, it was impossible to arrange any system of shore bearings, so as to be independent of a shore compass placed very close to the dock. In consequence of this, the observations are subject to any errors which belonged to the shore compass, which could not always be kept near the same place. From subsequent examination, it appeared probable that these errors were too small to sensibly affect the principal object of the experiments, but they probably influence the co-efficients for index error of the different compasses, and in consequence require to be mentioned here.

Great care was taken to keep the ship as far as possible from the other iron ships which were in the dock, and, with the exception of one instance, in which the compasses near the stern were seen to be influenced, and note of which is appended to the record, no error of consequence can be attributed to this cause.

Mr. Towson took charge of the dipping-needle compass, and conducted the vibration and dip experiments, with the assistance of the secretary; Mr. Gray and Captain Leitch read the compensated compasses; and Mr. Gray, with his assistant on shore, undertook to give ship's head correct magnetic. The secretary kept the record of the whole of the observations, and, as far as possible, checked the shore bearings by means of a "Friend's Pelorus."

In the accompanying tables the observations are given in the order in which they were made. A slight inspection will be sufficient to show that the deviations from heeling are so large in amount as to be affected only to a small extent by the causes of error which have been alluded to.

The magnetic co-efficients for the stations on board the "City of Baltimore," and on board the other ships which will have to be noticed, were obtained by the formula given by Mr. A. Smith in the "Supplement to the Practical Rules, &c," published by the Admiralty, no allowance being made for the polar deviation from horizontal induction which is due to the unsymmetrical arrangement of the ship's iron, especially when the ship is heeled. As this polar deviation retains the same sign in each semicircle, it affects the co-efficient for index error by producing an apparent plus A when the ship heels to port, and a minus A when the ship heels to starboard. Apparent index error from the same cause (unsymmetrical arrangement of the ship's iron as regards the compass) is also to be traced in most deviation tables for ship upright. Its amount can readily be found by inspecting the several equations for co-efficient A as obtained by Mr. Smith's formula.

As regards the varying values for quadrantal deviation at the same station in the same ship, (co-efficient D,) both in these experiments and in others of the same kind, these are thought to be to some extent due to the more or less rapid manner in which the swinging of the ship was effected, as there is reason to believe that when the ship is swung very quickly and easily the quadrantal deviation is not so large as when the ship is allowed to rest for a short time at each observation. The same cause and the direction in which the ship is swung are also believed to affect the value and the sign of co-efficient E.

In connexion with these remarks see particulars of the experiments on board the "Simla," Appendix C.

STEAMSHIP "CITY OF BALTIMORE."—HUSKISSON DOCK, LIVERPOOL.—JUNE 8, 1857.

Ship's head, correct magnetic.	I.—Compass placed above the aft side of the round house.		II.—Port steering compass.*		III.—Starboard steering compass.†		IV.—Standard compass.		V.—Azimuth compass.	
	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
SHIP UPRIGHT.										
S. 2 0 E.	S. 2 0 E.	0 0	S. 1 0 W.	3 0 W.	South	2 0 W.	S. 4 30 E.	2 30 E.	S. 3 30 E.	1 30 E.
N. 89 30 W	S. 45 30 W.	45 0 E.	West	0 30 E.	West	0 30 E.	S. 70 0 W.	29 30 E.	S. 70 0 W.	19 30 E.
							S. 69 0 W.	20 30 E.	S. 69 0 W.	20 30 E.
N. 77 30 W										
N. 70 0 W										
N. 67 30 W	S. 55 0 W.	57 0 E.					N. 84 30 W.	17 0 E.	N. 85 0 W.	17 30 E.
N. 60 30 W										
N. 47 0 W	S. 74 0 W.	59 0 E.	N. 38 30 W.	8 30 W.	N. 45 0 W.	2 0 W.	N. 52 15 W.	5 15 E.	N. 51 30 W.	4 30 E.
N. 2 0 W	N. 18 0 E.	20 0 W.	N. 4 0 E.	6 0 W.	N. 6 30 W.	4 30 E.	N. 6 30 E.	8 30 W.	N. 5 30 E.	7 30 W.
N. 44 0 E.	S. 76 0 E.	60 0 W.	N. 47 0 E.	3 0 W.	N. 40 0 E.	4 0 E.	N. 57 0 E.	13 0 W.	N. 61 30 E.	17 30 W.
S. 88 0 E.	S. 42 0 E.	46 0 W.	S. 83 30 E.	4 30 W.	S. 80 30 E.	7 30 W.	S. 70 0 E.	18 0 W.	S. 67 0 E.	21 0 W.
S. 90 0 E.	S. 45 0 E.	45 0 W.					S. 71 30 E.	18 30 W.	S. 69 0 E.	21 0 W.
S. 43 0 E.							S. 30 30 E.	12 30 W.	S. 28 30 E.	14 30 W.
SHIP HEELING TO STARBOARD.										
S. 1 45 W							S. 8 0 E.	9 45 E.		
SHIP HEELING 8° TO STARBOARD.										
S. 1 45 W	S. 7 0 E.	8 45 E.	S. 8 0 W.	6 15 W.	S. 14 30 W.	12 45 W.	S. 10 30 E.	12 15 E.	S. 9 0 E.	10 45 E.
							S. 9 30 E.	11 15 E.		
SHIP HEELING 11° TO STARBOARD.										
S. 1 45 W	S. 8 30 E.	10 15 E.	S. 10 0 W.	8 15 W.	S. 17 0 W.	15 15 W.	S. 14 0 E.	15 45 E.	S. 12 0 E.	13 45 E.
SHIP HEELING 12° 15′ TO STARBOARD.										
S. 1 45 W							S. 15 0 E.	16 45 E.	S. 13 45 E.	15 30 E.
S. 40 30 W	S. 8 30 W.	36 0 E.	S. 49 30 W.	5 0 W.	S. 54 0 W.	9 30 W.	S. 17 30 W.	27 0 E.	S. 20 0 W.	24 30 E.
S. 42 30 W				7 0 W.		11 30 W.	S. 14 0 W.	28 30 E.	S. 15 30 W.	27 0 E.

* When ship's head was N. 89° 30′ W., this compass, before any magnets were applied, showed S. 58° W., or a deviation of 32° 30′ East. After the transverse magnet was put in its place, the deviation was 14° 30′ East.

† When ship's head was South, this compass, before any magnets were applied, showed 22° 30′ West deviation; with head West, without any magnets, 28° East deviation; after the transverse magnet was applied, 17° 30′ East deviation.

STEAMSHIP "CITY OF BALTIMORE."—HUSKISSON DOCK, LIVERPOOL.—JUNE 8, 1857—Continued.

Ship's head, correct magnetic.	VI.—Dipping-needle compass.*				VII.—Fore compass.†		VIII.—Mr. Gray's Azimuth compass.	
	Ship's head.	Deviation.	Vibrations per minute of horizontal needle.	Dip.	Ship's head.	Deviation.	Ship's head.	Deviation.
° ′ SHIP UPRIGHT.	° ′	° ′		° ′	° ′	° ′	° ′	° ′
S. 2 0 E.	South	2 0 W.	23.8	53 0	S. 1 0 E.	1 0 W.	S. 11 30 W.	13 30 W.
N. 89 30 W	S. 72 30 W.	18 0 E.	19.0	54 30	West	0 30 E.	S. 82 0 W.	8 30 E.
	S. 72 0 W.	18 30 E.						
N. 77 30 W	S. 85 0 W.	17 30 E.						
N. 70 0 W	N. 85 0 W.	15 0 E.						
N. 67 30 W	N. 82 30 W.	15 0 E.						
N. 60 30 W	N. 72 30 W.	12 0 E.	18.0					
N. 47 0 W	N. 54 0 W.	7 0 E.	18.0	54 55	N. 43 0 W.	4 0 W.	N. 59 0 W.	12 0 E.
N. 2 0 W	N. 1 15 W.	0 45 W.	17.0	54 55	North	2 0 W.	N. 13 30 W.	11 30 E.
N. 44 0 E	N. 55 15 E.	11 15 W.	18.0	54 30	N. 45 0 E.	1 0 W.	N. 41 0 E.	3 0 E.
S. 88 0 E	S. 77 30 E.	10 30 W.	20.5	54 30	S. 88 0 E.	0 0	S. 73 0 E.	15 0 W.
S. 90 0 E	S. 79 30 E.	*10 30 W.					S. 74 0 E.	16 0 W.
S. 43 0 E	S. 27 30 E.	15 30 W.	21.5	54 0	S. 43 30 E.	0 30 E.	S. 22 0 E.	21 0 W.
SHIP HEELING TO STARBOARD.								
S. 1 45 W	S. 4 0 E.	6 45 E.			S. 1 0 E.	2 45 E.	S. 5 0 W.	3 15 W.
SHIP HEELING 8° TO STARBOARD.								
S. 1 45 W	S. 5 0 E.	6 45 E.	24.0	54 0	S. 3 30 E.	5 15 E.	S. 9 30 W.	7 45 W.
SHIP HEELING 11° TO STARBOARD.								
S. 1 45 W	S. 7 45 E.	9 30 E.	22.4	53 30	S. 5 0 E.	6 45 E.	South? (S. 14 0 W.)	(12 15 W.)
SHIP HEELING 12° 15′ TO STARBOARD.								
S. 1 45 W	S. 8 0 E.	9 45 E.			S. 6 0 E.	7 45 E.		
S. 44 30 W	S. 23 0 W.	21 30 E.	21.0	53 30			S. 33 0 W.	11 30 E.
							By shore bearing	14 30 E.
S. 42 30 W	S. 21 0 W.	21 30 E.			S. 36 30 E.	6 0 E.		

* The dipping-needle compass on shore vibrated 20 times per minute, and had a small lever attached to its axis, so arranged as to make it dip 45° when suspended in a plane at right angles with the magnetic meridian.

† The fore compass, before the fore-and-aft magnet was applied, showed 14° East deviation. Ship's head, correct magnetic, N. 89° 30′ W.

STEAMSHIP "CITY OF BALTIMORE." HUSKISSON DOCK, LIVERPOOL. -JUNE 9. 1857—Continued.

Ship's head, correct magnetic.	I.—Compass placed above the aft side of the round house.		II.—Port steering compass.		III.—Starboard steering compass.		IV.—Standard compass.		V.—Azimuth compass.	
	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.
SHIP UPRIGHT.										
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
S. 45 0 W.	S. 24 0 W.	21 0 E.	S. 44 0 W.	1 0 E.	S. 43 15 W.	1 45 E.	S. 29 0 W.	16 0 E.	S. 29 0 W.	16 0 E.
SHIP HEELING 10° TO PORT.	S. 35 0 W.	10 0 E.	S. 35 0 W.	10 0 E.	S. 36 0 W.	9 0 E.	S. 37 0 W.	8 0 E.	S. 38 0 W.	7 0 E.
South	S. 9 30 W.	9 30 W.	S. 8 30 E.	8 30 E.	S. 8 0 E.	8 0 E.	S. 8 30 W.	8 30 W.	S. 9 0 W.	9 0 W.
S. 19 0 E.	S. 6 0 W.	25 0 W.	S. 21 30 E.	2 30 E.	S. 21 30 E.	2 30 E.	S. 3 0 E.	16 0 W.	S. 2 0 E.	17 0 W.
	S. 4 30 W.	23 30 W.	S. 18 0 E.	1 0 W.	S. 18 0 E.	1 0 W.	S. 3 30 E.	15 30 W.	S. 3 45 E.	15 15 W.
S. 45 0 E.	S. 7 0 E.	38 0 W.	S. 46 30 E.	1 30 E.	S. 41 0 E.	4 0 W.	S. 21 0 E.	24 0 W.	S. 20 0 E.	25 0 W.
			S. 40 15 E.*	4 45 W.	S. 37 0 E.*	8 0 W.				
East	S. 30 0 E.	60 0 W.	S. 87 30 E.	2 30 W.	S. 85 0 E.	5 0 W.	S. 62 45 E.	27 15 W.	S. 60 30 E.	29 30 W.
			N. 86 0 E.*	4 0 E.	S. 84 0 E.	6 0 W.				
N. 44 15 E.	S. 70 0 E.	65 45 W.	N. 46 30 E.	2 15 W.	N. 41 0 E.	3 15 E.	N. 45 0 E.	0 45 W.	S. 47 30 E.	3 15 W.
			N. 37 30 E.*	6 45 E.	N. 37 30 E.*	6 45 E.				
North	N. 66 30 W.	66 30 E.	N. 6 0 E.	6 0 W.	North	0 0	N. 16 15 W.	16 15 E.	N. 15 30 W.	15 30 E.
			N. 0 45 W.	0 45 E.	N. 5 30 W.	5 30 E.				
N. 45 0 W.	S. 86 0 W.	49 0 E.	N. 37 0 W.	8 0 W.	N. 41 0 W.	4 0 W.	N. 64 30 W.	19 30 E.	N. 62 0 W.	17 0 E.
			N. 39 30 W.*	5 30 W.	N. 45 0 W.*	0 0				
West	S. 59 0 W.	31 0 E.	S. 87 45 W.	2 15 E.	S. 87 15 W.	2 45 E.	S. 72 30 W.	17 30 E.	N. 73 30 W.	16 30 E.
			N. 88 30 W.*	1 30 W.	S. 87 0 W.	3 0 E.				

Finished the above with 9° heel to port. The next observations were made with ship heeling slightly to starboard.

S. 89 30 W.	S. 45 0 W.	44 30 E.	N. 87 30 W.	2 0 E.	S. 89 30 W.	0 0	S. 68 30 W.	21 0 E.	S. 69 0 W.	20 30 E.

* In all the observations marked thus (*) a vertical magnet was introduced for the purpose of counteracting the effect of the heeling of the ship. The vertical magnets under the steering compasses were introduced by Mr. Gray. The position of the magnets was determined while ship's head was S.W., and it was agreed that they should be replaced in the same position each time the ship was held steady for making observations.

STEAMSHIP "CITY OF BALTIMORE."—HUSKISSON DOCK, LIVERPOOL.—JUNE 9, 1857—Continued.

Ship's head, correct magnetic.	VI.—Dipping-needle compass. Ship's head.	VI. Deviation.	VI. Vibrations per minute of horizontal needle.	VI. Dip.	VII.—Fore compass. Ship's head.	VII. Deviation.	VIII.—Mr. Gray's azimuth compass. Ship's head.	VIII. Deviation.	IX.—Compass placed over the fore hatch. Ship's head.	IX. Deviation.
SHIP UPRIGHT.										
° ′	° ′	° ′		° ′	° ′	° ′	° ′	° ′	° ′	° ′
S. 45 0 W.	S. 34 0 W.	11 0 E.	21.5	54 0	S. 42 45 W.	2 15 E.	S. 45 0 W.	0 0	......	......
SHIP HEELING 10° TO PORT.										
	S. 42 15 W.	2 45 E.	21.5	53 30	S. 45 30 W.	0 30 W.	S. 39 0 W.	6 0 E.	S. 40 0 W.	5 0 E.
	S. 35 0 W.*	10 0 E.								
South	S. 13 0 W.	13 0 W.	22.5	53 45	S. 7 0 W.	7 0 W.	S. 6 0 W.	6 0 W.	S. 7 30 W.	7 30 W.
	S. 13 30 W.	13 30 W.								
	S. 5 0 W.*	5 0 W.								
S. 19 0 E.	S. 3 30 E.	15 30 W.	......	......	S. 8 0 E.	11 0 W.	S. 5 0 E.	14 0 W.	S. 6 0 E.	13 0 W.
	S. 4 30 E.	14 30 W.								
S. 45 0 E.	S. 11 30 E.	33 30 W.	21.0	53 0	S. 33 0 E.	12 0 W.	S. 26 0 E.	19 0 W.	S. 19 0 E.	26 0 W.
	S. 18 30 E.*	26 30 W.								
East	S. 60 30 E.	29 30 W.	17.0	53 45	S. 85 0 E.	5 0 W.	S. 72 30 E.	17 30 W.	S. 55 0 E.	35 0 W.
	S. 65 30 E.*	24 30 W.								
N. 44 15 E.	N. 33 30 E.	10 45 W.	13.8	54 0	N. 37 0 E.	7 15 E.	N. 45 30 E.	1 15 W.	N. 57 30 E.	13 15 W.
	N. 41 0 E.	3 15 W.								
North	N. 22 30 W.	22 30 E.	17.9	55 0	N. 8 30 W.	8 30 E.	N. 3 30 W.	3 30 E.	N. 24 30 W.	24 30 E.
	N. 12 30 W.*	12 30 E.								
N. 45 0 W.	N. 65 15 W.	20 15 E.	20.2	54 45	N. 48 30 W.	3 30 E.	N. 51 45 W.	6 45 E.	N. 66 0 W.	21 0 E.
	N. 60 45 W.*	15 45 E.								
West	S. 73 30 W.	12 30 E.	22.0	54 45	S. 88 45 W.	1 15 E.	S. 80 0 W.	10 0 E.	S. 70 0 W.	20 0 E.
	S. 78 30 W.	11 30 E.								
Finished the above with 9° heel to port. The next observations were made with ship heeling slightly to starboard.										
S. 89 30 W.	S. 73 30 W.	16 0 E.	......	......	S. 88 30 W.	1 0 E.	S. 77 30 W.	12 0 E.	S. 75 0 W.	14 0 E.

* In all the observations marked thus (*) a vertical magnet was introduced for the purpose of counteracting the effect of the heeling of the ship. The vertical magnets under the steering compasses were introduced by Mr. Gray. The position of the magnets was determined while ship's head was S.W., and it was agreed that they should be replaced in the same position each time the ship was held steady for making observations.

STEAMSHIP "CITY OF BALTIMORE."—HUSKISSON DOCK, LIVERPOOL.—JUNE 9, 1857—Continued.

Ship's head, correct magnetic.	I.—Compass placed above the aft side of the round house.		II.—Port steering compass.		III.—Starboard steering compass.		IV.—Standard compass.		V.—Azimuth compass.	
	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.
SHIP HEELING 10° TO STARBOARD.										
° ′ ° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
N. 89 30 W. to S. 89 30 W.	S. 28 0 W.	62 0 E.	West	0 0	West	0 0	S. 59 0 W.	31 0 E.	S. 60 0 W.	30 0 E.
N. 45 30 W.	N. 57 0 W.	11 30 E.	N. 41 0 W.	4 30 W.	N. 47 30 W.	2 0 E.	N. 31 30 W.	14 0 W.	N. 32 30 W.	13 0 W.
			N. 29 0 W.*	16 30 W.	N. 44 0 W.*	1 30 W.				
North	N. 67 0 E.	67 0 E.	North	0 0	N. 9 30 W.	9 30 E.	N. 28 0 E.	28 0 W.	N. 25 30 E.	25 30 W.
			N. 14 0 E.*	14 0 W.	N. 6 0 W.	6 0 E.				
N. 45 0 E.	S. 84 30 E.	52 20 W.	N. 42 0 E.	2 10 E.	N. 31 30 E.	12 40 E.	N. 66 30 E.	22 20 W.	N. 67 0 E.	22 50 W.
N. 44 0 E.	....	....	N. 51 15 E.*	7 5 W.	N. 37 0 E.*	7 10 E.				
N. 43 30 E., say N. 44 10 E.	....	....	....	....	....	....	....	....	....	....
S. 89 30 E.	S. 54 0 E.†	35 30 W.	S. 82 0 E.†	7 30 E.	S. 79 30 E.†	10 0 W.	S. 74 30 E.	15 0 W.	S. 73 0 E.	16 30 W.
			S. 85 30 E.*†	4 0 E.	S. 81 0 E.*†	8 30 W.				
S. 43 0 E.	S. 31 30 E.	11 30 W.	S. 33 30 E.	9 30 W.	S. 30 0 E.	13 0 W.	S. 41 45 E.	1 15 W.	S. 39 45 E.	3 1 W.
			S. 43 30 E.*	0 30 E.	S. 33 0 E.*	10 0 W.				

* In all the observations marked thus (*) a vertical magnet was introduced for the purpose of counteracting the effect of the heeling of the ship. The vertical magnets under the steering compasses were introduced by Mr. Gray. The position of the magnets was determined while ship's head was S.W., and it was agreed that they should be replaced in the same position each time the ship was held steady for making observations.

† The stern of the ship was here nearly touching a large iron steamer on the west side of the dock.

STEAMSHIP "CITY OF BALTIMORE."—HUSKISSON DOCK, LIVERPOOL.—JUNE 9, 1857—Continued.

Ship's head, correct magnetic.	VI.—Dipping-needle compass.				VII.—Fore compass.		VIII.—Mr. Gray's azimuth compass.		IX.—Compass placed over the fore hatch.	
	Ship's head.	Deviation.	Vibrations per minute of horizontal needle.	Dip.	Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.
SHIP HEELING 10° TO STARBOARD.										
° ′ ° ′	° ′	° ′		° ′	° ′	° ′	° ′	° ′	° ′	° ′
N. 89 30 W. to S. 89 30 W.	S. 66 30 W.	23 30 E.	17.5	54 15	S. 89 0 W.	1 0 E.	S. 77 30 W.	12 30 E.	S. 73 0 W.	17 0 E.
	S. 70 15 W.*	19 45 E.								
N. 45 30 W.	N. 40 30 W.	5 0 W.	15.2	54 45	N. 37 15 W.	8 15 W.	N. 22 0 W.	23 30 W.	N. 63 30 W.	18 0 E.
	N. 45 0 W.*	0 30 W.								
North	N. 17 0 E.	17 0 W.	18.4	54 45	N. 7 15 E.	7 15 W.	N. 28 0 E.	28 0 W.	N. 7 0 W.	7 0 E.
	N. 11 0 E.*	11 0 W.								
N. 45 0 E.	N. 62 0 E.	17 40 W.	19.8	54 45	N. 48 15 E.	4 5 W.	N. 65 0 E.	20 50 W.	N. 63 30 E.	19 20 W.
N. 44 0 E.	N. 57 15 E.*	13 5 W.								
N. 43 30 E., say N. 44 10 E.										
S. 89 30 E.	S. 74 0 E.	15 30 W.	20.6	54 15	S. 86 45 E.	2 45 W.	S. 78 15 E.	11 15 W.	S. 63 30 E.	26 0 W.
	S. 75 15 E.*	14 15 W.								
S. 43 0 E.	S. 38 45 E.	4 15 W.	22.6	54 0	S. 43 30 E.	0 30 E.	S. 44 0 E.	1 0 E.	S. 29 0 E.	14 0 W.
	S. 37 0 E.*	6 0 W.			S. 42 45 E.	0 15 W.				

* In all the observations marked thus (*) a vertical magnet was introduced for the purpose of counteracting the effect of the heeling of the ship. The vertical magnets under the steering compasses were introduced by Mr. Gray. The position of the magnets was determined while ship's head was S.W., and it was agreed that they should be replaced in the same position each time the ship was held steady for making observations.

"CITY OF BALTIMORE."

Deviations of the compasses of the steamship "City of Baltimore," as obtained by drawing a fair curve through the observations recorded in the previous tables.

Ship's head by each compass, (disturbed.)	I.—Compass placed above the aft side of the round house.			II.—Port steering compass, (compensated.)					III.—Starboard steering compass, (compensated.)					IV.—Standard compass.		
				10° heel to port.		Ship upright.	10° heel to starboard.		10° heel to port.		Ship upright.	10° heel to starboard.				
	Heel to port.	Upright.	Heel to starboard.	With vertical magnet.	Without vertical magnet.		Without vertical magnet.	With vertical magnet.	With vertical magnet.	Without vertical magnet.		Without vertical magnet.	With vertical magnet.	Heel to port.	Upright.	Heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	40 0 E.	10 0 W.	54 20 W.	1 15 E.	7 0 W.	6 30 W.	0 0	16 30 W.	6 0 E.	0 0	5 15 E.	11 15 E.	6 50 E.	13 20 E.	7 30 W.	26 25 W.
N. by E.	21 0 E.	23 40	61 0	3 0	5 25	5 25	1 0 E.	14 45	6 35	1 35 E.	5 50	12 40	7 35	10 40	8 50	27 30
N. N. E.	0 0	35 0	65 10	4 35	4 20	4 30	1 40	12 45	7 0	2 30	5 30	13 0	7 55	7 30	9 50	27 45
N. E. by N.	21 0 W.	45 0	67 0	5 50	3 10	3 50	2 0	10 40	6 40	2 40	4 40	12 45	7 45	3 0 E.	11 15	28 0
N. E.	38 30	52 0	65 40	6 50	2 30	3 15	2 15	8 25	5 45	2 15	3 20	11 35	6 45	1 5 W.	11 50	27 40
N. E. by E.	52 30	57 0	61 10	7 10	1 40	2 40	2 0	6 0	3 40	0 55 E.	1 30 E.	9 30	5 40	5 30	13 0	26 30
E. N. E.	62 0	59 0	55 0	6 45	1 15	2 35	1 25	3 50	1 5 E.	0 30 W.	0 30 W.	6 50	3 45	10 45	14 10	24 30
E. by N.	66 40	58 40	48 40	5 25	1 35	2 10	0 5 E.	1 50	1 55 W.	2 35	2 50	3 20 E.	1 15 E.	15 5	15 5	22 0
East	68 0	57 0	42 50	3 0	2 0	3 45	1 25 W.	0 20 W.	4 45	4 30	5 30	0 35 W.	0 50 W.	19 10	17 0	19 10
E. by S.	67 20	53 30	36 20	0 20 E.	2 35	5 0	3 25	0 20 E.	7 15	5 50	7 55	4 10	3 35	23 0	18 10	16 25
E. S. E.	64 0	47 20	29 20	2 0 W.	2 20	6 0	5 20	0 45	9 5	6 35	10 0	7 0	5 55	26 25	18 50	12 25
S. E. by E.	57 30	40 0	21 20	4 0	1 25	6 30	7 0	1 25	9 30	6 40	11 20	9 15	7 25	27 50	18 30 W.	8 0
S. E.	50 0	32 20	13 10	4 45	0 10 W.	6 55	8 5	2 35	8 50	4 45	11 30	10 50	8 30	28 15	17 30	2 45 W.
S. E. by S.	42 30	24 0	4 0 W.	3 45	1 50 E.	6 45	8 40	4 15	7 10	1 50 W.	10 45	12 10	9 25	27 10	15 5	3 0 E.
S. S. E.	35 0	15 30	4 20 E.	2 0 W.	4 0	6 10	8 50	7 0	4 15	1 40 E.	8 25	13 25	9 45	24 25	11 20	9 20
E. by S.	27 0	7 30 W.	14 20	0 45 E.	6 0	5 10	8 45	10 0	0 30 W.	5 15	5 35	14 10	9 10	20 0	6 40	16 0
South	17 30	1 0 E.	24 0	3 45	8 10	3 20	8 5	12 30	2 50 E.	7 30	2 0 W.	14 50	8 0	14 0	0 20 W.	22 0
S. by W.	10 0	9 30	32 20	5 40	9 50	1 15 W.	7 15	13 45	5 30	8 30	0 20 E.	15 0	6 25	6 50 W.	7 10 E.	26 50
S. S. W.	3 0 W.	17 0	40 50	6 40	10 25	0 25 E.	5 50	13 50	6 45	9 10	2 0	13 50	3 50	0 30 E.	14 0	29 55
S. W. by S.	5 0 E.	25 0	48 40	6 45	10 5	1 40	4 25	13 0	7 15	9 10	2 45	12 10	1 20 W.	6 30	18 50	31 25
S. W.	12 0	32 0	55 20	6 25	9 0	2 30	3 0	11 30	7 30	8 30	3 0	9 40	0 45 E.	11 45	21 15	31 40
S.W. by W.	20 0	39 0	60 0	5 30	7 50	2 50	2 0	9 0	6 45	7 30	3 0	6 55	1 20	14 45	21 45	30 35
W. S. W.	26 30	46 0	64 0	3 35	6 0	2 30	1 10	5 50	5 50	6 0	2 30	4 0	1 20	16 40	21 10	28 5
W. by S.	34 0	51 20	63 0	1 30 E.	4 0	1 40	0 40	2 15 E.	4 5	4 22	1 30	2 0	0 50	18 0	19 50	24 20
West	41 0	56 0	57 30	0 40 W.	1 35 E.	0 20 E.	0 30	1 5 W.	2 45	2 30 E.	0 40 E.	0 20 W.	0 10 E.	19 0	17 45	19 40
W. by N.	46 0	58 0	48 0	3 0	0 45 W.	1 15 W.	1 15	5 0	1 30	0 30 E.	0 15 W.	0 30 E.	0 50 W.	19 10	15 0	13 45
W. N. W.	53 20	56 0	37 0	5 0	3 15	3 45	2 30	8 30	0 30 E.	0 55 W.	0 55	0 55	1 45	19 25	11 45 E.	6 40 E.
N.W. by W.	59 0 W.	51 30 E.	21 30 E.	5 50 W.	5 15 W.	5 50 W.	3 45 W.	11 30 W.	0 0	2 45 W.	1 40 W.	1 30 E.	2 0 W.	19 15 E.	8 0 E.	0 50 W.

Deviations of the compass of the steamship "City of Baltimore," &c.—Continued.

Ship's head by each compass, (disturbed.)	I.—Compass placed above the aft side of the round house.			II.—Port steering compass, (compensated.)					III.—Starboard steering compass, (compensated.					IV.—Standard compass.		
				10° heel to port.		Ship upright.	10° heel to starboard.		10° heel to port.		Ship upright.	10° heel to starboard.				
	Heel to port.	Upright.	Heel to starboard.	With vertical magnet.	Without vertical magnet.		Without vertical magnet.	With vertical magnet.	With vertical magnet.	Without vertical magnet.		Without vertical magnet.	With vertical magnet.	Heel to port.	Upright.	Heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
N. W.	63 30 E.	44 0 E.	4 0 E.	5 50 W.	6 50 W.	7 20 W.	4 25 W.	13 40 W.	0 20 E.	3 55 W.	1 45 W.	2 40 E.	1 20 W.	18 40 E.	4 0 E.	7 45 W.
N.W. by N.	66 40	33 0	14 0 W.	5 0	7 50	7 50	4 20	15 35	1 15	3 50	0 55 W.	4 5	0 5 E.	18 0	0 30 E.	14 0
N. N. W.	63 30	20 30	30 0	3 40	8 10	7 55	3 55	16 40	2 40	3 35	0 40 E.	6 0	1 45	17 0	2 45 W.	19 10
N. by W.	54 30 E.	6 0 E.	43 30 W.	2 0 W.	7 40 W.	7 15 W.	2 30 W.	17 0 W.	4 0 E.	2 15 W.	3 20 E.	9 0 E.	4 15 E.	15 30 E.	5 20 W.	23 40 W.

MAGNETIC CO-EFFICIENTS.

	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A	− 2 23	− 2 13	− 4 19	+ 1 10	+ 0 5	−3 28	− 3 1	− 1 45	+ 1 21	+ 0 57	−1 8	− 1 24	− 0 42	− 0 2	− 1 19	− 1 28
B	−54 14	−55 12	−46 54	+ 1 16	− 1 50	−1 57	+ 0 6	− 0.31	− 3 51	− 3 0	−3 16	+ 1 21	− 0 27	−19 58	−18 17	−19 6
C	+24 15	− 3 51	−36 22	− 0 45	− 7 4	−1 52	+ 3 29	−13 27	+ 2 4	− 2 15	+3 33	+12 36	+ 6 2	+12 48	− 3 53	−23 4
D	− 9 54	− 7 56	− 0 1	+ 6 2	+ 3 32	+3 26	+ 2 52	+ 6 39	+ 5 9	+ 4 47	+4 58	+ 2 37	+ 4 21	+ 5 0	+ 5 42	+ 3 55
E	+12 30	− 1 41	−11 26	+ 0 28	+ 0 28	−1 36	− 1 33	− 0 33	+ 2 35	+ 2 16	+1 44	− 0 25	0 0	+ 0 3	− 1 28	− 1 24

Deviations of the compasses of the steamship "City of Baltimore" &c.—Continued.

Ship's head by each compass (disturbed.)	V.—Azimuth compass. Heel to port.	V.—Azimuth compass. Ship upright.	V.—Azimuth compass. Heel to starboard.	VI.—Dipping-needle compass. 10° Heel to port. With vertical magnet.	VI.—Dipping-needle compass. 10° Heel to port. Without vertical magnet.	VI.—Dipping-needle compass. Ship upright.	VI.—Dipping-needle compass. 10° Heel to starboard. Without vertical magnet.	VI.—Dipping-needle compass. 10° Heel to starboard. With vertical magnet.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	12 50 E.	6 45 W.	23 20 W.	11 30 E.	20 10 E.	0 45 W.	15 5 W.	10 0 W.
N. by E	9 40	8 15	25 0	9 50	19 30	2 40	16 30	11 15
N. N. E	6 0	10 0	25 30	7 45	14 40	5 0	17 25	12 0
N. E. by N	1 45 E.	12 0	25 25	5 0	10 40	7 20	18 10	13 0
N. E	2 45 W.	14 10	25 20	1 40 E.	6 0	9 15	18 40	13 25
N. E. by E	7 25	16 30	24 35	1 35 W.	0 45	11 25	18 30	13 30
E. N. E	12 30	18 15	23 0	7 0	4 40	14 0	18 20	14 0
E. by N	17 10	19 50	21 40	12 0	11 50	16 20	18 15	14 15
East	21 30	20 40	20 15	16 40	16 40	18 15	17 30	14 35
E. by S	25 30	21 20	18 10	20 15	22 10	19 40	16 20	14 40
E. S. E	28 30	21 30	14 30	24 20	27 10	20 50	14 0	13 40
S. E. by E	30 0	20 50	10 30	26 55	31 0	20 50	10 10	11 50
S. E	30 0	19 40	5 45 W.	28 30	33 40	20 0	6 10	9 5
S. E. by S	28 50	17 10	0 20 E.	29 10	35 5	18 0	1 10 W.	4 0 W.
S. S. E	26 20	13 15	6 25	27 30	35 15	14 15	3 30 E.	1 30 E.
S. by E	21 45	7 50 W.	13 0	22 0	33 0	7 20	8 30	7 0
South	15 0	0 15 E.	19 30	11 15	26 30	1 30 W.	14 0	11 45
S. by W	7 30 W.	7 50	24 40	0 40 W.	16 0	3 45 E.	18 45	15 30
S. S. W	0 0	13 50	28 0	5 45 E.	6 55	8 50	22 15	19 0
S. W. by S	5 35 E.	18 0	30 0	9 45	0 45	13 0	24 20	21 10
S. W	10 0	20 50	30 40	12 30	3 45	16 0	25 10	21 45
S. W. by W	13 30	21 50	29 45	13 55	7 0	17 30	25 0	21 20
W. S. W	15 40	21 25	27 30	15 10	10 0	18 0	23 25	19 55
W. by S	16 50	20 20	24 10	15 45	12 50	17 45	20 40	17 45
West	17 15	17 45	19 25	15 55	15 55	15 55	17 5	15 15
W. by N	17 20	14 40	13 40	15 50	18 0	14 0	12 45	11 45
W. N. W	17 25	10 45	6 40 E.	16 0	20 0	11 50	7 30	7 30
N. W. by W	17 0	6 45	0 25 W.	15 40	21 20	9 0	2 10 E.	2 10 E.
N. W	16 35	3 0 E.	7 15	15 0	22 0	7 0	3 0 W.	3 0 W.
N. W. by N	16 10	0 20 W.	13 15	14 0	22 30	4 50	7 20	7 20
N. N. W	15 40	3 0	18 15	13 25	22 40	2 30	10 35	10 35
N. by W	15 15 E.	5 15 W.	21 45 W.	12 30 E.	21 50 E.	1 0 E.	13 10 W.	13 10 W.

Ship's head by each compass (disturbed.)	VII.—Fore compass (compensated.) Heel to port.	VII.—Fore compass (compensated.) Ship upright.	VII.—Fore compass (compensated.) Heel to starboard.	VIII.—Mr. Gray's Azimuth compass. Heel to port.	VIII.—Mr. Gray's Azimuth compass. Ship upright.*	VIII.—Mr. Gray's Azimuth compass. Heel to starboard.	IX.—Compass placed over the fore hatch. Heel to port.	IX.—Compass placed over the fore hatch. Heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	8 50 E.	2 0 W.	8 0 W.	3 45 E.	10 30 E.	27 50 W.	15 0 E.	4 20 E.
N. by E	8 50	1 30	7 30	3 0	8 50	28 35	9 40	0 10 E.
N. N. E	8 10	1 15	6 20	2 0	7 20	28 20	3 50 E.	4 5 W.
N. E. by N	7 25	1 15	5 20	0 45 E.	5 5	27 25	1 50 W.	8 45
N. E	6 0	1 0	4 35	1 10 W.	2 30 E.	25 30	7 25	13 0
N. E. by E	4 15	0 30	3 35	3 45	0 30 W.	23 0	12 50	16 50
E. N. E	1 55 E.	0 20	3 30	6 55	4 10	20 20	17 50	20 0
E. by N	1 0 W.	0 0	3 30	9 45	7 40	17 5	22 20	23 0
East	3 50	0 0	3 50	13 0	11 15	14 0	26 45	25 10
E. by S	6 15	0 5	3 15	16 0	14 20	11 0	30 35	26 30
E. S. E	8 35	0 30	2 30	18 30	17 20	7 0	33 25	26 30
S. E. by E	10 20	0 55	1 15 W.	20 0	19 10	3 0 W.	34 50	24 25
S. E	11 40	0 55	0 5 E.	20 15	20 40	1 30 E.	34 30	20 20
S. E. by S	12 0	1 10	1 50	19 55	21 20	6 25	32 20	15 30
S. S. E	12 10	1 20	3 30	18 20	20 50	12 0	27 35	9 50
S. by E	11 30	1 30	5 0	15 55	19 45	16 40	20 20	3 50 W.
South	9 30	1 0	6 25	12 0	17 30	20 30	14 20	1 5 E.
S. by W	6 40	0 15 W.	6 45	6 30	14 5	23 0	7 15	5 5
S. S. W	4 15	0 40 E.	7 0	1 0 W.	9 30	·24 0	1 10 W.	9 0
S. W. by S	2 15	1 30	7 0	3 55 E.	4 40 W.	23 45	3 50 E.	11 15
S. W	0 40 W.	2 20	6 30	7 40	0 0	22 35	9 25	13 30
S. W. by W	0 0	2 10	5 0	9 30	3 30 E.	20 5	14 5	15 0
W. S. W	0 40 E.	1 55	3 30	10 5	6 0	15 45	18 50	16 30
W. by S	1 0	1 10	2 0	10 15	7 55	12 15	23 15	17 30
West	1 15	0 30 E.	0 20 E.	10 0	9 20	7 0	25 50	18 0
W. by N	1 50	0 40 W.	1 55 W.	9 30	9 30	1 20 E.	30 0	18 10
W. N. W	2 15	2 25	4 20	8 20	8 20	4 30 W.	31 40	17 50
N. W. by W	2 45	3 40	6 0	7 15	7 15	10 0	31 45	17 5
N. W	3 40	4 40	7 30	6 0	6 0	15 20	30 0	15 45
N. W. by N	4 50	4 40	8 10	5 25	5 25	19 40	27 30	13 45
N. N. W	6 20	4 25	8 45	4 45	4 45	23 15	23 45	11 25
N. by W	7 45 E.	3 30 W.	8 50 W.	3 50 E.	3 50 E.	25 50 W.	20 20 E.	8 30 E.

* The position of this compass was altered on the second day. The observations made with ship upright are, therefore, not comparable with those made when the ship was heeled.

Deviations of the compasses of the steamship "City of Baltimore" &c.—Continued.

MAGNETIC CO-EFFICIENTS.

Ship's head by each compass (disturbed.)	V.—Azimuth compass.			VI.—Dipping-needle compass. 10° Heel to port.		VI.—Dipping-needle compass.	VI.—Dipping-needle compass. 10° Heel to starboard.		VII.—Fore compass (compensated.)			VIII.—Mr. Gray's Azimuth compass.			IX.—Compass placed over the fore hatch.	
	Heel to port.	Ship upright.	Heel to starboard.	With vertical magnet.	Without vertical magnet.	Ship upright.	Without vertical magnet.	With vertical magnet.	Heel to port.	Ship upright.	Heel to starboard.	Heel to port.	Ship upright.	Heel to starboard.	Heel to port.	Heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A	− 1 35	− 2 30	− 1 34	− 0 2	− 1 1	− 1 27	− 0 28	− 0 21	− 0 43	− 0 55	− 1 22	− 2 21	− 2 57	− 3 52	− 0 15	− 0 45
B	−20 14	−19 48	−19 23	−17 46	−17 28	−17 46	−16 24	−14 40	− 2 44	0 0	− 1 25	−11 59	− 9 13	−10 30	−27 7	−21 41
C	+12 46	− 3 50	−20 35	+11 31	+21 33	+ 1 9	−13 57	−11 16	+ 8 25	− 1 30	− 6 49	+ 6 58	+11 28	−23 26	+15 21	+ 2 10
D	+ 5 27	+ 6 2	+ 4 39	+ 7 34	÷ 5 35	+ 4 58	+ 4 1	+ 5 7	+ 3 23	+ 1 42	+ 2 18	+ 5 6	+ 4 23	+ 2 38	+ 1 35*	+ 1 24*
E	+ 0 26	− 0 41	− 0 56	+ 0 2	− 0 46	− 0 28	− 0 9	− 0 11	+ 0 24	− 0 55	+ 0 22	− 1 12	− 1 54	+ 0 2	+ 0 5	+ 1 40

* It will be seen that the + D for this compass is very small. See another example of this effect of cut beams at a succeeding page, in the compass placed over the after hatch of the "Slieve Donard," in which this co-efficient is only 0° 24′.

Direction and amount of the magnetic force of the steamship "City of Baltimore," at the station of the dipping-needle compass, 76 feet 9 inches before the rudder-head, 3 feet above the deck-house, and about 10 feet 6 inches above the deck.

No. of experiment.	Ship's head, correct magnetic.	Ship's head by compass.	Observed deviation.	Deviation corrected for index error.	Vibrations of horizontal needle in 30 seconds.*	Magnetic force in direction of needle.	Horizontal force to North.	Disturbing force to North.	Disturbing force to East.	Total horizontal disturbing force.	Azimuth of ship's force.	Starboard angle.	Observed dip.†	Ship's vertical force in terms of Earth's horizontal force.	Approximate. Ship's total magnetic force.	Approximate. Angle from the vertical of ship's magnetic force.
SHIP UPRIGHT.																
	° ′	° ′	° ′	° ′							° ′	° ′	° ′			° ′
1...	N. 0 30 W.	N. 1 15 W.	0 45 W.	0 45 E.	8.5	.723	.7229	—.2771	.0095	.277	N. 178 0 E.	177 30	54 45	1.139	1.17	13 30
2...	45 30 E.	55 15 E.	11 15	9 45 W.	9.0	.810	.7983	—.2017	—.1267	.238	212 0	166 30	54 30	1.095	1.12	12 0
3...	93 15	112 30	20 45	19 15	10.25	1.051	.9023	—.0077	—.3465	.347	269 0	175 45	54 30	1.095	1.15	17 30
4...	138 0	152 30	16 0	14 30 W.	10.75	1.156	1.1191	.1191	—.2895	.311	292 0	154 0	54 0	1.033	1.08	17 0
5...	180 45	180 0	0 45 W.	0 45 E.	11.75	1.381	1.3809	.3809	.0181	.381	2 30	181 45	53 0	.898	.975	23 30
6...	228 15	214 0	12 45 E.	14 15	10.75	1.156	1.1204	.1204	.2846	.309	67 0	198 45	54 0	1.033	1.08	16 30
7...	272 0	252 30	18 0	19 30	9.53	.908	.8559	—.1441	.3031	.336	·115 30	293 30	54 30	1.095	1.14	17 0
8...	N. 316 30 E.	N. 306 0 E.	9 0 E.	10 30 E.	9.05	.819	.8053	—.1947	.1498	.246	N. 142 15 E.	185 45	54 45	1.139	1.16	12 0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.306	.....	176 11	.....	1.066	1.11	17 30
SHIP HEELING 10° TO PORT.																
1...	N. 1 0 E.	N. 337 30 E.	22 30 E.	23 30 E.	8.95	.801	.7346	—.2654	.3194	.416	N. 129 45 E.	128 45	55 0	1.177	1.24	19 45
2...	45 0	33 30	10 30	11 30 E.	6.9	.476	.4664	—.5336	.0949	.544	169 30	124 30	54 0	1.034	1.17	28 0
3...	91 0	119 30	29 30 E.	28 30 W.	8.35	.697	.6125	—.3875	—.3326	.510	229 30	138 30	53 45	1.000	1.13	27 0
4...	136 0	168 30	33 30 W.	32 30	10.5	1.103	.9303	—.0697	—.5926	.596	263 30	127 30	53 30	.966	1.14	32 0
5...	179 0	193 30	15 30 W.	14 30 W.	11.25	1.266	1.2256	.2256	—.3170	.390	305 30	126 30	53 45	1.000	1.08	21 30
6...	225 0	232 30	1 30 E.	2 30 E.	10.75	1.156	1.1548	.1548	.0504	.163	18 0	153 0	53 30	.966	.98	9 30
7...	271 0	257 30	12 30	13 30	11.0	1.210	1.1766	.1766	.2824	.333	58 0	147 0	54 45	1.140	1.19	16 30
8...	N. 316 15 E.	N. 294 45 E.	20 15 E.	21 30 E.	10.1	1.020	.9490	—.0510	.3738	.377	N. 97 30 E.	141 15	54 45	1.140	1.20	18 0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.416	.....	136 0	.....	1.053	1.14	21.30

* Vibrations on shore, 10 in 30 seconds.

† Dip on shore with weighted needle, 45°.

Direction and amount of the magnetic force of the steamship "City of Baltimore" &c.—Continued.

SHIP HEELING 10° TO STARBOARD.

No. of experiment.	Ship's head, correct magnetic.	Ship's head by compass.	Observed deviation.	Deviation corrected for index error.	Vibrations of horizontal needle in 30 seconds.*	Magnetic force in direction of needle.	Horizontal force to North.	Disturbing force to North.	Disturbing force to East.	Total horizontal disturbing force.	Azimuth of ship's force.	Starboard angle.	Observed dip.†	Ship's vertical force in terms of Earth's horizontal force.	Approximate. Ship's total magnetic force.	Approximate. Angle from the vertical of ship's magnetic force.
	° ′	° ′	° ′	° ′							° ′	° ′	° ′			° ′
1...	N. 0 45 E.	N. 17 0 E.	17 0 W.	16 15 W.	9.2	.846	.8122	—.1878	—.2367	.300	N.·232 0 E.	231 15	54 45	1.140	1.18	15 0
2...	44 15	62 0	18 30	17 45	9.95	.990	.9429	—.0571	—.3019	.324	260 0	215 45	54 45	1.140	1.19	16 0
3...	91 0	106 0	15 45	15 0	10.3	1.061	1.0258	.0258	—.2668	.268	275 30	184 30	54 15	1.069	1.10	14 0
4...	138 45	141 15	3 0 W.	2 45 W.	11.3	1.277	1.2755	.2755	—.0613	.282	347 30	208 45	54 0	1.034	1.08	15 30
5...	183 15	172 30	10 0 E.	10 45 E.	11.27	1.260	1.2380	.2380	.2350	.335	44 45	221 30	53 30	.966	1.02	19 0
6...	224 45	203 0	21 0	21 45	10.5	1.103	1.0245	.0245	.4068	.410	86 30	221 45	53 30	.966	1.05	23 0
7...	271 0	246 30	23 30 E.	24 30 E.	8.75	.766	.6971	—.3029	.3177	.439	133 45	222 45	54 15	1.069	1.16	22 0
8...	N. 314 45 E.	N. 319 30 E.	5 0 W.	4 15 W.	7.7	.593	.5914	—.4086	.0439	.412	N. 174 0 E.	219 15	54 45	1.140	1.21	20 0
.....	....	....	....	....	....	....	....	....	....	.346	....	214 15	....	1.065	1.12	18 0

* Vibrations on shore, 10 in 30 seconds.

† Dip on shore with weighted needle, 45°.

By laying off the magnetic force observations recorded above as ordinates from a line of which the abscissæ represent the azimuth of ship's head by compass, and by passing a fair curve as nearly as possible through the ends of these ordinates, the elements for the following tables are obtained. These tables are arranged to show the ship's horizontal and vertical magnetic force at the station of the dipping-needle compass for ship's head correct magnetic on each second point of the compass. The resultants for amount and direction of ship's total magnetic force are calculated:

SHIP UPRIGHT.

Ship's head correct magnetic.		Deviation.	Deviation corrected for supposed index error.	Ship's hor. force.	Approximate azimuth of ship's force.	Approximate starboard angle.	Vertical force.	Resultants.	
In points.	In degrees.							Total force.	At angle from the vertical.
	° ′	° ′	° ′		° ′	° ′			° ′
0	N. 0 0 E.	0 50 W.	0 40 E.	.261	N. 178 0 E.	178 0	1.141	1.175	12 53
2	22 30	6 0	4 30 W.	.260	193 30	171 0	1.133	1.162	12 55
4	45 0	11 20	9 50	.265	210 0	165 0	1.113	1.144	13 24
6	67 30	17 0	15 30	.289	232 20	164 50	1.091	1.129	14 50
8	90 0	20 20	18 50	.322	254 45	164 45	1.064	1.112	16 50
10	112 30	20 0	18 30	.340	274 45	162 15	1.031	1.066	18 15
12	135 0	16 20	14 50	.335	296 20	161 20	1.010	1.064	18 21
14	157 30	8 50	7 20 W.	.309	328 0	170 30	.994	1.041	17 16
16	180 0	1 20 W.	0 10 E.	.298	1 0	181 0	.988	1.032	16 47
18	202 30	6 0 E.	7 30	.311	32 30	190 0	.996	1.043	17 22
20	225 0	12 40	14 10	.335	61 10	196 10	1.018	1.072	18 13
22	247 30	16 30	18 0	.340	83 45	196 15	1.050	1.104	17 57
24	270 0	17 40	19 10	.329	107 15	197 15	1.082	1.131	16 55
26	292 30	14 30	16 0	.305	131 45	199 15	1.112	1.153	15 20
28	315 0	8 10	9 40	.281	153 20	198 20	1.134	1.168	13 55
30	N. 337 30 E.	3 0 E.	4 30 E.	.268	N. 166 40 E.	189 10	1.144	1.175	13 11
....	....	....	....	.303	....	180 19	1.069	1.112	15 54

SHIP HEELING 10° TO PORT.

In points.	In degrees.	Deviation.	Deviation corrected for supposed index error.	Ship's hor. force.	Approximate azimuth of ship's force.	Approximate starboard angle.	Vertical force.	Total force.	At angle from the vertical.
0	N. 0 0 E.	22 0 E.	23 0 E.	.401	N. 126 40 E.	126 40	1.154	1.222	19 10
2	22 30	19 0	20 0	.425	143 30	121 0	1.114	1.192	20 53
4	45 0	10 0 E.	11 0 E.	.451	166 0	121 0	1.076	1.175	23 42
6	67 30	10 0 W.	9 0 W.	.465	191 0	123 30	1.041	1.140	24 4
8	90 0	29 0	28 0	.504	219 0	129 0	1.000	1.120	26 45
10	112 30	34 30	33 30	.540	241 45	129 15	.972	1.112	29 3
12	135 0	32 50	31 50	.577	262 20	127 20	.960	1.120	31 0
14	157 30	24 30	23 30	.538	288 30	133 0	.956	1.097	29 22
16	180 0	13 40	12 40	.389	310 40	135 0	.960	1.036	22 3
18	202 30	4 20 W.	3 20 W.	.228	340 30	145 0	.978	1.004	13 7
20	225 0	2 40 E.	3 40 E.	.213	21 30	154 0	1.007	1.029	11 57
22	247 30	7 50	8 50	.260	44 30	157 0	1.053	1.082	13 52
24	270 0	12 20	13 20	.314	61 10	151 10	1.102	1.146	15 54
26	292 30	16 40	17 40	.358	75 30	143 0	1.143	1.198	17 23
28	315 0	19 50	20 50	.383	92 30	137 30	1.172	1.239	18 6
30	N. 337 30 E.	21 50 E.	22 50 E.	.390	N. 108 30 E.	131 0	1.170	1.233	18 26
....	....	....	....	.421	....	130 16	1.054	1.134	20 55

STEAMSHIP "CITY OF BALTIMORE—Continued.

SHIP HEELING 10° TO STARBOARD.

Ship's head correct magnetic.		Deviation.	Deviation corrected for supposed index error.	Ship's hor. force.	Approximate azimuth of ship's force.	Approximate starboard angle.	Vertical force.	Resultants.	
In points.	In degrees.							Total force.	At angle from the vertical.
	° ′	° ′	° ′		° ′	° ′			° ′
0..........	N. 0 0 E.	16 40 W.	16 10 W.	.335	N. 223 0 E.	223 0	1.157	1.205	16 8
2..........	22 30	18 0	17 30	.320	240 30	218 0	1.152	1.195	15 31
4..........	45 0	18 0	17 30	.305	254 10	209 10	1.137	1.177	15 1
6..........	67 30	17 40	17 10	.308	268 15	200 45	1.110	1.152	15 30
8..........	90 0	15 20	14 50	.303	290 0	200 0	1.074	1.117	16 0
10..........	112 30	10 30	10 0	.300	314 30	202 0	1.039	1.081	16 6
12..........	135 0	4 15 W.	3 45 W.	.283	342 30	207 30	1.005	1.044	15 44
14..........	157 30	2 30 E.	3 0 E.	.288	14 0	216 0	.983	1.024	16 20
16..........	180 0	9 30	10 0	.329	42 30	222 30	.972	1.026	18 42
18..........	202 30	16 20	16 50	.376	62 15	219 45	.970	1.040	21 11
20..........	225 0	22 0	22 30	.410	91 0	226 0	.980	1.062	22 42
22..........	247 30	24 40	25 10	.425	114 30	227 0	1.010	1.096	22 49
24..........	270 0	23 30	23 50	.438	136 0	226 0	1.052	1.140	22 36
26..........	292 30	13 20 E.	13 50 E.	.428	159 15	226 45	1.100	1.180	21 16
28..........	315 0	5 0 W.	4 30 W.	.405	185 40	230 40	1.129	1.199	19 44
30..........	N. 337 30 E.	13 15 W.	13 45 W.	.375	N. 205 0 E.	227 30	1.148	1.208	18 5
....	....	....	....	.352	....	217 40	1.059	1.122	18 20

APPENDIX B.

Experiments to ascertain the effect of heeling on the compasses of the iron sailing ship "Aphrodita."

This ship was heeled and swung in the Wellington Basin, Liverpool, May 29 and 30, 1858. In the absence of the secretary, the swinging of the "Aphrodita" was kindly undertaken by Mr. Towson, assisted by Mr. Smart of the Local Marine School, the dipping-needle compass and the Admiralty standard compass being, respectively, observed by these gentlemen. The observations for the two steering compasses were rather discordant, owing, apparently, to the sluggishness of the cards; the resultant deviations for these compasses must, therefore, only be taken as roughly approximate.

"APHRODITA."

Deviation Tables for four compasses, ship upright, and with 10° heel to port and to starboard; also deviation tables for two of the compasses, as obtained some days afterwards.

Ship's head by each compass, (disturbed.)	I.—Compass under the companion, (approximate.)			II.—Compass over the companion, (approximate.)			III.—Admiralty standard compass.			IV.—Dipping-needle compass.			Dipping-needle compass.	Admiralty standard compass, ship upright.	
	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	July 10, ship upright.	July 10, in dock.	July 12, in the river.
	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '
North	43 0 E.	21 50 E.	4 0 W.	50 0 E.	18 0 E.	3 30 W.	36 0 E.	17 30 E.	5 45 E.	43 45 E.	28 35 E.	12 25 E.	25 45 E.	19 10 E.	18 30 E.
N. by E.	37 30	22 10	2 0 W.	43 30	12 0	6 30	35 10	15 40	5 45	44 10	29 40	14 50	28 30	17 50	17 45
N. N. E.	30 30	20 50	0 0	35 30	5 10 E.	8 30	31 50	13 10	5 3	42 50	28 40	15 50	29 10	16 0	15 55
N. E. by N.	22 30	18 40	1 30 E.	26 30	2 0 W.	10 30	26 30	10 20	3 0	39 0	26 30	14 45	28 10	13 15	13 0
N. E.	13 30	14 45	2 0	17 0	9 15	13 30	19 50	7 0	1 0 E.	33 20	22 40	12 50	25 35	9 30	9 40
N. E. by E.	4 0 E.	9 45	1 40	7 0 E.	15 50	16 0	12 0	3 0 E.	1 0 W.	25 30	17 40	10 0	21 10	5 30	5 15
E. N. E.	5 0 W.	4 30 E.	0 45 E.	3 0 W.	21 20	19 30	4 0 E.	1 5 W.	3 15	16 30	11 20	6 30	15 25	0 40 E.	0 25 E.
E. by N.	14 0	0 0	0 15 W.	12 0	26 15	22 30	4 10 W.	5 35	5 45	6 50 E.	4 30 E.	1 45 E.	8 50	5 0 W.	4 40 W.
East	24 0	6 0 W.	1 0	22 30	30 0	25 0	12 0	10 10	8 45	3 30 W.	2 50 W.	3 20 W.	1 0 E.	10 25	9 35
E. by S.	33 30	11 15	1 40	30 30	32 45	26 0	19 10	14 40	11 15	13 20	10 0	8 35	7 20 W.	15 40	14 40
E. S. E.	42 0	15 50	2 0	39 0	35 0	26 30	25 20	18 35	12 50	22 50	16 45	13 0	15 20	20 0	18 35
S. E. by E.	49 20	19 40	2 0	47 0	35 50	24 45	30 30	21 40	13 45	31 40	22 25	16 10	22 30	23 30	21 30
S. E.	54 40	22 15	2 0	53 0	35 30	20 30	34 0	23 35	18 40	38 15	26 30	17 45	29 5	25 10	22 50
S. E. by S.	58 20	24 0	1 0 W.	56 30	33 20	14 40	36 50	24 30	12 0	43 0	28 30	18 0	34 0	27 5	23 10
S. S. E.	60 30	24 20	1 0 E.	57 30	30 30	7 30 W.	38 0	24 30	10 0	45 0	23 45	17 10	37 20	27 30	22 25
S. by E.	59 0	22 30	4 30	55 0	24 40	0 0	37 40	22 0	6 20	44 50	26 50	14 40	38 30	26 40	20 0
South	54 0	19 40	9 30	49 0	16 50	8 0 E.	35 45	18 0	1 45 W.	41 20	21 50	10 15	37 35	23 50	17 15
S. by W.	45 0	13 30	13 30	38 0	8 30	17 0	31 20	12 30	3 0 E.	35 45	16 0	5 20	33 30	19 30	13 50
S. S. W.	35 30	7 0	16 30	27 30	0 50 W.	24 0	25 30	6 30	7 40	27 30	9 0	0 40 W.	27 20	13 50	9 50
S. W. by S.	25 30	3 40	17 30	17 30	6 10 E.	29 0	19 0	0 40 W.	10 40	19 50	3 0 W.	2 15 E.	19 50	7 20	5 30
S. W.	17 40	1 30	17 45	10 0	12 0	32 40	12 50	3 20 E.	11 50	13 0	1 0 E.	4 0	12 15	1 15 W.	1 30 W.
S. W. by W.	11 0	0 30 W.	16 40	2 30 W.	17 20	33 30	7 10	7 0	11 50	7 45	4 0	4 40	7 35	2 55 E.	2 30 E.
W. S. W.	6 0	0 0	14 30	4 30 E.	22 30	33 30	2 20 W.	9 50	11 20	3 20	6 20	4 5	5 10	5 30	5 30
W. by S.	1 30 W.	1 0 E.	11 30	11 30	26 0	33 20	0 45 E.	12 30	10 50	0 10 W.	8 0	3 0	3 45	7 35	7 45
West	4 0 E.	2 0	6 30	19 0	29 0	32 0	4 20	14 0	10 0	2 50 E.	9 30	1 50	2 30	9 50	9 25
W. by N.	10 40	3 10	1 0 E.	29 0	31 25	30 0	8 40	15 45	8 40	6 40	10 35	1 15	1 10 W.	11 30	10 50
W. N. W.	18 0	4 50	4 45 W.	38 30	32 0	28 0	13 30	17 0	7 0	11 15	11 45	1 10	0 45 E.	13 15	12 15
N. W. by W.	25 0	6 50	9 30	48 0	31 35	24 0	18 40	17 40	5 45	16 10	13 30	0 50	3 0	15 0	13 35
N. W.	32 30	8 45	12 0	54 30	30 35	20 0	23 50	18 25	4 40	22 50	15 40	1 15	6 0	16 45	14 50
N. W. by N.	38 30	11 10	13 0	58 0	28 50	14 45	28 0	18 40	3 35	30 45	18 25	2 25	9 40	17 20	16 20
N. N. W.	43 0	15 0	11 0	57 0	26 10	8 40	32 0	18 30	3 15	37 30	21 35	4 40	14 40	18 40	17 25
N. by W.	45 0 E.	19 45 E.	7 30 W.	55 0 E.	22 50 E.	2 0 E.	35 0 E.	18 0 E.	3 50 E.	41 20 E.	25 20 E.	8 0 E.	20 30 E.	19 15 E.	18 0 E.

Deviation Tables for four compasses, &c.—Continued.

MAGNETIC CO-EFFICIENTS.

Ship's head by each compass, (disturbed.)	I.—Compass under the companion, (approximate.)			II.—Compass over the companion, (approximate.)			III.—Admiralty standard compass.			IV.—Dipping-needle compass.			Dipping-needle compass.	Admiralty standard compass, ship up right.	
	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	July 10, ship upright.	July 10, in dock.	July 12, in the river.
	° ′	° ′	° ′	° ′	° ′	° ′	6 ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A.	− 7 9	− 0 12	+ 1 54	+ 1 4	− 0 13	+ 3 55	− 1 19	+ 1 3	+ 1 6	+ 0 57	+ 3 13	+ 0 6	− 3 1	− 0 51	+ 0 7
B.	−16 10	− 4 35	− 2 55	+23 2	−29 55	−29 13	− 8 26	−12 51	− 9 32	− 4 7	− 6 34	− 3 10	+ 1 35	−10 23	− 9 34
C.	+44 3	+18 30	− 8 3	+46 29	+16 19	− 3 44	+33 33	+16 44	+ 2 58	+39 58	+23 39	+10 28	+28 37	+20 4	+17 38
D.	+ 4 26	+ 6 47	+ 8 32	+ 1 36	+ 2 3	+ 4 54	+ 4 27	+ 4 0	+ 5 43	+ 8 46	+ 8 42	+ 8 17	+ 8 54	+ 4 17	+ 3 56
E.	+ 2 32	+ 1 46	− 0 16	+ 1 8	+ 0 43	− 0 12	+ 2 27	− 1 7	+ 0 37	+ 0 50	− 0 3	+ 0 46	− 2 45	− 1 3	+ 0 31

APPENDIX C.

Experiments to ascertain the effect of heeling on the compasses of the iron ship "Simla."

This ship was swung in the Canada Dock, Liverpool, August 24 and 26, 1858. Ship's head correct magnetic was obtained by the known bearing of a distant chimney, by the secretary, by means of a "Friend's Pelorus." Mr. Towson took sole charge of the dipping-needle compass, and conducted the vibration experiments which are recorded in the annexed tables. Some observations for dip were also made. Captain Williams superintended the swinging and heeling of the ship.

Before swinging, the "Simla" lay for some time with her head to the eastward. August 24, she was swung upright, commencing at east, and going round by way of north to E. S. E. August 26, she was heeled to starboard while she was hauling off from the quay, the swinging commencing with ship's head at north 39° west, and went on by way of west and south to north 23° west. While in this position she was trimmed over to 6° 30′ of port heel, the deviations of the different compasses being constantly noted during the whole time. The particulars are given in a tabular form at a succeeding page. The trimming over occupied so much time, and the day was so far advanced when 6° 30′ of heel to port was obtained, that it was determined to proceed with the swinging and heeling of the ship at the same time, and to make a correction for the difference between the deviation at the observed heel and the intended heel of 10°.

"SIMLA."

Swung in the Canada Dock, Liverpool, August 24, 1858.

SHIP NEARLY UPRIGHT.

Head, ship's correct magnetic.	Estimated heel to starboard.	Steering compass.		Compass over the companion.		Dipping-needle compass.			Standard compass.		Forward compass.	
		Head by compass.	Deviation.	Head by compass.	Deviation.	Head by compass.	Deviation.	Vibrations per minute.	Head by compass.	Deviation.	Head by compass.	Deviation.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′	° ′	° ′
N. 1 45 W.	0 45	N. 21 30 E.	23 15 W.	N. 11 45 E.	13 30 W.	N. 15 0 E.	16 45 W.	20.69	N. 9 0 E.	10 45 W.	N. 6 0 E.	7 45 W.
0 30 E.		21 30	21 0	11 45	11 15							
21 30	1 0	38 45	17 15	29 15	7 45	30 0	8 30	20.78	27 0	5 30	24 30 E.	3 0
21 45		38 45	17 0	29 15	7 30	30 0	8 15		27 0	5 15 W.	24 15 W.	2 30 W.
46 20	1 0	60 15	13 55	50 0	3 40							
45 50						46 30	0 40	21.05	45 35	0 15 E.	43 15 E.	2 35 E.
45 20						47 30	2 10 W.		45 15	0 5	43 15	2 5
67 10	1 15	80 0	12 50	69 10	2 0 W.							
67 25						65 0	2 25 E.	20.78	65 45	1 40	60 45	6 40
88 40	1 15	100 0	11 20	88 30	0 10 E.							
80 25						85 30	3 55	20.34	88 30	0 55	85 0	4 25
110 45	1 0	115 30	4 15	109 15	1 30	102 45	8 0	21.23	106 15	4 30	100 45	10 0
134 40	1 0	135 0	0 20 W.	130 30	4 10	123 30	11 10	20.50	127 30	7 10		
135 40		135 0	0 40 E.	130 30	5 10	123 30	12 10		127 30	8 10	124 30	11 10
158 10	0 45										149 0	9 10
158 40						141 0	17 40	20.00	149 15	9 25		
159 10		151 0	8 10	150 0	9 10							
182 5	0 45	163 0	19 5	166 30	15 35	157 0	25 5	19.35	168 30	13 35	168 0	14 5 E.
197 28	0 30	172 0	25 28	179 30	17 58	169 0	28 28	18.00	182 0	15 28	182 30	14 58
227 40	0 30	191 0	36 40	207 45	19 55	196 5	31 35	15.48	212 5	15 35	216 25	11 15
234 35	0 15	197 15	37 20	217 0	17 35	206 0	28 35	15.48	220 30	12 5	229 0	5 35 E.
235 35		197 15	38 20	217 0	18 35				220 30	13 5		
251 20	0 15	212 45	38 35	237 45	13 35	233 30	17 50	13.33	244 30	6 50	251 30	0 20 W.
258 0	0 15			249 30	8 30							
259 30		223 30	36 0						255 30	4 0 E.		
261 30						249 30	12 0 E.	12.00			266 15	4 45
270 35	0 15	241 30	29 5	268 0	2 35 E.	278 0	7 25 W.	14.40	274 0	3 25 W.	280 15	9 40
291 35	0 0	290 55	0 40 E.	301 45	10 10 W.	318 0	26 25	13.85	306 0	14 25	309 15	17 40
292 20						317 15	24 55		305 15	12 55	309 15	16 55
312 30	0 0	333 15	20 45 W.	328 15	15 45	341 0	28 30	16.88	330 0	17 30	330 0	17 30
341 30	0 0					N. 2 30 E.	21 0 W.	20.00	N. 355 0 E.	13 30 W.	N. 355 0 E.	13 30 W.
N. 344 0 E.		N. 7 30 E.	23 30 W.	N. 358 0 E.	14 0 W.							

"SIMLA"—Continued.

Swung in the Canada dock, Liverpool, August 26, 1858.

SHIP HEELING TO PORT.

Ship's head, correct magnetic.	Heel to port.	Steering compass.		Compass over the companion.		Dipping-needle compass.			Standard compass.		Forward compass.	
		Head by compass.	Deviation.	Head by compass.	Deviation.	Head by compass.	Deviation.	Vibrations per minute.	Head by compass.	Deviation.	Head by compass.	Deviation.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′	° ′	° ′
N. 358 0 E.	9 30	N. 337 30 E.	0 30 E.	N. 355 30 E.	2 30 E.							
359 45		337 30	2 15	355 30	4 15 E.	N. 9 0 E.	9 15 W.	20.00	N. 2 30 E.	2 45 W.	N. 2 30 E.	2 45 W.
19 30	9 15	14 45	4 45 E.	?20 30	1 0 W.	22 30	3 0	20.34	20 0	0 30	17 30	2 0 E.
				?15 30	6 0 E.							
41 5	9 20	42 0	0 55 W.	35 0	6 5	43 0	1 55 W.	20.69	40 0	1 5 E.	35 45	5 20
43 5		42 0	1 5 E.	35 0	8 5	43 0	0 5 E.		40 0	3 5		
70 20	9 15	81 0	9 40 W.	68 0	2 20	66 0	4 20	20.69	66 0	4 20	62 30	7 50
102 40	9 30	117 15	14 35	105 45	3 5 W.							
104 10		117 15	13 5	105 45	1 35	100 0	4 10	20.00	102 30	1 40 E.	100 30	3 40
139 40	9 30	150 0	10 20	144 0	4 20	134 0	5 40	20.00	140 0	0 20 W.	139 30	0 10
140 20		151 10	10 50	145 10	4 50	134 0	6 20		140 0	0 20 E.	139 30	0 50 E.
153 50	9 5	159 10	5 40	158 30	4 40	145 0	8 50	19.35	154 0	0 10 W.	155 30	1 40 W.
154 20		159 30	5 10 W.	158 30	4 10							
175 35	9 50	172 30	3 5 E.	175 45	0 10 W.	162 0	13 35	19.35	172 30	3 5 E.	174 30	1 5 E.
202 0	9 5	189 0	13 0	199 15	2 45 E.	183 30	18 30	19.29	199 0	3 0	200 30	1 30 E.
230 45	9 0	210 0	20 45	226 30	4 15	212 30	18 15	15.87	?222 0	?8 45	231 0	0 15 W.
									?228 0	?2 45		
251 35	8 30	228 30	23 5	247 45	3 50	244 0	7 35 E.	14.48	251 0	0 35 E.	255 0	3 25
266 0	7 45	246 0	20 0	265 30	0 30	271 0	5 0 W.	14.00	270 15	4 15 W.	277 30	11 30
267 30		246 0	21 30	265 30	2 0 E.	271 0	3 30		270 15	2 45	277 30	10 0
290 40	7 30	284 30	6 10	294 30	3 50 W.	313 0	22 20	14.48	301 30	10 40	304 15	13 35
291 10		284 30	6 40 E.	294 30	3 20							
315 5	7 15	321 30	6 25 W.	322 15	7 10	341 30	26 25	17.42	331 0	15 55	330 15	15 10
332 25	6 30	347 30	15 5	342 45	10 20							
N. 335 55 E.		N. 347 30 E.	11 35 W.	N. 342 45 E.	6 55 W.	N. 358 30 E.	22 35 W.	19.35	N. 348 0 E.	12 5 W.	N. 348 0 E.	12 5 W.

"SIMLA"—Continued.

Swung in the Canada dock, Liverpool, August 26, 1858.

SHIP HEELING TO STARBOARD.

Ship's head, correct magnetic.	Heel to port.	Steering compass.		Compass over the companion.		Dipping-needle compass.			Standard compass.		Forward compass.	
		Head by compass.	Deviation.	Head by compass.	Deviation.	Head by compass.	Deviation.	Vibrations per minute.	Head by compass.	Deviation.	Head by compass.	Deviation.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′	° ′	° ′
N. 351 50 E.	10 35	N. 35 30 E.	43 40 W.	N. 28 15 E.	36 25 W.	N. 21 0 E.	29 10 W.	20.87	N. 10 0 E.	18 10 W.	N. 11 15 E.	19 25 W.
30 50	10 5	58 0	27 10	48 0	17 10	45 0	14 10	22.56	41 0	10 10	38 0	7 10
58 12	10 15	77 0	18 48 W.	67 30	9 18	63 0	4 48 W.	22.43	61 0	2 48 W.	58 15	0 3 W.
87 25	10 15	86 30	0 55 E.	88 0	0 35 W.	82 0	5 25 E.	22.37	83 30	3 55 E.	80 30	6 55 E.
		?94 30	7 5 W.									
121 0	9 45	120 0	1 0 E.	113 45	7 15 E.	110 30	10 30	21.43	112 30	8 30	109 0	12 0
147 55	9 45	135 15	12 40	133 0	14 55	132 0	15 55	21.05	136 0	11 55	134 0	13 55
151 10	9 45	138 30	12 40	136 15	14 55	132 0	19 10		136 0	15 10	134 0	17 10
171 35	9 30	150 0	21 35	150 30	21 5	145 45	25 50	20.69	152 0	19 35	151 30	20 50
201 10	8 40	166 0	35 10	173 30	27 40	166 0	35 10	18.75	178 0	23 10	177 30	23 40
212 55	9 5	172 0	40 55	182 45	30 10	174 0	38 55	17.14	187 30	25 25	188 30	24 25
230 55	9 30					191 30	39 25	14.55	209 0	21 55	208 30	22 25
231 40		179 10	52 30	198 40	33 0				208 20	23 20	218 15	23 25
245 45	10 5	188 45	57 0	216 0	29 45	212 0	33 45	12.00	228 0	17 45	234 0	11 45 E.
245 0						212 0	33 0					
258 25	10 15	200 0	58 25	240 30	17 55	247 0	11 25 E.	10.00	254 0	4 25 E.	261 0	2 35 W.
272 30	10 15	218 0	54 30	?262 45	?9 45 E.	293 0	20 30 W.	10.75	282 30	10 0 W.	286 45	14 15
281 5	10 25	257 30	23 35 E.	293 45	12 40 W.	318 30	37 25	12.00	301 30	20 25	303 30	22 25
298 50	10 35	355 20	56 30 W.	332 50	34 0	343 0	44 10	14.76	325 0	26 10	326 45	27 55
319 45	10 38	18 0	58 15	358 15	38 30				347 15	27 30	347 30	27 45
319 45									349 0	29 15		
320 15	10 38	19 0	58 45	359 45	39 30	North	39 45	18.46	349 30	29 15	348 0	27 45
336 45	10 35	35 30	58 45	28 15	41 30							
N. 338 5 E.	10 35	N. 35 30 E.	57 25 W.	N. 28 15 E.	40 10 W.	N. 12 30 E.	34 25 W.	19.51	N. 3 30 E.	25 25 W.	N. 1 30 E.	23 25 W.

"SIMLA"—Continued.

Deviation Tables for ship upright and with a list to starboard and to port of 10°; *obtained from curves passed through the observations recorded in the preceding tables, corrections being applied for the difference between the observed angle of heel and* 10°.

Ship's head by each compass (disturbed.)	Steering compass.			Compass over the companion.			Dipping-needle compass.			Standard compass.			Forward compass.		
	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	2 45 E.	25 30 W.	53 45 W.	3 40 E.	15 20 W.	37 35 W.	13 50 W.	24 10 W.	39 10 W.	4 15 W.	13 50 W.	24 15 W.	3 5 W.	12 30 W.	23 25 W.
N. by E	4 45	24 50	54 30	5 30	12 50	36 30	7 20	18 45	34 0	0 45 W.	9 45	19 30	0 50 E.	7 45	18 25
N. N. E	4 15	21 45	52 40	6 30	9 45	33 30	2 55 W.	12 10	26 0	1 10 E.	6 30	15 15	3 30	3 45	13 15
N. E. by N	2 30 E.	18 45	44 0	6 30	6 30	26 40	0 0	6 15	18 50	2 45	3 20	11 15	5 0	0 15 W.	8 0
N. E	0 10 W.	16 20	33 30	5 55	4 35	18 25	1 40 E.	2 0 W.	12 45	3 30	0 35 W.	7 25	6 30	2 10 E.	4 0
N. E. by E	3 25	14 40	27 0	4 40	3 0	12 50	3 0	0 45 E.	7 10	4 15	1 0 E.	4 0	6 55	3 40	0 15 W.
E. N. E	6 40	13 25	22 20	2 50	1 50	8 35	3 45	2 45	2 50 W.	4 30	2 5	0 50 W.	6 50	4 50	2 40 E.
E. by N	9 40	12 30	17 45	0 55 E.	1 0	5 30	4 15	4 10	0 40 E.	3 50	2 50	1 30 E.	6 30	5 25	5 25
East	12 0	11 55	13 0	0 40 W.	0 5 W.	1 40 W.	4 0	5 15	4 0	3 0	3 25	3 50	5 15	6 25	7 40
E. by S	13 45	9 50	7 40	2 30	0 35 E.	2 5 E.	3 55	6 50	7 25	2 0	3 50	6 15	3 50	6 50	9 50
E. S. E	14 45	7 27	2 0 W.	3 55	1 30	6 30	4 0	8 50	11 0	0 50 E.	4 50	8 45	2 0	7 15	12 45
S. E. by E	15 10	4 30	4 15 E.	5 0	3 0	10 50	4 30	11 10	15 45	0 10 W.	5 50	11 30	0 30 E.	8 0	15 0
S. E	14 25	0 30 W.	12 55	5 40	4 50	15 20	5 45	14 15	21 15	0 45	7 30	15 0	0 30 W.	9 10	17 40
S. E. by S	12 0	5 10 E.	23 10	5 45	7 45	20 40	7 55	18 40	26 50	0 40	9 40	18 45	1 10	10 50	20 10
S. S. E	7 30	13 55	35 30	4 45	11 50	25 50	11 30	23 45	32 40	0 15 W.	11 50	22 15	1 30	12 40	22 45
S. by E	1 0 W.	24 20	45 50	3 0	15 50	29 30	14 30	27 45	37 30	0 40 E.	14 25	25 0	1 15	14 0	24 30
South	6 0 E.	32 30	53 50	1 0 W.	18 30	32 30	16 50	29 50	40 0	1 35	15 45	26 30	0 5 W.	15 0	26 0
S. by W	12 10	37 15	57 25	0 50 E.	20 0	33 40	17 40	29 50	39 50	2 0	16 10	26 20	0 35 E.	14 50	24 45
S. S. W	16 0	39 0	57 30	2 15	20 30	33 10	17 45	28 30	37 45	2 30	15 50	24 50	0 35 E.	13 45	23 45
S. W. by S	18 40	38 15	54 50	3 0	19 20	30 50	16 30	25 45	33 25	2 5	14 45	22 0	0 0	11 40	20 20
S. W	20 15	35 50	49 15	3 15	17 25	26 45	13 55	21 45	27 20	1 50	12 45	18 0	0 45 W.	8 40	15 40
S. W. by W	20 0	31 30	41 40	3 0	14 15	20 50	10 30	16 35	20 10	0 50 E.	9 50	13 30	1 50	5 10	10 20
W. S. W	18 55	25 50	32 30	2 30	10 20	14 25	6 0	10 35	14 10	0 5 W.	6 15	8 0	3 10	1 25 E.	4 20 E.
W. by S	17 0	19 50	22 45	1 20	6 10	7 55	1 10 E.	3 50 E.	8 45 E.	1 15	1 55 E.	2 5 E.	5 0	2 50 W.	1 30 W.
West	14 0	13 35	13 10	0 20 E.	1 30 E.	0 50 E.	3 30 W.	3 0 W.	4 45 W.	3 0	1 45 W.	4 0 W.	6 45	6 45	7 20
W. by N	10 45 E.	6 50 E.	2 50 E.	0 40 W.	2 10 W.	6 15 W.	8 15 W.	9 35 W.	13 20 W.	5 10 W.	6 5 W.	10 5 W.	8 40 W.	10 35 W.	12 45 W.

"SIMLA"—Continued.

Deviation Tables for ship upright, &c.—Continued.

Ship's head by each compass (disturbed.)	Steering compass.			Compass over the companion.			Dipping-needle compass.			Standard compass.			Forward compass.		
	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.	Deviation, ship heeling 10° to port.	Deviation, ship upright.	Deviation, ship heeling 10° to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
W. N. W.	7 0 E.	0 5 E.	7 25 W.	1 35 W.	6 40 W.	13 20 W.	13 10 W.	15 55 W.	21 40 W.	7 35 W.	10 15 W.	16 0 W.	10 20 W.	14 0 W.	17 40 W.
N. W. by W.	3 30	6 40 W.	17 35	2 10	10 40	20 0	17 10	21 20	29 10	8 15	13 45	21 5	11 15	16 50	22 25
N. W.	0 5 E.	13 0	27 20	2 40	13 45	26 0	20 40	25 35	35 35	10 25	16 30	25 0	11 50	18 0	25 35
N. W. by N.	2 30 W.	18 10	36 30	2 20	15 45	30 50	22 25	28 5	40 0	10 30	17 40	27 20	11 30	18 30	27 30
N. N. W.	3 0	22 5	44 20	1 0 W.	16 45	34 40	21 45	28 35	42 45	9 35	17 20	27 45	10 0	17 40	27 40
N. by W.	1 15 W.	24 30 W.	50 10 W.	1 0 E.	16 30 W.	36 45 W.	19 15 W.	27 30 W.	42 35 W.	7 15 W.	16 10 W.	26 15 W.	7 5 W.	16 0 W.	26 40 W.

MAGNETIC CO-EFFICIENTS.

	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A	+ 1 55	+ 1 48	− 0 7	+ 0 21	+ 1 8	− 1 10	+ 0 31	+ 2 7	+ 0 5	− 1 3	+ 0 51	+ 0 25	− 1 27	+ 0 31	+ 0 51
B	−12 38	−12 57	−14 40	− 0 21	− 1 10	− 1 23	+ 4 31	+ 5 0	+ 5 39	+ 3 32	+ 3 11	+ 4 19	+ 6 19	+ 6 57	+ 7 56
C	− 2 0	−26 29	−49 19	+ 2 7	−15 28	−33 6	−14 17	−24 40	−37 17	− 2 43	−13 54	−23 29	− 1 33	−12 50	−23 17
D	+ 8 41	+ 8 7	+ 6 47	+ 4 26	+ 5 19	+ 4 14	+ 7 51	+ 7 35	+ 7 24	+ 4 5	+ 5 8	+ 5 10	+ 4 38	+ 4 51	+ 4 56
E	+ 0 55	+ 1 6	− 0 29	+ 0 39	+ 0 26	− 1 12	+ 0 36	+ 0 52	+ 0 20	− 0 55	+ 0 11	+ 0 46	− 0 23	+ 0 52	+ 0 32

As the "Simla" was being trimmed from heel to starboard to heel to port, the deviations of the different compasses were frequently observed, so as to ascertain, by comparison with the observations made while the ship was being swung, whether the induced magnetism changed immediately, or took some time for its complete development. The following tables give the record of these observations, and show the difference of deviation due to each degree of heel as obtained by passing a fair curve as nearly as possible through the projection of each observation.

"SIMLA"—Continued.

Deviation Tables, &c.—Continued.

Ship's head, correct magnetic.	Heel.	Steering compass.		Compass over the companion.		Dipping-needle compass.		Standard compass.		Forward compass.	
		Head by compass.	Deviation.	Head by compass.	Deviation.	Head by compass.	Deviation.	Head by compass.	Deviation.	Head by compass.	Deviation.
	Starboard.										
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
N. 21 45 W.	10 38	N. 27 30 E.	49 15 W.	N. 12 45 E.	34 30 W.	N. 12 30 E.	34 15 W.	N. 3 30 E.	25 15 W.	N. 1 30 E.	23 15 W.
22 30			50 0		35 15						
23 30								2 30	26 0	North	23 30
22 35	9 22	27 30	50 5	10 45	33 20	12 30	35 5	3 0	25 35	N. 0 30	23 5
		27 0	49 35	10 30	33 5						
22 35	9 0	27 0	49 35	10 15	32 50			3 30	26 5	0 15 E.	22 50
22 35	8 0	25 45	48 20	9 0	31 35	11 30	34 5	2 0	24 35	0 15 W.	22 20
22 35	7 0	23 0	45 35	7 45	30 20	11 0	33 35	1 55	24 30	0 45	21 50
21 50	6 0	21 30	43 20	5 45	27 35	10 30	32 20	0 15 E.	22 5	1 30	20 20
22 5			43 35		27 50		32 35		22 20		20 35
22 35	5 0	20 0	42 35	4 30	27 5	9 15	31 50	0 10 W.	22 25	2 15	20 20
22 20	4 0	18 0	40 20	3 10 E.	25 30	8 45	31 5	1 20	20 0	2 45	19 35
22 5	3 0	16 0	38 5	North	22 5	8 15	30 20	1 40	20 25	3 0	19 5
28 30	1 0	6 30	35 0	N. 8 0 W.	20 30	2 0	30 30	9 20	19 10	10 0	18 30
23 25	0 0	7 0	30 25	6 45	16 40	5 30	28 55	5 0	18 25	6 0	17 25
	Port.										
22 55	0 30	6 30	29 25	6 15	16 40	5 0	27 55	5 0	17 55	6 0	17 0
23 25	1 30	4 0	27 25	7 20	16 5	3 30	26 55	6 40	16 45	7 30	15 35
23 25	2 30	1 0	24 25	9 0	14 25	3 0	26 25	8 0	15 25	8 0	15 25
23 40	3 45	2 45	20 55	11 45	11 55	1 30	25 10	9 0	14 40	9 30	14 10
23 40	5 0	6 30	17 10	15 45	7 55	0 30 E.	24 10	9 30	14 10	10 30	13 10
N. 24 0 W.	6 30	N. 12 30 W.	11 30 W.	N. 17 15 W.	6 45 W.	N. 1 30 W.	22 30 W.	N. 12 0 W.	12 0 W.	N. 12 0 W.	12 0 W.

"SIMLA"—Continued.

Deviation Tables, &c.—Continued.

Ship's head, correct magnetic.	Heel.	Steering compass.		Compass over the companion.		Dipping-needle compass.		Standard compass.		Forward compass.	
		Deviation.	Deviation from heeling.	Deviation.	Deviation from heeling.	Deviation.	Deviation from heeling.	Deviation.	Deviation from heeling.	Deviation.	Deviation from heeling.
° ′	*Starboard.* ° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
N. 23 0 W.	12 0	53 5 W.	21 55 W.	35 40 W.	17 0 W.	35 30 W.	7 40 W.	27 40 W.	9 25 W.	24 2 W.	6 42 W.
	11 0	51 58	20 48	34 45	16 5	35 0	7 10	27 5	8 50	23 38	6 18
	10 0	50 45	-19 35	33 40	15 0	34 25	6 35	26 25	8 10	23 15	5 55
	9 0	49 15	18 5	32 35	13 55	33 50	6 0	25 45	7 30	22 45	5 25
	8 0	47 45	16 35	31 25	12 45	33 15	5 25	24 55	6 40	22 18	4 58
	7 0	46 0	14 50	29 55	11 15	32 35	4 45	24 5	5 50	21 42	4 22
	6 0	44 10	13 0	28 35	9 55	32 0	4 10	23 20	5 5	21 10	3 50
	5 0	42 10	11 0	27 5	8 25	31 20	3 30	22 27	4 12	20 35	3 15
	4 0	40 10	9 0	25 30	6 50	30 45	2 55	21 45	3 30	20 0	2 40
	3 0	38 10	7 0	23 45	5 5	30 0	2 10	20 55	2 40	19 20	2 0
	2 0	35 55	4 45	22 10	3 30	29 10	1 20	20 0	1 45	18 42	1 22
	1 0	33 45	2 35 W.	20 25	1 45 W.	28 35	0 45 W.	19 5	0 50 W.	18 2	0 42 W.
	0 0	31 10	0 0	18 40	0 0	27 50	0 0	18 15	0 0	17 20	0 0
	Port. 1 0	28 35	2 35 E.	16 58	1 42 E.	27 0	0 50 E.	17 25	0 50 E.	16 38	0 42 E.
	2 0	25 35	5 35	15 5	3 35	26 5	1 45	16 30	1 45	15 50	1 30
	3 0	22 55	8 15	13 20	5 20	25 10	2 40	15 30	2 45	15 5	2 15
	4 0	20 0	11 10	11 35	7 5	24 15	3 35	14 30	3 45	14 20	3 0
	5 0	16 45	14 25	9 35	9 5	23 25	4 25	13 33	4 42	13 30	3 50
	6 0	13 40	17 30	7 40	11 0	22 25	5 25	12 33	5 42	12 35	4 45
	7 0	10 0	21 0	5 35	13 5	21 25	6 25	11 25	6 50	11 40	5 40
	8 0	6 20	24 50	3 25	15 15	20 5	7 45	10 10	8 5	10 35	6 45
	9 0	2 45 W.	28 25	1 5 W.	17 35	19 0	8 50	9 5	9 10	9 30	7 50
	10 0	1 0 E.	32 10 E.	1 10 E.	19 50 E.	17 40 W.	10 10 E.	7 50 W.	10 25 E.	8 30 W.	8 50 E.
Deviation due to ship heeling from 10° to port to 10° to starboard.		....	51 45 E.	....	34 50 E.	....	16 45 E.	....	18 35 E.	....	14 45 E.
Mean difference for each degree of heel of the ship.		....	2 35 E.	....	1 45 E.	....	0 50 E.	....	0 56 E.	....	0 44 E.

On the 24th August, when the ship was swung on an even beam, the deviations for these compasses, with ship's head in the same direction, were respectively 24° 40′ W., 18° 40′ W., 27° 50′ W., 18° 15′ W., and 17° 20′ W., thus showing that when the ship was trimmed upright on the 26th August after being heeled 10° to starboard she retained enough of the induced magnetism due to heeling to produce the following deviations: 6° 30′, 2° 50′, 2° 30′, 2° 55′, and 2° 40′.

APPENDIX D.

Experiments to ascertain the effect of heeling upon the compasses of the iron ship "Slieve Donard."

This vessel, before swinging, had been lying for some time with her head to the west. The operation of swinging extended over several days; and as the bit-by-bit manner in which it was effected may have influenced the results, the observations for the dipping-needle compass, which, as on former occasions, was in charge of Mr. Towson, are given in the order in which they were made. The other compasses were observed at the same time.

Date.	Ship's head correct magnet.	Head by compass.	Deviation.	Heel—P, port & S, starboard.	Date.	Ship's head correct magnetic.	Head by compass.	Deviation.	Heel—P, port & S, starboard.
1859.	° ′	° ′	° ′	° ′	1859.	° ′	° ′	° ′	° ′
Feb. 21	W. 2 30 S.	N. 71 30 W.	21 0 W.	0 30 P.	Feb. 25	N. 24 0 W.	N. 24 0 W.	0 0	1 23 S.
21	S. 84 0 W.	N. 73 30	22 30	0 0	25	4 45 W.	13 30	8 45 E.	1 15 S.
21	23 0	S. 45 0	22 0	....	25	7 0 E.	6 45	13 45	....
21	2 0	23 0	21 0	....	25	19 30	0 25 W.	19 55	....
21	43 30	S. 67 30	24 0	....	25	50 30	18 0 E.	32 30	....
22	S. 88 30	N. 68 30	23 0	10 7 P.	25	68 30	32 30	36 0	1 0 S.
22	N. 64 30	49 0	15 30	11 15 P.	25	N. 89 0	51 45	37 15	0 30 S.
22	53 0	42 0	11 0	10 30 P.	25	S. 69 30	N. 81 0	28 30	....
22	39 0	32 45	6 15 W.	10 0 P.	25	49 45	S. 57 30	7 45 E.	0 0
22	26 20	26 40	0 20 E.	....	25	22 0	1 30	20 30 W.	....
22	26 50	26 55	0 5 E.	....	25	16 30	6 30 E.	10 0	1 0 S.
22	19 15	21 40	2 15	....	25	10 30	6 0 W.	16 30	10 0
22	4 45	14 0	9 15	....	25	18 0	4 0 E.	14 0 W.	....
23	12 30	16 30	4 0	10 0 P.	25	45 0	45 0	0 0	....
23	0 30 W.	11 0 W.	10 30	....	25	62 30	82 0	19 30 E.	10 30 S.
23	22 30 E.	1 15 E.	21 15	....	25	65 30	East..........	24 30	....
23	45 0	14 0	31 0	....	25	S. 86 15	N. 60 30 E.	33 15	11 0 S.
23	64 0	24 0	40 0	....	25	N. 89 0	51 30	37 30	....
23	S. 87 0	54 0	39 0	....	25	65 0	30 0	35 0	....
23	....	55 0	38 0	....	25	44 0	14 30	29 30	....
23	55 15	S. 64 30	9 15 E.	....	25	35 0	9 0	24 0	....
23	40 0	33 15	6 45 W.	10 30 P.	25	21 0	1 30 E.	19 30	....
23	22 30	2 30 E.	20 0	11 0 P.	25	5 0 E.	8 30 W.	13 30 E.	11 15 S.
23	8 45 E.	17 30 W.	26 15	....	25	27 30 W.	21 30	6 0 W.	11 0 S.
23	10 30 W.	37 30	27 0	....	25	49 0	44 0	9 0	....
23	23 30	52 30	29 0	11 15 P.	25	62 0	48 30	13 30	....
23	32 0	58 0	26 0	....	25	N. 82 30	N. 65 15	17 15	....
23	42 30	70 30	28 0	....	25	S. 66 30	S. 88 30	22 0	10 45 S.
23	S. 48 0	S. 75 0	27 0	11 30 P.	25	55 0	S. 78 0	23 0	....
23	N. 80 30	N. 67 30	21 0	1 0 S.	25	74 30	N. 84 0	21 30	....
25	70 30	54 15	16 15	....	25	S. 88 45 W.	N. 70 0 W.	21 15 W.	9 30 S.
25	N. 41 0 W.	N. 34 30 W.	6 30 W.	1 30 S.					

"SLIEVE DONARD"—Continued.

Deviation Tables for ship upright, and with a list to starboard and to port of 11° obtained from curves passed through the projection of observations made in the Queen's Basin, Liverpool, August 21 to 25, 1859.

Ship's head by compass, (disturbed.)	Steering compass, (compensated.)			Upper steering compass, (compensated.)			Skylight compass, (compensated.)			Mast compass.		
	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	8 0 E.	2 40 E.	0 25 W.	8 0 W.	7 20 W.	6 0 W.	3 25 W.	0 25 E.	2 45 E.	5 15 E.	2 50 E.	1 45 W.
N. by E	8 0	2 10	1 0	8 30	7 20	5 50	3 20	0 40 W.	2 0	7 30	5 0	0 40 E.
N. N. E.	7 45	1 30	1 30	8 30	7 20	5 35	3 0	1 15	1 35	9 30	7 20	3 0
N. E. by N.	7 15	1 10	1 45	8 45	6 50	5 30	2 45	2 0	1 0	11 15	9 30	5 45
N. E.	6 20	0 45	1 30	8 45	6 30	4 45	2 0	2 10	0 35	12 15	11 0	8 0
N. E. by E.	5 40	0 30	0 50 W.	8 30	5 50	4 0	1 15 W.	2 40	0 40	12 45	12 45	9 15
E. N. E.	4 45	0 30	0 0	8 0	5 0	3 0	0 0	2 10	0 45	12 10	13 30	9 45
E. by N.	3 45	0 40	0 40 E.	7 0	3 45	1 50	1 10 E.	1 50	1 30	11 45	13 40	9 45
East	2 20	0 40	0 45	5 20	2 30	0 40 W.	2 0	0 45 W.	2 0	10 50	13 20	8 45
E. by S.	0 40 E.	0 45	0 45	0 30 W.	1 15 W.	0 20 E.	3 15	0 20 E.	1 30	9 40	12 40	7 20
E. S. E.	1 15 W.	0 30	0 30 E.	3 0 E.	0 0	1 20	4 30	1 40	1 10	8 0	11 0	5 30
S. E. by E.	2 30	0 20 E.	0 0	5 20	0 50 E.	1 50	5 30	2 15	0 30 E.	6 10	9 0	3 40
S. E.	2 45	0 0	0 45 W.	6 30	1 0	1 55	5 50	2 0	0 0	4 30	7 0	1 45 E.
S. E. by S.	3 20	0 20 W.	1 15	6 40	0 50	1 40	5 40	1 45	0 45 W.	2 40	4 40	0 10 W.
S. S. E.	3 0	1 0	2 35	6 40	0 30	1 0	5 0	0 45 E.	1 45	0 40 E.	1 50 E.	2 0
S. by E.	2 30	1 50	3 45	5 50	0 30	0 20 E.	4 30	0 20 W.	3 20	1 5 W.	0 50 W.	3 45
South	1 40	2 5	4 45	5 0	1 0	0 35 W.	3 30	1 0	5 30	2 40	3 30	5 40
S. by W	1 15	2 40	5 30	4 0	1 30	1 0	2 40	1 40	5 40	6 30	6 30	7 30
S. S. W.	1 0	2 55	5 55	2 40	2 0	1 10	1 25	2 15	5 50	5 40	8 30	9 10
S. W. by S.	1 20	3 30	6 0	1 30	2 30	1 0	0 20 E.	2 30	6 0	7 20	11 0	11 0
S. W.	1 30	3 30	5 35	0 45 E.	2 0	0 30 W.	0 20 W.	2 20	5 40	8 0	12 10	12 0
S. W. by W.	1 30	3 30	4 50	0 30 W.	2 0	0 0	0 45	2 0	5 0	9 15	13 0	12 30
W. S. W.	1 20	2 50	3 15	2 20	1 15	0 20 E.	1 0	1 35	3 50	10 0	13 20	13 0
W. by S.	1 10	2 15	2 5	4 0	0 30 E.	0 0	1 0	0 30 W.	2 10	11 0	12 50	13 30
West	0 45	1 30	2 5	5 10	0 0	0 15 W.	1 0	1 0 E.	0 15	11 15	11 45	13 50
W. by N	0 15 W.	0 40 W.	1 20	5 30	1 0 W.	1 0	1 0	2 10	2 10	11 0	10 0	13 30
W. N. W.	0 20 E.	0 20 E.	0 50	5 30	1 50	1 30	1 15	3 0	3 45	10 30	8 15	13 15
N. W. by W.	1 0	0 30	0 50	5 30	3 20	2 0	1 40	3 40	4 40	8 50	6 30	12 40
N. W.	1 30	2 0	0 40	5 45	4 30	2 55	1 55	3 40	5 0	7 0	4 45	11 0
N. W. by N.	3 10	2 45	0 30	6 15	5 45	3 50	2 30	3 15	5 10	4 30	2 40	9 0
N. N. W.	5 45	3 3	0 10	6 45	6 30	4 40	2 50	2 10	4 40	1 15 W.	0 45 W.	6 0
N. by W.	6 15 E.	3 3 E.	0 15 W.	7 15 W.	7 0 W.	5 30 W.	3 20 W.	1 30 E.	3 40 E.	2 10 E.	1 0 E.	3 40 W.

"SLIEVE DONARD"—Continued.

Deviation tables for ship upright, &c.—Continued.

MAGNETIC CO-EFFICIENTS OBTAINED FROM THE DEVIATIONS ON THE SIXTEEN PRINCIPAL POINTS.

Ship's head by compass, (disturbed.)	Steering compass, (compensated.)			Upper steering compass, (compensated.)			Skylight compass, (compensated.)			Mast compass.		
	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A	+ 1 28	− 0 6	− 1 50	− 2 28	− 2 7	− 1 42	+ 0 21	+ 0 5	− 0 1	+ 0 26	+ 0 17	− 3 10
B	+ 1 13	+ 0 52	+ 1 23	+ 0 38	− 1 12	+ 0 1	+ 1 52	− 0 36	+ 0 37	+11 5	+12 23	+11 17
C	+ 4 40	+ 2 14	+ 1 49	− 7 5	− 4 33	− 2 57	− 3 21	+ 0 40	+ 3 59	+ 3 27	+ 3 45	+ 2 12
D	+ 1 28	− 1 8	− 1 26	− 1 9	− 0 14	− 1 2	− 1 30	− 2 33	− 2 37	+ 1 40	− 0 48	+ 1 13
E	+ 0 48	+ 0 23	− 1 2	+ 1 34	− 1 0	− 1 24	− 0 16	− 0 13	− 0 55	+ 0 38	− 0 36	− 0 34

"SLIEVE DONARD"—Continued.

Deviation Tables for ship upright, &c.—Continued.

Ship's head by compass. (disturbed.)	Compass placed on port side of the skylight.			Compass placed on starboard side of skylight.			Compass placed over the after hatch.	Dipping-needle compass.		
	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.	Ship upright.	11° heel to port.	Ship upright.	11° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	11 30 E.	10 30 E.	6 15 E.	26 0 E.	20 0 E.	22 30 E.	13 0 E.	21 30 E.	20 0 E.	18 50 E.
N. by E.	18 15	17 45	13 0	31 30	25 40	28 15	19 30	31 15	28 30	26 40
N.N.E.	23 40	23 10	18 30	35 0	29 50	32 15	24 30	37 50	34 50	32 30
N.E. by N.	27 20	26 30	23 0	36 40	32 50	34 0	28 0	40 45	37 30	35 30
N.E.	29 50	27 50	26 0	36 0	34 0	33 45	29 45	40 50	37 0	36 15
N.E. by E.	30 30	28 10	26 45	34 0	33 50	32 0	30 0	39 15	36 45	35 20
E.N.E.	29 40	27 20	26 30	30 40	32 15	28 50	28 0	36 0	34 10	32 50
E. by N.	27 40	25 30	24 30	26 30	29 0	25 0	25 50	31 45	30 10	29 0
East	25 0	23 0	21 40	21 45	24 30	20 30	22 45	25 45	25 0	24 0
E. by S.	21 30	20 0	18 20	16 40	18 50	15 45	18 30	18 50	19 10	18 30
E.S.E.	17 45	16 45	15 0	11 15	13 0	10 50	13 40	11 40	15 20	12 20
S.E. by E.	14 0	13 0	11 15	5 45	7 30	5 50	8 30	4 50 E.	7 0	6 0 E.
S.E.	10 0	9 10	7 40	0 45 E.	1 30 E.	1 15 E.	3 0 E.	1 50 W.	0 40 E.	0 0
S.E. by S.	6 30	5 30	4 20	4 30 W.	4 0 W.	3 45 W.	2 0 W.	8 0	5 30 W.	5 0 W.
S.S.E.	3 0 E.	2 0 E.	1 15 E.	9 15	9 0	8 40	7 15	13 20	10 35	9 20
S. by E.	0 0	1 10 W.	1 30 W.	13 30	13 0	13 0	12 40	17 45	15 0	12 50
South	3 0 W.	4 20	4 30	17 15	16 0	16 50	17 45	21 40	17 50	15 0
S. by W.	6 0	7 20	7 20	19 30	18 0	19 30	21 30	24 30	20 0	16 30
S.S.W.	8 45	10 20	10 10	20 50	19 45	20 50	25 0	26 25	21 15	17 0
S.W. by S.	11 50	13 0	12 45	22 0	20 45	22 0	27 30	27 10	22 0	17 50
S.W.	14 30	15 20	15 15	22 45	21 40	22 45	29 0	27 25	22 30	19 20
S.W. by W.	16 50	17 30	16 50	23 0	21 40	23 0	28 30	28 10	23 30	20 50
W.S.W.	18 30	19 10	18 15	22 45	21 20	22 20	27 0	28 25	24 25	22 10
W. by S.	20 0	20 30	19 30	22 0	20 15	21 30	24 30	27 50	24 45	22 45
West	21 0	21 0	20 0	20 50	18 40	19 50	21 30	26 50	24 30	22 30
W. by N.	21 45	20 45	20 30	19 0	16 20	18 0	17 0	25 10	23 20	21 50
W.N.W.	21 45	19 15	20 30	16 15	13 20	15 20	12 20	22 35	21 0	19 30
N.W. by W.	20 0	17 0	19 0	11 30	9 40	11 30	7 45	19 10	18 0	16 45
N.W.	16 45	13 50	16 0	6 0 W.	5 0 W.	7 15	3 45 W.	13 40	13 0	12 0
N.W. by N.	11 10	9 20	11 45	0 45 E.	0 20 E.	1 0 W.	0 20 E.	6 45 W.	6 15 W.	5 30 W.
N.N.W.	3 45 W.	3 30	5 15 W.	8 45	6 0	6 15 E.	4 0	1 45 E.	1 45 E.	1 45 E.
N. by W.	4 30 E.	2 40 E.	0 30 E.	16 45 E.	12 30 E.	14 0 E.	8 15 E.	11 0 E.	10 0 E.	9 20 E.

"SLIEVE DONARD"—Continued.

Deviation Tables for ship upright, &c.—Continued.

MAGNETIC CO-EFFICIENTS OBTAINED FROM THE DEVIATIONS ON THE SIXTEEN PRINCIPAL POINTS.

Ship's head by compass, (disturbed.)	Compass placed on port side of the skylight.			Compass placed on starboard side of the skylight.			Compass placed over the after hatch.	Dipping-needle compass.		
	11° heel to port.	Ship upright.	11° heel to starboard.	11° heel to port.	Ship upright.	11° heel to starboard.	Ship upright.	11° heel to port.	Ship upright.	11° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A	+ 2 39	+ 2 4	+ 0 49	+ 0 29	+ 2 17	+ 1 24	− 0 18	− 0 26	+ 0 52	+ 1 22
B	+24 9	+22 39	+21 49	+22 1	+21 34	+21 19	+22 16	+26 59	+25 26	+23 26
C	+ 6 46	+ 7 17	+ 5 51	+19 32	+17 25	+18 1	+17 9	+20 39	+17 31	+16 0
D	+ 5 31	+ 4 22	+ 4 40	+ 4 46	+ 4 9	+ 4 10	+ 0 24	+ 7 17	+ 6 43	+ 7 14
E	+ 1 11	+ 1 2	+ 0 8	− 1 56	− 0 33	+ 1 4	− 1 18	+ 0 24	+ 0 16	+ 0 40

APPENDIX E.

Experiments to ascertain the effect of heeling on the compasses of the iron sailing ship "Beann Uamha."

This ship is of 1,166 tons register, and was built with her head about E. by S. Length of keel 200 feet, length over all 222 feet, beam 35 feet, depth of hold 23 feet. She was swung in the Brunswick dock, April 20 to 22. The arrangement of her steering compasses resembles that of the "Slieve Donard." The standard compass was placed near the break of the poop, between the mizzen and main masts, and a little to the starboard side of the middle line of the poop deck, so as not to be in the way of the poop ladder, which was exactly amidship. The spare compass was fixed for experiment a few feet further aft than the standard compass, and over the middle line of the poop deck. This ship was swung with a list to port first, and was trimmed to a starboard heel of 9° 30′, while her head was S. 3° W. At each swinging she was turned from N. by way of E. to S., &c., or from left to right.

"BEANN UAMHA."

Deviation Tables for ship upright and with a list to starboard and to port of 10°, *obtained from curves passed through the projection of observation made in the Brunswick docks, Liverpool, April* 20 *to* 22, 1861.

Ship's head by compass, (disturbed.)	Steering compass, (compensated.			Upper steering compass, (compensated.)			Standard compass, (compensated.)*			Spare compass.		
	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	• Ship upright.	10° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	19 0 E.	1 45 E.	10 10 W.	12 15 E.	1 0 E.	7 0 W.	12 30 E.	1 15 E.	9 0 W.	25 0 E.	10 45 E.	2 55 W.
N. by E.	17 25	1 0	11 0	11 30	0 15	7 45	14 40	3 0	6 30	26 40	13 30	0 0
N.N.E.	15 40	0 30	10 50	10 25	0 25 E.	8 0	15 0	3 10	4 15	27 10	14 40	1 35 E.
N.E. by N.	13 20	0 25	10 0	8 25	1 15 W.	7 40	14 30	4 30	2 40	26 10	14 35	4 30
N.E.	11 20	0 30	8 15	6 25	2 0	7 0	12 45	4 20	1 50	23 10	13 20	5 40
N.E. by E.	9 20	1 0	5 35	4 45	2 40	6 0	10 0	3 45	1 20	19 40	11 35	6 0
E.N.E.	7 10	1 15	2 35 W.	3 15	2 40	4 30	6 50	2 15	1 20	15 20	9 10	5 50
E. by N.	5 0	1 50	0 10 E.	1 55	2 5	2 15 W.	3 35 E.	0 35 E.	1 30	10 30	6 15	5 10

East	2 40	2 15	2 15	0 45	0 50 W.	0 20 E.	0 0	1 15 W.	2 0	5 30	3 0 E.	4 0
E. by S.	0 50 E.	2 35	4 15	0 5 E.	0 30 E.	3 0	4 0	3 25	2 40	0 15 E.	0 30 W.	2 20
E.S.E.	0 50 W.	2 50	5 40	0 0	1 40	4 25	7 20	5 15	3 0	5 30 W.	4 0	0 45 E.
S.E. by E.	2 10	2 55	7 0	0 0	2 5	5 5	9 45	6 20	3 0	9 35	7 0	1 0 W.
S.E.	2 55	3 0	7 55	0 20 W.	1 50	4 50	10 45	6 40	2 35	13 0	9 30	2 10
S.E. by S.	3 5	2 45	8 20	1 5	1 0	4 15	10 30	6 15	1 40	15 25	11 0	2 55
S.S.E.	3 30	2 20	8 40	2 10	0 5	3 25	9 30	5 0	0 10	17 0	11 30	3 15
S. by E.	3 40	1 50	8 45	3 30	0 50	2 20	8 15	3 25	1 40 E.	17 15	11 30	3 10
South	4 20	1 10	8 35	4 40	1 55	1 15 E.	6 40	1 40	3 25	16 45	10 30	2 25
S. by W.	5 20	0 25	8 0	5 40	3 0	0 0	4 35	0 5 W.	4 55	15 15	8 40	1 0 W.
S.S.W.	6 0	0 15 W.	7 30	6 40	4 15	1 20	2 45	1 0 E.	5 40	13 0	6 15	0 30 E.
S.W. by S.	6 20	1 0	6 35	7 15	5 0	2 40	1 40	1 40	5 40	10 15	4 0	1 45
S.W.	6 15	1 20	5 35	7 40	5 40	3 45	1 0	1 45	5 0	8 0	2 45	2 10
S.W. by W.	5 55	1 40	4 15	7 15	5 45	4 25	0 45	1 15	3 30	6 0	2 20	2 0
W.S.W.	4 50	1 45	3 0	6 0	5 10	4 30	1 0	0 15 E.	1 30 E.	4 45	2 25	1 0
W. by S.	3 0	1 35	* 1 0 E.	3 55	3 45	3 50	1 30	1 0 W.	1 0 W.	3 30	2 50	0 40 W.
West	0 45 W.	1 10	0 45 W.	0 40 W.	1 25 W.	2 40	1 25	2 0	3 15	2 5	3 10	3 0
W. by N.	1 20 E.	0 40 W.	2 40	4 0 E.	1 10 E.	1 35	1 0	2 45	5 20	0 35 W.	3 15	5 0
W.N.W.	4 35	0 0	4 30	7 35	3 10	1 15	0 10 W.	3 30	7 35	1 35 E.	3 0	6 45
N.W. by W.	8 10	0 45 E.	5 45	10 0	4 5	1 30	0 45	4 0	9 0	4 15	2 15	7 40
N.W.	12 45	1 45	7 0	11 25	4 15	2 0	2 15	4 0	10 0	8 0	0 55 W.	8 0
N.W. by N.	16 0	2 40	7 50	12 15	3 45	3 0	4 15	3 35	10 45	12 40	1 0 E.	7 30
N.N.W.	18 30	3 0	8 25	12 45	2 55	4 10	7 0	2 40	10 40	17 10	3 30	6 30
N. by W.	19 30 E.	2 50 E.	9 10 W.	12 45 E.	1 50 E.	5 45 W.	10 0 E.	1 0 W.	9 50 W.	21 30 E.	6 40 E.	4 45 W.

MAGNETIC CO-EFFICIENTS OBTAINED FROM THE DEVIATIONS BELONGING TO THE SIXTEEN PRINCIPAL POINTS.

	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A	+ 3 51	+ 1 0	− 0 21	+ 2 18	− 0 36	− 2 0	+ 1 3	− 1 2	− 2 31	+ 2 34	+ 0 2	− 0 51
B	+ 1 21	+ 1 23	+ 0 57	+ 1 23	+ 0 19	+ 1 23	+ 0 23	+ 0 18	+ 0 42	+ 3 51	+ 3 59	+ 3 20
C	+11 44	+ 0 18	− 9 14	+ 8 55	+ 1 52	− 3 51	+ 9 32	+ 1 26	− 5 32	+19 38	+ 9 28	− 0 39
D	− 1 11	− 1 27	− 0 50	− 3 4	− 3 32	− 3 33	+ 5 0	+ 3 59	+ 4 0	+ 4 53	+ 5 19	+ 4 27
E	+ 3 14	+ 0 32	− 0 48	+ 1 47	− 0 4	− 0 50	+ 2 2	+ 0 29	+ 0 3	+ 1 28	+ 0 8	− 1 23

* Compensated for polar magnetism only.

APPENDIX F.

Experiments to ascertain the effect of heeling on the compasses of the iron ship "Gitana."

This ship is of 1,323 tons register, and was built at Chester, with her head about S. 20° W. After launching, she was towed to Liverpool, and lay, while she was fitting and loading, with her head to the north.

The card of the steering compass was 2 feet 10½ inches above the deck, 5 feet 9 inches before the centre of the rudder-head, 2 feet 10 inches before the end of the spindle of the wheel, and 4 feet 2 inches before the iron standard of the steering apparatus. The end of the spindle nearest to the compass was 3 feet 3½ inches from the deck.

The standard compass was placed over the fore skidd, 11 feet above the deck, 17 feet before the mizzenmast, 39 feet aft of the mainmast, and 18 feet 6 inches aft of the capstans.

The fore compass was placed over a boat, and stood about 10 feet 3 inches above the deck, 36 feet before the mainmast, and 30 feet aft of the foremast.

The masts and yards were made of iron.

It was expected, from this ship having been built with her head to the southward, that the deviations from heeling of the aftermost compasses would have indicated a strong attraction to the lee side of the ship, but the only compass which deviated to the lee side was the steering compass, and that only to a small extent when the ship was heeled to port. The standard and fore compasses deviated to the weather side, the former to to about two-thirds the extent of a similarly placed compass in the "Beann Uamha."

The following table will exhibit the deviation due to heeling when ship's head was at north and at south, correct magnetic, in both ships.

"GITANA" AND "BEANN UAMHA."

Position of the compass.	Deviations obtained for ship's head, north correct magnetic.					Deviations obtained for ship's head, south correct magnetic.				
	Port heel.	Ship upright.	Starboard heel.	Change by heeling ship from 10° to port to 10° to starboard.	Average change in deviation from each degree of heel.	Port heel.	Ship upright.	Starboard heel.	Change by heeling ship from 10° to port to 10° to starboard.	Average change in deviation from each degree of heel.
"GITANA."										
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Steering compass, compensated	2 30 W.	1 30 W.	2 0 W.	0 30	0 2	5 35 E.	0 15 W.	0 15 W.	5 50	0 18
Standard compass	0 30 E.	6 0	10 0	10 30	0 32	12 0 E.	19 40 E.	24 20 E.	12 20	0 37
Fore compass	1 15	6 0 W.	13 30	14 45	0 44	1 20 W.	11 20	21 0	22 20	1 7
"BEANN UAMHA."										
Steering compass, compensated	18 40	1 55 E.	11 0	29 0	1 27	4 40	1 15 E.	8 40	13 20	0 40
Upper steering compass, compensated	12 45	1 10	7 30	20 15	1 1	5 10	2 0 W.	1 20	6 30	0 20
Standard compass, compensated	10 10	1 5	7 10	17 10	0 52	5 30	1 30	3 0 E.	8 30	0 26
Spare compass	18 40 E.	7 45 E.	2 45 W.	21 25	1 4	14 40 W.	8 50 W.	2 20 W.	12 20	0 37

"GITANA."

Deviation Tables for ship upright and with a list to starboard and to port of 10°, obtained from curves passed through the projection of observations made in the Brunswick dock, Liverpool, April 23 and 24, 1861.

Ship's head by compass, (disturbed.)	Steering compass, (compensated.)*			Standard compass.			Fore compass.		
	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.	10° heel to port.	Ship upright.	10° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	2 40 W.	1 40 W.	2 15 W.	0 40 E.	9 0 W.	16 0 W.	1 50 E.	11 15 W.	27 0 W.
N. by E.	2 10	1 15	1 30	6 30	3 0 W.	9 0	10 10	2 15 W.	15 50
N. N. E	1 45	0 45	0 45	12 30	3 0 E.	2 15 W.	18 30	6 30 E.	6 0 W.
N. E. by N	1 20	0 0	0 10 W.	17 15	9 0	5 0 E.	26 20	14 15	3 20 E.
N. E	1 5	0 45 E.	0 40 E.	20 40	13 30	11 0	32 0	21 15	10 50
N. E. by E	0 50	1 20	1 30	23 15	17 0	16 0	34 40	25 40	17 0
E. N. E.	0 30 W.	2 40	2 0	24 20	19 45	19 10	34 50	28 15	22 20
E. by N	0 0	1 25	2 30	24 30	21 50	22 0	33 20	29 25	26 0
East	0 20 E.	0 30 E.	2 45	23 20	23 0	24 15	30 30	29 15	28 45
N. by S.	1 15	0 30 W.	2 10	22 20	23 40	26 0	27 10	28 15	30 20
E. S. E.	2 0	1 30	0 20 E.	20 45	23 30	26 40	23 15	26 30	30 45
S. E. by E.	2 45	2 10	1 30 W.	19 15	23 0	27 0	19 15	24 10	29 50
S. E.	3 45	2 30	2 45	17 50	22 30	26 40	15 0	21 30	27 40
S. E. by S	4 30	2 30	2 45	16 0	21 40	25 40	10 50	18 40	24 50
S. S. E.	5 0	1 50	2 0	14 0	20 0	23 45	6 50	15 20	21 45
S. by E.	5 30	1 0	1 15	11 45	18 0	21 30	2 50 E.	11 45	17 50
South	5 40	0 20 W.	0 20 W.	9 30	15 20	18 30	1 0 W.	7 50	14 10
S. by W.	5 30	0 15 E.	0 30 E.	6 50	12 0	14 40	4 40	3 30 E.	9 40
S. S. W.	4 45	0 50	1 20	3 50 E.	8 20	10 45	8 50	0 55 W.	5 15
S. W. by S.	3 30	1 10	2 10	0 0	4 0 E.	5 45	13 0	5 30	0 25 E.
S. W	2 10	1 20	2 50	3 50 W.	0 20 W.	0 40 E.	17 0	10 15	4 30 W.
S. W. by W.	0 40 E.	1 10	3 15	8 20	5 15	4 40 W.	21 0	15 10	9 40
W. S. W.	1 0 W.	0 50	3 15	12 50	10 0	10 0	24 0	19 50	15 5
W. by S.	2 40	0 20 E.	2 10	16 40	14 30	15 20	27 0	24 10	20 40
West	3 40	0 10 W.	0 40 E.	19 30	18 30	20 20	29 20	27 50	25 30
W. by N.	4 0	0 45	1 10 W.	21 45	21 40	24 20	31 0	30 30	29 40
W. N. W	4 10	1 0	2 45	22 30	24 0	27 40	30 30	32 0	33 15
N. W. by W.	4 10	1 30	3 40	23 10	25 10	29 45	28 10	32 45	35 50
N. W.	4 0	1 50	4 0	21 20	25 15	30 30	24 10	32 10	37 40
N. W. by N.	3 40	2 0	3 45	18 0	23 30	30 0	18 40	29 50	38 10
N. N. W.	3 20	2 0	3 15	13 30	20 20	27 15	12 30	25 15	37 0
N. by W.	3 0 W.	2 0 W.	2 40 W.	7 30 W.	15 30 W.	22 45	5 40 W.	19 15 W.	33 10 W.

MAGNETIC CO-EFFICIENTS.

	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A	+0 6	−0 25	−0 19	+ 3 22	+ 2 36	+ 1 43	+ 0 58	− 0 11	− 1 4
B	+1 38	+0 4	+0 21	+21 54	+21 6	+22 47	+30 4	+29 10	+27 33
C	−4 12	−0 16	−1 8	− 4 49	−12 2	−16 50	+ 2 26	− 8 47	−18 37
D	+0 21	+1 42	+2 32	+ 5 8	+ 3 57	+ 3 54	+ 5 59	+ 5 18	+ 4 10
E	+1 33	−0 42	−1 21	+ 1 26	+ 0 21	− 0 28	0 0	− 1 15	− 3 51

* The cast-iron correctors for quadrantal deviation were placed with their long axis fore-and-aft. The deviations for the steering compass must be taken as approximate only.

APPENDIX G.

Deviation Tables for ships belonging to the Royal Navy which have been swung to ascertain the effect of heeling on their compasses, as obtained by passing fair curves through the projection of the recorded observations.

Ship's head by compass, (disturbed.)	STEAMER BLOODHOUND.			BRIG RECRUIT.			STEAMER SHARPSHOOTER.				
	Swung by Captain E. J. Johnson, R. N.			Swung at Plymouth by Mr. Walker, R. N.			Swung at Portsmouth by Captain J. N. Strange, R. N.				
	Standard compass.			Steering compass.			April 25, 1848, standard compass.			April 26, 1848, steering compass.	
	5° heel to port.	Ship upright.	8° heel to starboard.	8° heel to port.	Ship upright	8° heel to starboard.	Ship upright, funnel down.	Ship upright, funnel up.	7° heel to starboard.	Ship upright.	7° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	4 45 W.	1 0 W.	0 45 E.	2 45 E.	7 15 E.	13 40 E.	0 0	0 35 E.	1 10 W.	0 0	1 30 E.
N. by E.	1 0 W.	2 45 E.	3 50	6 40	12 30	18 0	2 35 E.	0 25	1 20	0 0	0 30 E.
N. N. E.	2 25 E.	6 20	7 30	10 0	15 50	21 10	4 50	0 10 E.	1 15	0 0	0 10 W.
N. E. by N.	6 0	9 0	9 50	12 30	17 45	22 30	6 30	0 5 W.	1 15	0 20 W.	1 10
N. E.	8 30	11 15	11 55	14 20	18 45	22 50	7 20	0 40	1 45	1 5	2 0
N. E. by E.	10 15	12 15	13 0	15 20	18 45	21 50	7 0	1 40	2 35	2 15	2 45
E. N. E.	11 5	12 40	13 0	15 40	17 30	20 0	6 15	3 20	3 45	4 15	3 50
E. by N.	11 35	12 25	12 30	15 20	15 45	17 0	5 10	5 30	5 25	6 45	6 0
East	11 25	11 40	11 15	14 20	13 30	13 40	3 35	7 35	7 20	8 50	8 5
E. by S.	10 45	10 30	10 0	13 10	10 50	9 50	1 50	9 10	8 40	10 0	10 40
E. S. E.	10 10	9 20	8 10	11 45	8 10	5 50	0 5 E.	10 15	9 40	11 0	12 0
S. E. by E.	9 20	8 15	6 25	9 50	5 30	1 40 E.	1 30 W.	10 45	10 0	11 15	12 45
S. E.	8 40	7 10	4 50	8 0	2 50	2 0 W.	2 30	10 40	9 50	10 40	12 10
S. E. by S.	7 50	6 5	2 50	6 10	0 10 E.	5 50	2 40	9 40	8 40	9 40	10 40
S. S. E.	7 0	5 0	1 10 E.	4 0	0 30 W.	9 10	1 50	7 30	6 0	7 10	7 20
S. by E.	6 5	3 40	0 40 W.	2 10 E.	5 0	12 0	0 45 W.	3 50	3 10 W.	3 0 W.	3 20 W.
South	4 50	2 40	2 0	0 0	7 0	14 20	0 45 E.	0 10 W.	0 0	3 0 E.	0 15 E.
S. by W.	3 10	1 20 E.	3 20	1 45 W.	8 15	16 0	2 0	3 25 E.	3 25 E.	6 0	5 15
S. S. W.	1 50	0 25 W.	4 35	3 30	9 0	17 10	3 0	6 45	6 30	9 45	10 10
S. W. by S.	0 15 E.	1 55	5 40	5 0	9 30	17 50	3 15	8 50	8 45	12 30	13 40
S. W.	1 45 W.	3 50	7 0	6 20	9 40	18 10	2 50	10 0	10 0	13 50	15 40
S. W. by W.	4 20	6 0	8 0	7 30	9 45	17 50	1 25 E.	10 15	10 25	14 0	16 10
W. S. W.	6 50	8 0	9 0	6 30	10 30	16 45	0 10 W.	9 45	10 0	13 10	15 25

Deviation Tables, &c.—Continued.

Ship's head by compass, (disturbed.)	STEAMER BLOODHOUND.			BRIG RECRUIT.			STEAMER SHARPSHOOTER.				
	Swung by Captain E. J. Johnston, R. N.			Swung at Plymouth by Mr. Walker, R. N.			Swung at Portsmouth by Captain J. N. Strange, R. N.				
	Standard compass.			Steering compass.			April 25, 1848, standard compass.			April 26, 1848, steering compass.	
	8° heel to port.	Ship upright.	8° heel to starboard.	8° heel to port.	Ship upright.	8° heel to starboard.	Ship upright, funnel down.	Ship upright funnel up.	7° heel to starboard.	Ship upright.	7° heel to starboard.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
W. by S.	9 10 W.	9 50 W.	10 5 W.	9 10 W.	10 40 W.	15 0 W.	2 10 W.	8 30 E.	9 0 E.	11 50 E.	14 20 E.
West	11 30	11 45	11 20	9 30	10 20	12 45	4 0	6 50	7 50	9 50	12 20
W. by N.	13 5	12 45	11 45	10 0	9 20	10 10	5 50	5 0	6 10	7 40	10 0
W. N. W.	14 45	13 20	12 0	9 50	8 0	8 10	7 20	3 20	4 20	5 40	8 0
N. W. by W.	15 40	13 30	11 45	8 40	6 40	5 20	8 10	1 45	2 55	3 45	6 35
N. W.	15 35	13 0	11 10	6 50	4 30	2 30	8 35	0 45	1 30	2 30	5 30
N. W. by N.	14 5	11 15	9 20	4 30	2 0 W.	0 40 E.	7 55	0 0	0 20 E.	1 30	4 30
N. N. W.	11 50	8 20	6 30	2 0	0 30 E.	4 15	6 35	0 5	0 10 W.	0 50	3 40
N. by W.	8 30 W.	4 45 W.	3 0 W.	0 10 W.	3 45 E.	8 15 E.	3 45 W.	0 20 E.	0 45 W.	0 20 E.	2 30 E.

MAGNETIC CO-EFFICIENTS.

	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
A.	− 0 3	+ 0 24	− 0 19	+ 2 9	+ 1 28	+ 0 2	− 0 10	− 0 8	− 0 3	+ 1 1	+ 1 41
B.	+11 42	+12 2	+11 45	+12 20	+12 4	+13 53	+ 3 51	− 7 29	− 7 47	− 9 51	−11 13
C.	− 4 55	− 1 41	+ 1 10	+ 1 49	+ 7 17	+14 2	− 0 36	+ 0 17	− 0 23	− 0 45	− 0 2
D.	+ 3 19	+ 3 15	+ 2 49	+ 1 44	+ 3 0	+ 2 25	+ 5 16	+ 4 52	+ 4 8	+ 5 28	+ 5 8
E.	0 0	+ 0 23	− 0 27	− 0 15	− 0 25	− 0 24	+ 0 11	+ 0 9	− 0 23	− 0 5	− 0 26

APPENDIX H.

Particulars of some of the cases in which vertical iron bars have been introduced to compensate the effect of the changing magnetism of the stern-post, rudder-head, rudder-casing, &c., on the steering compasses of iron ships.

1. "ACCRINGTON."—As a vertical bar immediately before the steering compass would have interfered with the fitting of the companion, two bars were introduced, one on each side of the companion, but before the compass. No fore-and-aft magnet was employed. In reply to an inquiry how this answered during the ship's first voyage to Calcutta and back, the managing owner wrote as follows, under date April 11, 1861: "In reply to your inquiry, I beg to inform you that the steering compass of the "Accrington" is reported to be as accurate as that of a wooden ship could be. You will no doubt recollect she had two vertical bars and cylinders."

2. "ADVANCE."—A vertical bar was introduced in 1857, to compensate about half of the observed attraction towards the stern at Liverpool. This being found insufficient, another bar was fixed nearer the compass in 1860, so as to over-compensate the attraction in Liverpool. The trial of this, on a voyage to Ceylon and back, shows that a rather stouter piece of iron, or the same bar placed a little nearer, would practically compensate the changing magnetism at the stern of the ship. (See log of this ship.)

3. "APHRODITA."—A long vertical bar was introduced immediately before the steering compass, so as to compensate all the deviations towards the stern observed at Liverpool, except about 7°, which was corrected by a magnet. This has acted well during two voyages to Calcutta and back. (See logs of this ship.)

4. STEAMSHIP "ARAXES."—The vertical bar in this steamer was firmly connected with the ironwork near the bottom of the ship, so as to partake of any vibration which might be caused by the screw. It is reported to have acted very satisfactorily during several voyages to and from Alexandria. About twelve months after it was introduced, the ship underwent a thorough refit in graving-dock, with her head N.N.E. On trying her afterwards with her head east and west, the compensation was still found perfect.

5. STEAMSHIP "ARCADIA."—A short stout bar was introduced, as a long bar would have interfered with the cabin fittings. Reported to have acted very satisfactorily during several voyages to Alexandria.

6. STEAMSHIP "BŒOTIA."—A short bar, four feet long, three inches in diameter, fixed inside the skylight, in front of the compass, in 1857, and is reported to have acted well ever since.

7. "CRINOLINE."—Short bar introduced in spring of 1857. No report; but the bar has been seen in place again, after a temporary removal.

8. "EDMOND PRESTON."—This ship's steering compass had no fore-and-aft compass error in Liverpool, but was reported to have had very large deviations in the southern hemisphere, on her first voyage round the Horn. Before her second voyage, a short vertical iron bar was fixed so as to produce a deviation of the needle to the bow of about 20°. This was compensated by a permanent magnet. The captain, on his return, reported that in high south latitude the error with ship's head east or west was not more than in the northern hemisphere, but that there was an error of about four points with ship's head northeast or northwest, in north latitude, towards the end of his voyage. He added, that he had not allowed the compass card to be touched from the time he sailed until he again returned to Liverpool.

9. STEAMSHIP "LACONIA."—Short vertical bar introduced. Under-compensated, but said to be improved.

10. STEAMSHIP "NEMESIS."—A vertical bar carried nearly to the bottom of the vessel, and there firmly secured. Slightly under-compensated. A refit in graving-dock did not disturb the compensation.

11. STEAMSHIP "ORONTES."—A short bar introduced, and reported to work well.

12. STEAMSHIP "SCAMANDER."—Same fitting and effect as in the steamship "ARAXES."

13. "SLIEVE DONARD."—A vertical bar secured to a bulkhead, reaching to the bottom of the ship, which compensated the whole of the attraction towards the stern, except about 10°, which was corrected by a magnet. The first voyage to Bombay showed that the bar was far too weak. On the ship's return to Liverpool, the compass was moved nearer to the bar, so as to make it show an attraction to the bow of about 26°, which was corrected by a magnet. The captain reported, on his return from a second voyage to Calcutta, that his compass never varied more than half a point from the deviations observed in the dock before she sailed. (See logs of this ship.)

12. STEAMSHIP "THESSALIA."—Same as Laconia.

Similar bars have been introduced in several other ships; also in some steamers, to partially compensate bridge compasses which have been fixed near the funnel or other masses of vertical iron.

APPENDIX K.

Experiments to ascertain the effect of cast-iron cylinders as correctors for quadrantal deviation, with three kinds of compass cards, with some examples of quadrantal deviation.

The cylinders were placed in the horizontal position, one on each side of the compass, and athwart-ships, this being the usual mode of applying them, as they thus become to some extent correctors also for the deviation which arises from heeling. In some ships it may be advisable to apply them on each side of the compass, but in the fore-and-aft direction, and in the other ships, they may have a better effect if placed vertically instead of horizontally. If the centre of the cylinders be placed in the same horizontal plane as the needles of the card, it does not much matter, as respects quadrantal deviation, which of the three positions named may be adopted.*

1. Compass card with a single needle 6.3 inches long, such as is used in the Board of Trade azimuth compasses.

2. Compass card with two parallel needles, each 6.4 inches long and 2.93 inches apart.

3. Admiralty compass card with four compound and parallel needles, the two middle needles each 7.13 inches long and 2 inches apart, the two outside needles each 5.25 inches long and 1.25 inches from the adjacent needle.

Ship's head by compass.	Deviations of the compass card with a single needle with the 9-inch cylinders. Distance of nearest end of the cylinders from the centre of the card, in inches.					
	5 inches.	7 inches.	8 inches.	9 inches.	10 inches.	11 inches.
	° ′	° ′	° ′	° ′	° ′	° ′
North and South	0 0	0 0	0 0	0 0	0 0	0 0
N. by E. and S. by W.	−2 11	−1 32	−1 13	−0 56	−0 44	−0 31
N. N. E. and S. S. W.	−4 45	−3 18	−2 26	−1 45	−1 15	−0 47
N. E. by N. and S. W. by S.	−8 0	−5 15	−3 36	−2 23	−1 35	−0 56
N. E. and S. W.	−11 56	−7 18	−4 39	−2 40	−1 45	−1 2
N. E. by E. and S. W. by W.	−15 49	−8 48	−5 18	−3 6	−1 47	−1 5
E. N. E. and W. S. W.	−16 45	−8 31	−5 7	−2 50	−1 40	−1 0
E. by N. and W. by S.	−12 30	−5 32	−3 3	−1 51	−1 10	−0 43
East and West	0 0	0 0	0 0	0 0	0 0	0 0
E. by S. and W. by N.	12 30	5 32	3 3	1 51	1 10	0 43
E. S. E. and W. N. W.	16 45	8 31	5 7	2 50	1 40	1 0
S. E. by E. and N. W. by W.	15 49	8 48	5 18	3 6	1 47	1 5
S. E. and N. W.	11 56	7 18	4 39	2 40	1 45	1 2
S. E. by S. and N. W. by N.	8 0	5 15	3 36	2 23	1 35	0 56
S. S. E. and N. N. W.	4 45	3 18	2 26	1 45	1 15	0 47
S. by E. and N. by W.	2 11	1 32	1 13	0 56	0 44	0 31

* Since this was in type, a joint paper has been contributed to the Royal Society, by Mr. Archibald Smith, M.A., and Mr. F. J. Evans, R.N., showing that the "octantal" inequality illustrated in these tables disappears when a double needle card is employed in which the parallel needles (their similar effective poles) are sixty degrees apart from each other. The experiments recorded above, show that a corrector when acting on a single needle card would under-compensate a true quadrantal deviation to which the card was subject

Examples af quadrantal deviation, &c.—Continued.

Ship's head by compass.	Deviations of the compass card with two needles with the 12-inch cylinders. Distance of nearest end of the cylinders from the centre of the card, in inches.					
	7 inches.	8 inches.	9 inches.	10 inches.	11 inches.	12 inches.
	° ′	° ′	° ′	° ′	° ′	° ′
North and South	0 0	0 0	0 0	0 0	0 0	0 0
N. by E. and S. by W	−3 44	−2 30	−1 39	−1 10	−0 51	−0 37
N. N. E. and S. S. W	−8 17	−5 20	−3 28	−2 18	−1 37	−1 9
N. E. by N. and S.W. by S	−11 23	−7 38	−5 0	−3 18	−2 10	−1 28
N. E. and S.W	−12 25	−8 30	−5 50	−3 47	−2 23	−1 35
N. E. by E. and S.W. by W	−11 54	−8 11	−5 30	−3 33	−2 17	−1 31
E. N. E. and W. S.W	−9 14	−5 57	−3 53	−2 38	−1 51	−1 17
E. by N. and W. by S	−3 28	−2 21	−1 42	−1 11	−0 54	−0 41
East and West	0 0	0 0	0 0	0 0	0 0	0 0
E. by S. and W. by N	3 28	2 21	1 42	1 11	0 54	0 41
E. S. E. and W. N.W	9 14	5 57	3 53	2 38	1 51	1 17
S. E. by E. and N.W. by W	11 54	8 11	5 30	3 33	2 17	1 31
S. E. and N.W	12 25	8 30	5 50	3 47	2 23	1 35
S. E. by S. and N.W. by N	11 23	7 38	5 0	3 18	2 10	1 28
S. S. E. and N. N.W	8 17	5 20	3 28	2 18	1 37	1 9
S. by E. and N. by W	3 44	2 30	1 39	1 10	0 51	0 37

Examples of quadrantal deviation, &c.—Continued.

Ship's head by compass.	Deviations of the Admiralty compass card with the 12-inch cylinders, at the following distances.					
	7 inches.	8 inches.	9 inches.	10 inches.	11 inches.	12 inches.
	° ′	° ′	° ′	° ′	° ′	° ′
North and South	0 0	0 0	0 0	0 0	0 0	0 0
N. by E. and S. by W	−6 0	−3 50	−2 40	−1 52	−1 17	−0 58
N. N. E. and S. S.W	−10 32	−6 42	−4 39	−3 27	−2 30	−1 52
N. E. by N. and S.W. by S	−12 50	−8 27	−5 57	−4 17	−3 4	−2 15
N. E. and S.W	−12 37	−8 27	−6 0	−4 19	−3 10	−2 20
N. E. by E. and S.W. by W	−10 15	−7 22	−5 18	−3 52	−2 55	−2 9
E. N. E. and W. S.W	−8 2	−5 29	−3 58	−2 55	−2 13	−1 40
E. by N. and W. by S	−4 29	−3 1	−2 6	−1 35	−1 13	−0 57
East and West	0 0	0 0	0 0	0 0	0 0	0 0
E. by S. and W. by N	4 20	3 1	2 6	1 35	1 13	0 57
E. S. E. and W. N.W	8 2	5 29	3 58	2 55	2 13	1 40
S. E. by E. and N.W. by W	10 15	7 22	5 18	3 52	2 55	2 9
S. E. and N.W	12 37	8 27	6 0	4 19	3 10	2 20
S. E. by S. and N.W. by N	12 50	8 27	5 57	4 17	3 4	2 15
S. S. E. and N.N.W	10 32	6 42	4 39	3 27	2 30	1 52
S. by E. and N. by W	6 0	3 50	2 40	1 52	1 17	0 58

in the first, fourth, fifth, and eighth octant, and over-compensate it in the remaining octants; and that this over and under-compensation in the same quadrant rapidly increases as the corrector is brought nearer to the card. The corrector has a similar effect on a double needle card, when the parallel needles are placed near to each other, but when they are placed beyond a certain distance apart on the card it is found that a contrary result is exhibited; the regular quadrantal deviation is over-compensated in the first, fourth, fifth, and eighth octants, and under-compensated in the others. It will be inferred from this that there is some distance for the needles at which there would be neither over nor under-compensation. Mr. Smith, it is understood, demonstrates that this particular distance is found when the similar effective poles of the needles are placed sixty degrees apart from each other, measuring the angle from the centre of the card. Mr. Evans, it is understood, shows by experiments that the Admiralty standard compass card with four parallel needles is free from the octantal error here alluded to. The double needle card is now almost universally used in the merchant service. Nautical instrument makers and compass adjusters will see the importance of attending to this most opportune and interesting discovery. The paper in question will, it is hoped, be published without delay.*

B. F. G.

* See ninth paper of first volume of Magnetism and Ships.

Examples of quadrantal deviation, &c.—Continued.

Ship's head by compass.	Deviations of the Admiralty compass card with the 9-inch cylinders at the following distances.					
	7 inches.	8 inches.	9 inches.	10 inches.	11 inches.	12 inches.
	° ′	° ′	° ′	° ′	° ′	° ′
North and South	0 0	0 0	0 0	0 0	0 0	0 0
N. by E. and S. by W.	− 5 39	− 3 37	− 2 14	− 1 21	− 0 55	− 0 37
N. N. E. and S. S. W.	− 9 5	− 5 36	− 3 36	− 2 27	− 1 35	− 1 9
N. E. by N. and S.W. by S.	−10 25	− 6 26	− 4 7	− 2 50	− 1 57	− 1 24
N. E. and S.W.	−10 10	− 6 17	− 4 8	− 2 52	− 1 58	− 1 24
N. E. by E. and S.W. by W.	− 8 42	− 5 30	− 3 41	− 1 36	− 1 48	− 1 16
E. N. E. and W. S.W.	− 6 35	− 4 14	− 2 48	− 2 0	− 1 24	− 1 0
E. by N. and W. by S.	− 3 30	− 2 18	− 1 30	− 1 8	− 0 50	− 0 36
East and West	0 0	0 0	0 0	0 0	0 0	0 0
E. by S. and W. by N.	3 30	2 18	1 30	1 8	0 50	0 36
E. S. E. and W. N.W.	6 35	4 14	2 48	2 0	1 24	1 0
S. E. by E. and N.W. by W.	8 42	5 30	3 41	1 36	1 48	1 16
S. E. and N.W.	10 10	6 17	4 8	2 52	1 58	1 24
S. E. by S. and N.W. by N.	10 25	6 26	4 7	2 50	1 57	1 24
S. S. E. and N. N.W.	9 5	5 36	3 36	2 27	1 35	1 9
S. by E. and N. by W.	5 39	3 37	2 14	1 21	0 55	0 37

On the next page is given a dozen examples of quadrantal deviations which have been observed on shipboard after the ship's polar magnetism has been more or less completely compensated by magnets. Some of them have been selected as examples of the large amount of induced magnetism which is sometimes observed. In the first example the compass was placed about three feet above a raised platform or bridge, about midship between the wheels of a paddle steamer, and about midway between two funnels situated on the fore-and-aft middle line of the ship, and estimated at more than 30 feet apart. No attempt at great accuracy has been made. The tables are merely transcripts from the cards of deviation supplied to the several vessels.

In each table the two cardinal points on which the deviations are smallest will indicate the points on which the ship's head was placed when the compensating magnets were applied. It will be observed that the ship's polar magnetism is either over-compensated or under-compensated by the amount of the index error added to the small quadrantal deviation which arises from oblique horizontal iron.

Compass deviations observed when the polar deviations have been more or less completely compensated by magnets.

Ship's head by compass.	Russian steamer, April, 1858.		Steamer Emperor Alexander, June, 1858.		Steamer Ionia, 1858.		Steamer Cairo. Dec. 1858.	Steamer Imperador. Jan., 1859.	Steamer.	Russian steamer, Aug. 1859.	Steamer Urara, 1859.	Steamer Inca. April. 1860.	Mean of the twelve tables.
	Midship steering compass.	Standard compass.	Aftermost steering compass.	Forward steering compass.	Steering compass.	Bridge compass.	Standard compass.	Fore compass.	Steering compass.	Midship steering compass.	Bridge compass.	Midship steering compass.*	
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	— 2 0	+ 1 0	— 5 20	— 2 0	— 1 0	— 1 30	+ 0 30	0 0	+ 5 30	+ 3 10	0 0	— 1 0	— 0 13
	+10 40	+ 3 0	+ 0 40	+ 1 0	+ 1 0	— 1 0	+ 3 0	+ 1 30	+ 8 15	+ 7 15	+ 2 20	+ 1 0	+ 2 43
N. N. E	+10 40	+ 4 20	+ 4 0	+ 3 15	+ 3 0	0 0	+ 5 0	+ 2 15	+10 0	+10 15	+ 4 40	+ 2 20	+ 4 59
	+15 0	+ 5 45	+ 6 15	+ 5 0	+ 4 0	+ 0 30	+ 6 30	+ 2 30	+11 15	+11 30	+ 6 50	+ 3 30	+ 6 33
N. E.	+16 10	+ 6 20	+ 7 0	+ 6 0	+ 4 30	+ 1 0	+ 6 45	+ 2 30	+10 50	+11 15	+ 8 20	+ 4 20	+ 7 0
	+15 0	+ 6 15	+ 6 10	+ 5 40	+ 4 0	+ 1 0	+ 6 15	+ 2 0	+ 9 20	+10 15	+ 8 20	+ 4 10	+ 6 24
E. N. E	+12 15	+ 5 15	+ 5 0	+ 4 20	+ 3 0	+ 0 30	+ 4 50	+ 1 30	+ 7 20	+ 8 0	+ 6 30	+ 3 15	+ 5 9
	+ 8 30	+ 3 50	+ 2 50	+ 2 10	+ 1 30	0 0	+ 2 50	+ 1 0	+ 4 50	+ 5 15	+ 2 30	+ 1 40	+ 3 5
East	+ 4 0	+ 1 50	0 0	0 0	— 1 0	— 0 30	+ 1 10	0 0	+ 1 50	+ 1 45	— 2 0	+ 0 40	+ 0 39
	0 0	0 0	— 3 40	— 2 15	— 3 0	— 1 0	— 0 30	— 1 30	— 1 0	— 2 0	— 6 0	— 1 40	— 1 53
E. S. E.	— 4 10	— 2 20	— 7 15	— 4 15	— 4 30	— 1 30	— 2 30	— 2 30	— 3 50	— 5 15	— 8 0	— 3 0	— 4 5
	— 7 0	— 4 30	—10 10	— 5 30	— 5 0	— 1 30	— 4 15	— 3 .0	— 5 50	— 8 0	— 8 0	— 3 40	— 5 32
S. E.	—10 0	— 5 45	—12 0	— 6 0	— 5 30	— 1 0	— 5 15	— 3 15	— 7 25	—10 0	— 7 0	— 3 10	— 6 22
	—11 40	— 6 0	—12 0	— 5 50	— 5 0	0 0	— 5 30	— 3 0	— 7 50	—10 20	— 5 15	— 1 40	— 6 10
S. S. E	—10 30	— 5 30	— 8 0	— 5 0	— 3 0	+ 1 0	— 4 30	— 2 30	— 7 20	— 9 10	— 3 0	+ 1 0	— 4 42
	— 6 40	— 3 0	— 5 0	— 3 30	0 0	+ 2 30	— 2 0	— 1 0	— 6 0	— 6 15	— 1 0	+ 3 50	— 2 20
South	— 0 20	— 0 15	+ 0 40	— 0 20	+ 3 0	+ 4 0	+ 1 0	+ 1 15	— 3 0	— 2 45	+ 1 0	+ 6 30	+ 0 45
	+ 6 0	+ 2 10	+ 5 30	+ 3 0	+ 5 0	+ 5 0	+ 4 20	+ 4 0	— 0 15	+ 1 0	+ 3 0	+ 8 30	+ 3 55
S. S. W	+10 40	+ 3 30	+ 8 45	+ 5 40	+ 7 0	+ 5 0	+ 6 50	+ 5 0	+ 1 50	+ 4 15	+ 5 0	+ 9 20	+ 6 4
	+12 40	+ 4 0	+10 25	+ 6 40	+ 9 0	+ 4 30	+ 7 30	+ 5 30	+ 3 20	+ 6 10	+ 6 20	+ 9 20	+ 7 7
S. W.	+13 0	+ 4 0	+11 0	+ 6 30	+10 0	+ 4 0	+ 7 20	+ 6 0	+ 3 45	+ 6 15	+ 7 30	+ 8 20	+ 7 18
	+11 0	+ 3 10	+10 0	+ 5 40	+10 0	+ 3 0	+ 5 30	+ 5 0	+ 3 25	+ 5 15	+ 7 30	+ 6 20	+ 6 19
W. S. W	+ 8 0	+ 2 15	+ 8 10	+ 3 50	+ 9 30	+ 1 0	+ 3 30	+ 3 30	+ 2 15	+ 3 30	+ 6 15	+ 4 0	+ 4 39
	+ 4 0	+ 1 10	+ 5 30	+ 1 45	+ 8 0	— 2 0	+ 1 0	+ 0 30	+ 0 50	+ 1 45	+ 4 0	+ 1 40	+ 2 21
West	0 0	0 0	+ 1 50	— 1 10	+ 5 0	— 4 30	— 1 20	+ 2 30	— 0 10	— 0 15	+ 1 0	— 0 45	— 0 14
	— 4 15	— 1 20	— 1 50	— 3 30	+ 1 30	— 6 30	— 3 15	— 4 30	— 0 45	— 2 15	— 1 30	— 3 15	— 2 37
W. N. W	— 8 40	— 2 45	— 5 30	— 5 50	— 2 0	— 8 0	— 4 45	— 6 15	— 1 0	— 4 0	— 4 0	— 5 10	— 4 50
	—12 0	— 3 20	— 8 40	— 7 30	— 4 30	— 9 0	— 5 30	— 7 15	— 1 15	— 5 45	— 5 40	— 6 45	— 6 26
N. W	—14 20	— 3 30	—11 30	— 8 15	— 7 0	— 9 0	— 5 45	— 7 30	— 1 0	— 6 30	— 6 0	— 7 30	— 7 19
	—15 0	— 2 45	—12 45	— 8 30	— 6 15	— 8 0	— 5 15	— 7 0	— 0 20	— 6 10	— 5 30	— 7 10	— 7 6
N. N. W	—12 50	— 1 30	—13 0	— 7 30	— 5 30	— 6 30	— 3 45	— 5 30	+ 0 50	— 4 0	— 4 0	— 6 20	— 5 54
	— 8 15	0 0	—10 30	— 5 0	— 3 30	— 4 0	— 2 0	— 3 0	+ 3 0	— 0 30	— 2 15	— 3 50	— 3 19

* In this case no fore-and-aft magnet was used. The transverse magnets compensated a deviation of about 28° to the port side.

In the preceding examples* the inequality of the deviations in the different quadrants which arises from the residual polar magnetism, and from index error, must carefully be distinguished from that which may possibly arise from a greater susceptibility in the horizontal iron to induction in one direction. Thus, in the first example, the deviations on the four-point courses are, respectively, +16° 10′, — 10° 0′, + 13° 0′, — 14° 20′. Correcting them for polar deviation they become + 14° 57′, — 12° 3′, + 14° 33′, — 12° 17′, and correcting again for apparent index error of + 1° 12′, they are + 13° 45′ — 13° 15′, + 13° 1′, — 13° 29′; or an extreme difference of 44′ on a mean value of 13° 23′, instead of a difference of 6° 10′, as might appear at first sight. Again, in example No. 10, the deviations on the four-point courses are, respectively, +11° 15′, — 10° 0′, + 6° 15′, — 6° 30′; and after applying the correction for polar deviation + 8° 35′, — 8° 20′ + 8° 55′, and — 8° 10′. Correcting for an apparent index error of + 0° 15′, they become + 8° 20′, — 8° 35′, + 8° 40′, and —8° 25′, showing an extreme difference of only 20′ on a mean value of 8° 30′. But in example No. 6 a much larger difference remains after these corrections are made. Here the deviations on the four-point courses are restively, + 1° 0′, — 1° 0′, + 4° 0′, and — 9° 0′; after correction for polar deviation, they are + 2° 0′, — 4° 14′, + 3° 0′, and — 5° 46′; and correcting for an apparent index error of — 1° 15′, they become + 3° 15′, — 2° 59′, + 4° 15′, and — 4° 31′; showing an extreme difference of 1° 32′ on a mean value of only 3° 45′, and apparently indicating a less capacity for horizontal induction in this ship in the direction of port to starboard than in the contrary direction.

Another explanation of the inequality in the amount of the quadrantal deviation in different quadrants may be suggested by the fact that in swinging ships it is not infrequent to get the deviations for some quadrants in a much less time than in others. Thus, when the ship is to the windward side of the dock, she is turned from point to point very

* As the above are examples of *plus* quadrantal deviation, it has been thought desirable to add one or two deviation tables showing minus quadrantal deviation. Cases of this kind have been so rarely met with that it has been supposed they do not exist. The writer has met with very few instances, and in these the quadrantal error, as may be expected, was small. The extraordinary quadrantal deviations of the compass No. 1, in the experiments on board the "City of Baltimore, (see co-efficients, Appendix A,) is altogether an exceptional case. Deviation tables for mast compasses are also excepted. and, of course, cases in which the quadrantal error may be said to have been artificially produced. One example is that of a vessel in which the plates in her bottom had become very much corroded and were quite thin. After new plates had been put in, it was found that the quadrantal deviation which she had exhibited at two previous swingings had changed to a very small plus quadrantal deviation. In connexion with this topic, it may also be noted that in the floating batteries "Meteor," "Thunder," and "Trusty," which are wood-built ships plated with iron, the quadrantal deviation is either small plus or minus, being, respectively, + 0° 12′ — 0° 40′, and + 1° 37′, while the iron-built floating battery "Terror" has a plus quadrantal deviation of 6° 17′.

quickly, but when on the leeward side the movement is so slow as to afford ample time for the Earth's inductive power to have full effect. It has also been noticed that when ships have been swung for deviation in the river by change of tide the co-efficient for quadrantal deviation for the same compass has been smaller than when the ship was swung in dock.

The difference in the amount of the quadrantal deviations in the different quadrants when the polar force is uncompensated, must sometimes be very great, and vary with the variations in the polar force on change of latitude. Thus, in the standard compass of the "Royal Charter," with a polar magnetic force equal to about .378 of Earth's horizontal force at Liverpool, it seems probable that that part of the deviation which is due to horizontal induction was nearly twice as great in two of the quadrants as it was in the two adjacent ones. An attempt has been made to show this by the following diagram and table of numerical results.

Ship's head by compass, (disturbed.)	Steamship "Tamaulipus," steering compass,* Liverpool, June 25, 1859, (compensated with magnets only.)	Steamship "Forwood."† Bridge compass at Lota, April 4, 1860, (no compensation.)	Steamship "Forwood."† Deck-house compass at Liverpool, December 20, 1860, (compensated by magnets only.)	Ship's head by compass, (disturbed.)	Steamship "Tamaulipus," steering compass, Liverpool, June 25, 1859, (compensated with magnets only.	Steamship "Forwood." Bridge compass at Lota, April 4, 1860, (no compensation.	Steamship "Forwood." Deck-house compass at Liverpool, December 20, 1860, (compensated with magnates only.)
	° ′	° ′	° ′		° ′	° ′	° ′
North	1 0 E.	19 30 W.	1 20 W.	South	4 15 E.	19 0 E.	0 30 W.
N. by E	0 30 W.	19 50	1 40	S. by W	3 10	18 0	0 45
N. N. E	1 20	19 0	1 30	S. S. W	2 10	16 30	1 0
N. E. by N	2 20	17 25	1 10	S. W. by S	1 45	14 25	1 0
N. E	2 45	15 0	0 45	S. W	1 25	12 0	0 45
N. E. by E	2 30	12 20	0 15 W.	S. W. by W	1 15	9 25	0 30 W.
E. N. E	1 30 W.	8 45	0 30 E.	W. S. W	1 20	6 20	0 0
E. by N	0 0	5 0	1 20	W. by S	1 45	3 30	0 15 E.
East	1 30 E.	1 0 W.	2 0	West	2 20	0 30 E.	0 45
E. by S	3 0	3 0 E.	2 30	W. by N	3 0	2 40 W.	1 0
E. S. E	4 15	7 0	2 30	W. N. W	3 45	5 45	1 0
S. E. by E	5 30	10 40	2 25	N. W. by W	4 20	9 0	0 45
S. E	6 30	14 15	2 10	N. W	4 40	12 0	0 30
S. E. by S	6 30	17 0	1 30	N. W. by N	4 20	14 40	0 15 E.
S. S. E	6 15	18 45	0 45 E.	N. N. W	3 35	16 40	0 20 W.
S. by E	5 15 E.	19 15 E.	0 0	N. by W	2 25 E.	18 20 W.	0 45 W.

MAGNETIC CO-EFFICIENTS.

	A	B	C	D	E
STEAMSHIP "TAMAULIPUS."	° ′	° ′	° ′	° ′	° ′
Steering compass	+2 20	−0 38	−1 50	−3 4	+0 25
STEAMSHIP "FORWOOD."					
Bridge compass	−0 14	−1 27	−18 47	−1 23	+0 4
Deck-house compass	+0 15	+1 5	+ 0 40	−1 5	−1 6

* Placed over a skylight.

† These compasses were situated before the funnel, about midships. The iron beams of this vessel, for a considerable distance, both before and abaft the positions of these compasses, are stated to be scarphed on each side. Each beam is thus formed of three pieces, the ends of the pieces nearest the side being connected by "fore-and-afters." This construction may possibly affect the inductive capacity of the beams, as compared with that of beams formed only of one piece.

APPENDIX L.

Diagram to show graphically the components of a ship's magnetism to produce a deviation table similar to that of the standard compass of the "Royal Charter."

The construction, Plate 45, is made upon the hypothesis that the horizontal induction in the iron which affects the compass is proportional to the Earth's horizontal force in combination with the polar force of the ship measured in the direction of the disturbed needle. The quadrantal deviations on the four four-point courses, estimated in this way, are, respectively, + 9° 15′, — 9° 50′, + 5° 57′, — 4° 20′.

The diagram and table are also intended to show, that in investigating the components of a ship's magnetism, it is necessary to consider the plus quadrantal effect which is almost invariably observed as the result of a large plus quadrantal induction combined with a smaller minus quadrantal induction, the concealed and apparently cancelled parts of which may in some cases very seriously affect the directive power of the needle. It is believed that the deviations of the standard compass of the "Royal Charter," when she was first swung, are pretty closely represented in this diagram; and it will be observed that when the ship's polar force acts in the same direction as the Earth's force on the needle, as when the ship's head is between east and E.S.E., the total directive power is not equal to the Earth's horizontal force; while, when the ship's head is between west and W.N.W. (correct magnetic,) it is considerably less than one-half of the Earth's horizontal force.

In some cases, however, it is possible that the horizontal induction in ship's iron may have the opposite effect to that shown here, and tend to increase the directive power of the needle.

Description of the diagram, Plate 45.

The vertical line PO represents direction and amount of Earth's horizontal force = 1.

The lines O.N., O.NNE, O.NE, &c., represent the direction and amount of the ship's polar magnetic force = .378, when ship's head correct magnetic is respectively, N., N.N.E., N.E., &c,

The inter-dotted lines proceeding from the ends of the lines last named, represent, in amount and direction, the effect of the inductive forces acting in the direction of the disturbed needle on the ship's horizontal transverse iron, producing plus quadrantal deviation.

The dotted lines connected with the preceding in the same way, show the effect of induction on the fore-and-aft iron, causing minus quadrantal deviation.

The heavy lines proceeding from the last, in like manner, show the effect of induction in the oblique horizontal iron of the ship.

The lines P 0″, P 2″, P 4″, P 6″, &c., are the resultants of the inductive forces, and show the direction and force of the needle; the angles OP 0″, OP 2″, OP 4″, &c., show the deviation of the needle when the ship's head is N., E.N.E., N.E., &c. The dotted curve marked 5°, 10°, 15°, 20°, &c., is a scale of degrees for reading off the angles of deviation of the needle from the meridian or line PO in degrees; those to the right of the meridian show plus or easterly deviation; those to the left minus or westerly deviation.

It may be necessary to state that by ship's transverse iron is meant the excess of that which produces plus quadrantal deviation above that which produces minus quadrantal deviation. By the ship's fore-and-aft iron is meant the excess of that portion which produces minus quadrantal above that which produces plus quadrantal deviation. In like manner, by oblique horizontal iron, is meant the excess of that which produces minus deviation, when ship's head is north, above that which produces plus quadrantal deviation; in effect, the action of a bar placed below the compass, with its ends northeast and southwest when ship's head is north, this being sufficiently accurate for the small deviation due to oblique horizontal iron.

The construction at the bottom of the diagram is to facilitate the cutting off, without the trouble of calculation, lines proportional to the inductive force, or to the lines P 0″, P 2″, P 4″, &c., and likewise proportional to the capacity (according to direction) of the fore-and-aft, the transverse, and the oblique iron of the ship for horizontal induction.

In this construction PQ = { half the capacity of the transverse iron of the ship for Earth's magnetic induction, when in the direction of the magnetic meridian.................................. } $= \frac{0.3}{2}$

PR = { half the capacity for Earth's magnetic induction of fore-and-aft iron of the ship, when in the direction of the magnetic meridian............. .... } $= \frac{0.091}{2}$

also PR = { total capacity for Earth's magnetic induction in ship's oblique iron, when in the direction of the magnetic meridian............ } $= .046$

and Pp : PQ = NO : OP

also Pp′ : PR = Pp : PQ

The numerical results are given in the annexed table. The columns *a* and *d* have been calculated, and will afford by comparison with columns *b* and *e*, some idea of the limits of error to which the table is liable.

Table to show the deviations supposed to be due to the different components of a ship's magnetism, and which, in combination, will produce a deviation table similar to that of the standard compass of the "Royal Charter" when swung at Liverpool, in January, 1856.

Points of the compass.	Polar deviation from ship's force = .378 of Earth's horizontal force at a starboard angle = 257°. Ship's head, correct magnetic. By calculation.	Ship's head, correct magnetic. By construction.	Ship's head by compass from curve.	Quadrantal deviation from capacity for + horizontal induction = 0.3 of Earth's horizontal force. Ship's head, correct magnetic. By calculation.	Ship's head, correct magnetic. By construction.	Ship's head by compass from curve.	Polar and + quadrantal deviation combined. Ship's head, correct magnetic, or sums of columns b and e.	Ship's head by compass from curves or sums of cols. c and f.	The preceding with the − quadrantal due to capacity, = .091 of Earth's horizontal force. Deviation from curve, ship's head, by compass.	Sum of columns h and i.	All the preceding, with the quadrantal deviation arising from oblique iron capacity, = .046 of Earth's force. Deviation from curve, ship's head, by compass.	Sum of columns k and l.	Sum of columns f and i.	Polar deviation .378 combined with + quadrantal due to inductive capacity .209 = 0.3 − .091. Deviation from curve, ship's head, by compass.	Sum of columns c and o.	Difference of columns k and p or n and o.
	a.	b.	c.	d.	e.	f.	g.	h.	i.	k.	l.	m.	n.	o.	p.	q.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North.....	−21 55	−22 0	−21 35	+ 6 12	+ 6 7	0 0	−15 53	−21 35	0 0	−21 35	− 1 48	−23 23	0 0	0 0	−21 35	0 0
			−22 14			+ 4 15		−17 59	− 1 13	−19 12	− 1 28	−20 40	+ 3 2	+ 2 30	−19 44	− 0 32
N. N. E...	−19 20	−19 25	−22 2	+ 9 46	+ 9 57	+ 8 48	− 9 28	−13 14	− 2 29	−14 43	− 0 55	−16 38	+ 6 19	+ 5 40	−16 22	− 0 39
			−20 44			+11 47		− 8 57	− 3 18	−12 15	− 0 35	−12 50	+ 8 19	+ 7 30	−13 14	− 0 49
N. E......	−14 57	−15 0	−18 36	+ 9 31	+ 9 30	+12 30	− 5 30	− 6 6	− 3 15	− 9 21	+ 0 10	− 9 11	+ 9 15	+ 8 25	−10 11	− 0 50
			−15 54			+11 8		− 4 46	− 2 43	− 7 29	+ 1 18	− 6 11	+ 8 25	+ 7 40	− 8 14	− 0 45
E. N. E...	− 9 32	− 9 22	−12 40	+ 4 56	+ 5 7	+ 8 15	− 4 15	− 4 25	− 1 52	− 6 17	+ 1 50	− 4 27	+ 6 23	+ 5 55	− 6 45	− 0 28
			− 9 2			+ 4 35		− 4 27	− 1 8	− 5 35	+ 2 5	− 3 30	+ 2 27	+ 3 10	− 5 52	− 0 17
East......	− 3 33	− 3 30	− 4 58	− 1 30	− 1 35	0 0	− 5 4	− 4 58	0 0	− 4 58	+ 1 58	− 3 0	0 0	0 0	− 4 58	0 0
			− 0 43			− 4 43		− 5 26	+ 1 12	− 4 14	+ 1 40	− 2 35	− 3 31	− 3 10	− 3 53	+ 0 21
E. S. E...	+ 2 36	+ 2 42	+ 3 30	− 7 25	− 7 39	− 8 50	− 4 57	− 5 20	+ 2 20	− 3 0	+ 1 20	− 1 40	− 6 30	− 5 55	− 2 25	+ 0 35
			+ 7 44			−11 50		− 4 6	+ 3 2	− 1 4	+ 0 55	− 0 9	− 8 48	− 7 58	− 0 14	+ 0 50
S. E........	+ 8 36	+ 8 47	+11 35	−10 5	−10 12	−13 30	− 1 25	− 1 55	+ 3 40	+ 1 45	− 0 10	+ 1 35	− 9 50	− 8 58	+ 2 37	+ 0 52
			+15 0			−13 0		+ 2 0	+ 3 50	+ 5 50	− 0 55	+ 4 55	− 9 10	− 8 10	+ 6 50	+ 1 0
S. S. E. ...	+14 9	+14 10	+17 53	− 9 10	− 9 15	−10 15	+ 4 55	+ 7 18	+ 2 57	+10 35	− 1 35	+ 9 0	− 7 18	− 6 25	+11 28	+ 0 53
			+20 14			− 5 35		+14 39	+ 1 33	+16 12	− 2 15	+13 57	− 4 2	− 3 40	+16 34	+ 0 22
South.....	+18 45	+18 50	+21 35	− 5 24	− 5 33	0 0	+13 17	+21 35	0 0	+21 35	− 2 10	+19 25	0 0	0 0	+21 35	0 0
			+22 14			+ 5 7		+27 21	− 1 23	+25 58	− 1 45	+24 13	+ 3 42	+ 3 18	+25 32	− 0 24
S. S. W...	+21 43	+21 40	+22 2	+0 33	+0 10	+ 7 25	+21 50	+29 27	− 1 37	+27 50	− 1 3	+26 47	+ 5 48	+ 5 12	+27 14	− 0 36
			+20 44			+ 7 47		+28 31	− 1 20	+27 11	− 0 10	+27 1	+ 6 27	+ 5 50	+26 34	− 0 37
S. W.......	+21 52	+21 55	+18 36	+ 6 28	+ 6 45	+ 7 8	+28 40	+25 44	− 1 12	+24 32	+ 0 20	+24 52	+ 5 56	+ 5 25	+24 1	− 0 31
			+15 54			+ 6 8		+22 2	− 1 8	+30 54	+ 0 35	+21 29	+ 5 0	+ 4 34	+20 26	− 0 26

Table—Continued.

Points of the compass.	Polar deviation from ship's force = .378 of Earth's horizontal force at a starboard angle = 257°.			Quadrantal deviation from capacity for + horizontal induction = 0.3 of Earth's horizontal force.			Polar and + quadrantal deviation combined.		The preceding with the — quadrantal due to capacity. = .091 of Earth's horizontal force.		All the preceding, with the quadrantal deviation arising from oblique iron capacity, = .046 of Earth's force.			Polar deviation .378 combined with + quadrantal due to inductive capacity .209 = 0.3 — .091.		
	Ship's head, correct magnetic.		Ship's head by compass from curve.	Ship's head, correct magnetic.		Ship's head by compass from curve.	Ship's head, correct magnetic, or sums of columns *b* and *e*.	Ship's head by compass from curves or sums of cols. *c* and *f*.	Deviation from curve, ship's head, by compass.	Sum of columns *h* and *i*.	Deviation from curve, ship's head, by compass.	Sum of columns *k* and *l*.	Sum of columns *f* and *i*.	Deviation from curve, ship's head, by compass.	Sum of columns *c* and *o*.	Difference of columns *k* and *p* or *n* and *o*.
	By calculation.	By construction.		By calculation.	By construction.											
	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*	*i.*	*k.*	*l.*	*m.*	*n.*	*o.*	*p.*	*q.*
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
W. S. W..	+17 36	+17 38	+12 40	+10 10	+10 20	+ 4 20	+27 58	+17 0	— 0 52	+16 8	+ 0 50	+16 58	+ 3 28	+ 3 10	+15 50	— 0 18
			+ 9 2			+ 2 12		+11 14	— 0 30	+10 44	+ 0 55	+11 39	+ 1 42	+ 1 31	+10 35	— 0 9
West......	+ 7 40	+ 7 32	+ 4 58	+ 3 10	+ 3 23	0 0	+10 55	+ 4 58	0 0	+ 4 58	+ 0 45	+ 5 43	0 0	0 0	+ 4 58	0 0
			+ 0 43			— 2 8		— 1 25	+ 0 33	— 0 52	+ 0 35	+ 0 17	— 1 35	— 1 28	— 0 51	+ 0 7
W. N. W..	— 5 41	— 5 52	— 3 30	— 9 17	— 9 16	— 4 2	—15 8	— 7 34	+ 1 5	— 6 27	+ 0 32	— 5 55	— 2 57	— 2 42	— 6 12	+ 0 15
			— 7 44			— 5 40		—13 24	+ 1 35	—11 49	+ 0 18	—11 31	— 4 5	— 3 40	—11 24	+ 0 25
N. W.....	—16 26	—16 35	—11 35	— 7 40	— 7 55	— 6 50	—24 30	—18 25	+ 2 10	—16 15	0 0	—16 15	— 4 40	— 4 20	—15 55	+ 0 20
			—15 0			— 7 10		—22 10	+ 2 13	—19 57	— 0 45	—20 42	— 4 57	— 4 22	—19 22	+ 0 35
N. N. W..	—21 30	—21 40	—17 53	— 0 33	— 0 17	— 6 30	—21 57	—24 23	+ 1 48	—22 35	— 1 3	—23 38	— 4 42	— 4 5	—21 58	+ 0 37
			—20 14			— 4 16		—24 29	+ 1 10	—23 19	— 1 25	—24 54	— 3 5	— 2 38	—22 52	+ 0 27

APPENDIX M.

Extracts from compass logs of iron ships.

"ADVANCE," Captain Dalison.—May, 1855, to October, 1860.
"ASTRÆA," Captain S. Nickels.—August, 1856, to January, 1859.
"SIMLA," Captain W. Williams.—September, 1858, to October, 1860.
"APHRODITA," Captain H. Stewart.—August, 1858, to July, 1859.
"SLIEVE DONARD," Captain Thompson.—March, 1859, to February, 1860.

IRON SHIP "ADVANCE," CAPTAIN DALISON.

Liverpool to Colombo.

Date.	Latitude. By observat'n.	Latitude. By dead reckoning.	Longitude. By chronometer.	Longitude. By dead reckoning.	Difference between position by observation and by dead reckoning. Direction.	Difference … Amount.	Winds. Direction.	Winds. Force.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Standard compass, (uncompensated.) Head by compass.	Standard compass. Total error.	Standard compass. Deviation.	Steering compass, (compensated.) Head by compass.	Steering compass. Total error.	Steering compass. Deviation.
	North. ° ′	*North.* ° ′	*West.* ° ′	*West.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
1855. May 2	46 55	46 21	11 45	10 37	....	....	Easterly......	7	....	....	....	....	....	....	....	....
3	43 29	43 39	13 52	13 15	S. 70 W.	29	N. E. by E...	6	....	....	....	....	....	....	....	....
4	39 59	40 10	14 26	14 12	S. 47 W.	16	N. E. by N....	5	....	....	....	....	....	....	....	....
5	36 54	36 59	15 22	15 25	S. 77 W.	23	N. E. by N....	4	....	....	....	....	....	....	....	....
6	34 41	34 42	17 1	16 50	S. 85 W.	11	N. E. by E....	3	62 0	23 0 W.	S. 45 W.......	21 15 W.	+ 1 45	S. W. ½ S......	29 41 W.	— 6 41
7	32 15	32 2	17 54	17 48	S. 37 W.	5	E. by N.	3	....	....	....	....	....	....	....	....
8	29 23	29 19	....	19 26	....	....	E. N E........	6	....	....	....	....	....	....	....	....
9	25 59	25 4	21 12	21 13	S. 1 E.	45	E. N. E........	4	56 0	20 30	S. 50 W........	21 0	— 0 30	S. 42 W........	13 0	+ 7 30
10	23 15	23 22	22 52	22 33	S. 65 W.	17	E. N. E........	4	53 0	19 30	S. 50 W........	20 0	— 0 30	S. 42 W........	12 0	+ 7 30
11	20 43	20 43	24 10	24 4	S. 77 W.	5	N. E. by E....	3	....	....	....	....	....	....	....	....
12	18 25	18 23	24 55	25 10	N. 85 E.	12	N. E...........	4	....	....	....	....	....	....	....	....
13	16 17	16 11	27 8	26 14	N. 83 W.	49	N. E...........	4	47 0	16 0	S.W. by S.½S.	25 36	— 9 36	S. W. by S....	20 0	— 4 0
14	13 13	13 40	27 14	26 3	N. 89 W.	60	East............	3	42 0	15 30	S. 17 W........	25 30	—10 0	S. 11 W........	19 30	— 4 0
15	11 0	11 12	26 22	26 59	N. 72 E.	39	E. by S........	3	40 0	15 30	S. 14 E........	29 27	—13 57	S. S. E.........	37 57	—22 27
16	8 41	8 32	24 40	24 1	S. 77 W.	40	East............	3	....	....	....	....	....	....	....	....
17	....	6 11	....	22 25	....	....	V'ble S. W...	2 to 4	....	....	....	....	....	....	....	....
18	....	4 23	21 29	21 15	....	....	S. W. by S....	5	28 0	17 0	S. 10 E........	33 41	—16 41	S. by E. ½ E..	26 49	— 9 40
19	....	3 45		20 33			S. W...........	2	....	....	....	....	....	....	....	....
20	3 36	3 48	19 14	19 37	S. 62 E.	26	S. W. by S....	3	....	....	....	....	....	....	....	....
21	....	3 6	....	18 58	....	....	S. W. by S. ..	4	25 0	18 0	S. 58 E........	26 51	— 9 51	E. S. E.........	17 20	+ 0 40
22	1 50	2 17	18 21	18 35	S. 41 E.	45	S. by W.......	5	23 0	18 20	S. 59 W........	22 32	— 4 12	S. 68 W........	41 32	—23 12
	South.	*South.*														
23	0 22	0 23	20 42	20 4	N. 88 W.	37	S. S. E.........	4	....	....	....	....	....	....	....	....
24	2 57	3 1	21 54	21 25	N. 42 W.	13	S. S. E.........	5	17 30	16 45	S. 43 W........	21 8	— 4 23	S. 45 W........	23 8	— 6 23
25	6 27	5 24	23 10	23 24	S. 85 W.	45	S. E.............	4	14 0	16 0	S. 27 W........	21 55	— 5 55	S. S. W........	17 25	— 1 25
											S. 1 E.	27 58	—11 28	S. by E........	17 43	— 2 13
											S. 8 W........	25 3	— 0 33	South...........	17 3	— 1 33
											S. 17 W........	23 48	— 8 18	S. by W........	18 3	— 2 33

		4 16	....	22 23	....	....	....	....	15 0	15 30	S. 25 W.	20 0	— 4 30	S. S. W.	17 30	— 2 0
											S. 33 W.	21 55	— 6 25	S. W. by S.	22 40	— 7 10
											S. 43 W.	21 14	— 5 44	S. W.	23 14	— 7 44
											S. 51 W.	19 43	— 4 13	S. W. by W.	24 58	— 9 28
26	8 3	8 7	23 40	23 37	N. 53 W.	7	S. E. by S.	4	10 0	15 40	S. 26 W.	22 10	— 6 30	S. S. W.	18 20	— 2 40
27	11 13	11 18	24 2	23 49	N. 65 W.	15	S. E.	4	4 0	15 0	S. 33 W.	23 20	— 8 20	S. by W. ¼ W.	5 2	....
											?S. 22 W.	....	....	....	?17 2	— 2 2
28	13 31	13 16	23 58	23 35	....	....	East	2	0 0	14 30	S. 17 W.	23 58	— 8 28	S. by W.	18 13	— 3 43
											S. 12 W.	24 58	—10 28	South	12 58	+ 1 32
											S. 3 W.	25 58	—11 28	S. by E.	11 43	+ 2 47
29	14 46	14 48	23 22	22 57	S. 78 W.	39	E. by N.	1	— 2 30	14 45	S. 14 E.	31 15	—16 30	S. E. by S.	11 30	+ 3 15
30	16 1	15 48	....	23 5	....	....	Variable E.	1	— 4 0	14 45	S. 18 W.	25 33	—10 48	S. by W.	18 48	— 4 3
31	16 43	16 47	....	22 27	....	....	N. W.	1	....	....	....	....	....	....	....	....
June 1	18 5	17 58	21 34	21 50	S. 67 E.	18	S. E. by S.	5 to 8	—10 0	15 30	S. 42 W.	25 41	10 11 W.	S. 46 W.	29 30	14 0 W.
2	19 40	19 46	22 2	21 56	N. 46 W.	9	....	....	—11 0	15 15	S. 67 E.	23 26	8 11	East	0 16	14 59 E.
							S. E. by S.	2	....	....	S. 41 W.	24 18	9 3	S. 43 W.	26 18	11 3 W.
3	21 25	21 23	22 8	22 9	....	....	S. E. by E.	3	—13 0	14 40	S. 8 30 W.	27 54	13 14	S. 5 30 E.	13 58	0 42 E.
4	23 10	23 20	21 33	21 22	N. 50 W.	14	E. by N.	4	—16 0	14 50	S. 40 E.	31 22	16 32	E. S. E.	3 52	10 58
											S. 35 E.	32 22	17 32	S. E. by E.	11 7	3 43
											S. 20 E.	31 52	17 2	S. E.	6 52	7 58
											S. 12 E.	30 22	15 32	S. E. by S.	8 37	5 13
											S. 3 E.	29 22	14 32	S. S. E.	9 52	4 58
											S. 4 W.	28 22	13 32	S. by E.	13 7	1 43 E.
											S. 11 W.	27 22	12 32	South	16 22	1 32 W.
5	24 24	24 40	19 36	19 27	S. 64 W.	9	N. E. by E.	4	—20 0	15 30	S. 18 E.	34 10	18 40	S. E.	7 10	8 20
											S. 20 E.	35 59	20 29	S. E. ¼ E.	5 22 W.	19 8 W.
6	26 30	25 59	17 10	17 0	S. 67 W.	10	W. N. W.	6	—23 0	16 30	....	....	....	....	....	....
7	26 20	26 55	15 20	15 54	....	....	S. E. by E.	6	—23 0	18 0	N. 46 E.	1 24	16 36 E.	N. 41 E.	3 36 E.	21 36 E.
											N. 64 E.	8 15	9 45	N. E. ¼ E.	5 8	23 8
											E. by N.	17 8	0 52	....	....	....
8	25 17	25 5	14 18	13 25	S. 76 W.	50	S. Easterly	4	—23 0	18 40	N. 52 E.	3 12	15 28	N. 42 E.	6 48	25 28
											N. E. ¼ E.	1 16	17 24 E.	N. E. by N.	5 36 E.	24 16 E.
9	25 57	25 27	13 40	14 14	S. 45 E.	42	Calm	....	—24 0	19 0	S. 15 E.	37 5	18 5 W.	S. 31 E.	21 5 W.	2 5 W.
10	26 9	26 26	13 1	13 13	N. 58 E.	13	Northerly	2	....	....	....	....	....	....	....	....
11	....	27 16	....	11 48	....	....	W. N. W.	3	—27 0	20 0	S. 8 E.	38 22	18 22	S. E.	1 22 W.	18 38 E.
											S. 15 E.	40 22	20 22	S. E. by E.	0 53 E.	20 53
											S. 22 E.	39 22	19 22	E. S. E.	4 8	24 8
											S. 31 E.	35 22	15 22	E. by S.	12 23	32 23
											S. 35 E.	35 52	15 52	East	19 8	39 8
12	28 42	28 51	9 15	9 36	N. 59 W.	17	N. W.	5	—30 30	....	....	....	....	....	....	....
13	29 14	29 47	6 50	6 31	N. 37 W.	41	S. and S. E.	7 to 3	—32 30	22 20	S. 53 E.	34 0	11 40	....	....	....
14	29 48	30 3	4 46	4 53	N. 50 W.	14	N. E. and N.	6	....	....	....	....	....	....	....	....
15	31 41	31 32	1 14	1 19	S. 28 W.	10	North	8	—39 0	24 0	S. 16 E.	44 34	20 34	S.E. by E. ¼ E.	1 18	25 18
			East.	*East.*												
16	33 20	33 23	2 58	2 45	....	....	W. by S.	10 to 8	—43 30	25 40	S. 19 E.	46 36	20 56	E. by S. ¼ S.	7 31	33 11
17	34 10	34 18	5 19	5 23	N. 22 W.	9	N. W.	4 to 9	—46 0	26 0	S. 18 E.	48 25	22 35 W.	E. by S. ¼ S.	6 32	32 32
18	35 20	35 20	9 2	9 21	West	16	West	9	....	....	....	....	....	....	....	....
19	36 22	36 27	12 44	12 52	N. 52 W.	8	W. by S.	6	....	....	....	....	....	....	....	....
20	37 8	37 21	15 58	16 0	N. 5 W.	20	Southerly	4	....	....	....	....	....	....	....	....
21	36 32	36 22	18 37	19 0	....	....	S. E. by E.	4	—53 30	29 40	N. 55 E.	9 40	20 0 E.	N. E. ¼ N.	5 58	35 28
22	....	36 49	....	18 26	....	....	E. S. E.	4	—53 30	29 40 W.	N. 55 E.	9 40 W.	20 0 E.	N. E. ¼ N.	5 58 E.	35 28 E.
23	38 26	37 15	21 40	20 18	N. 42 E.	96	N. W. by W.	4 to 7	....	....	....	....	....	....	....	....

Iron ship "Advance"—Liverpool to Colombo—Continued.

Date.	Latitude. By observa'n.	Latitude. By dead reckoning.	Longitude. By chronometer.	Longitude. By dead reckoning.	Difference between position by observation and by dead reckoning. Direction.	Difference … Amount.	Winds. Direction.	Winds. Force.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Standard compass, (uncompensated.) Head by compass.	Standard compass. Total error.	Standard compass. Deviation.	Steering compass, (compensated.) Head by compass.	Steering compass. Total error.	Steering compass. Deviation.
	South. ° ′	South. ° ′	East. ° ′	East. ° ′	°	Miles.			° ′	° ′	°	° ′	° ′	°	° ′	° ′
1855. June 24	38 58	38 55	24 0	22 53	S. 86 E.	53	Calm	0	—57 30	31 10 W.	S. 24 E.	32 18 W.	1 8 W.	S. 14 E.	42 18 W.	11 8 W.
25	39 11	39 27	26 41	26 31	N. 25 E.	18	N. by E.	3								
26	39 11	39 7	29 22	29 31	N. 51 W.	10	S. E. by S.	5								
27	38 31	38 53	32 46	33 8	N. 22 W.	24	W. by S.	8	—60 0	30 40	S. E.	51 37	20 57	N.E.by E.¼ E.	21 31 E.	52 11 E.
28		38 3		37 43			S. W.	9 to 11	—61 0	29 30	S. E. ¼ S.	55 17	25 47	N.E.by E.¼ E.	23 29	52 59
29	35 59	36 40	40 36	41 38			South	11 to 7								
30	35 12	35 25	42 40	43 36	N. 47 W.	47	S. E. by S	6 to 3								
July 1	34 43	34 49	43 43	43 50	N. 54 W.	10	Calm	0								
2	35 11	34 53	44 52	44 43	S. 62 W.	38	W. N. W.	3								
3	36 3	36 1	48 8	47 59	S. 72 E.	6	W. by N.	5	—62 0	25 30	S. 15 E.	42 30	17 0 W.	N. 77 E.	45 30	71 0
4		35 21		52 35			N. W. by W.	6								
5	33 34	33 45	56 2	56 20	N. 54 W.	14	W. N. W.	5 to 1	—62 0	20 30	E. by N. ¼ N.	10 53 W.	9 37 E.	N. E. ¼ N.	22 52	43 22
							S. E.									
											N. 55 E.	3 51 E.	24 21	N. E. by N.	25 6	45 36
											N. 26 E.	24 15 E.	44 45	N. N. E.	27 45 E.	48 15 E.
6	32 54	32 46	57 35	56 48			V'ble E.N.E.	2	—62 0	19 30	N. 36 W.	8 30 W.	11 0	N. 15 W.	29 30 W.	10 0 W.
											N. 15 W.	0 30 E.	20 0	North	14 30 W.	5 0 E.
7	32 10	32 7	58 42	59 5	S. 82 W.	22	W. N. W.	1 to 3	—62 0	18 30	N. 55 E.	1 50	20 20	N. E. by N.	23 5 E.	41 35
											N. 15 E.	13 10 E.	31 40	N. by E. ¼ E.	11 18	29 48
8	31 40	31 15	61 37	61 32			N. N. W.	4	—62 0	17 20	E. N. E.	0 20 W.	17 0	N. E. ¼ N.	28 28	45 48
											N. ¼ E.	8 40 E.	26 0	N. by E.	3 2 E.	20 22
9	30 57	30 58	62 57	62 44	N. 62 E.	2	N. N. W.	1	—61 30	16 20	N.W.by N.¼ N	1 20	17 40	N. by W.	11 32 W.	4 48
10	29 27	29 13	63 27	63 44	N. 58 E.	21	S.E. to E.S.E.	4								
11	26 33	26 42	64 2	64 46	N. 77 E.	40	E. S. E.	3	—57 30	11 0	N. 25 E.	6 38	17 38	N. N. E.	9 8 E.	20 8
12	24 17	24 17	64 57	64 52	N. 84 E.	5			—57 0	10 15	N. 11 W.	4 38	14 53	North	6 22 W.	3 53
13	20 27	20 59	65 27	65 52	N. 47 E.	33	Easterly	6 to 7	—53 30	7 40	N. 7 E.	7 21	15 1	N. by E.	3 6 E.	10 46
											N. 18 E.	8 20	16 0	N. by E. ¼ E.	9 26	17 0
14	17 37	17 40	66 21	66 23	N. 10 E.	12	E. S. E.	5	—50 30	5 40	N. 22 E.	11 57	17 37	N. 20 E.	13 15	18 55
15	14 38	14 32	6 0	67 30	S. 78 W.	30	E. S. E.	5	—47 30	4 30	N. 9 E.	9 30	14 0	N. 15 E.	3 30	8 0
16	11 7	11 15	67 51	8 52	N. 75 W.	33	E. S. E.	4 to 7	—41 0	3 20	N. 2 E.	6 9	9 29	N. 8 E.	0 9	3 20
17	8 26	8 29	05 41	09 7	N. 83 W.	30	V'ble E'y	5 to 7	—37 0	3 0	N. 40 E.	11 20	14 20	N. E. by N.	17 35	20 35

18	6 22	6 30	70 20	70 25	N. 33 W.	11	V. S. E. by S.	6	—31 0	2 0						
19	3 17	3 28	72 15	72 9	N. 23 E.	12	South	4	—26 0	1 30	N. 28 E.	14 0	15 30	N. 28 E.	14 0	15 30
20	0 50	1 14	73 9	73 10	N. 3 W.	23	South	3								
	North.	*North.*														
21	0 25	0 14	74 18	74 34	N. 22 W.	21	S. S. W.	2	—19 0	0 40	N. 30 E.	13 0	13 14	N. 30 E.	13 0	13 40
22	1 25	1 26	75 32	75 35			N. W.	4	—16 0	0 25 W.	N. 30 E.	14 30	14 55	N. 30 E.	14 30	14 55
23	3 26	3 40	77 56	77 33	S. 53 E.	29	N. W.	7	—13 0	0 0	N. 15 E.	14 12	14 12	N. by E. ½ E.	9 20	9 20
24	6 7	5 53	79 29	79 29	North	14	V'le W. N. W.	5	— 7 0	0 20 E.	N. N. E.	11 0 E.	10 40 E.	N. 20 E.	13 30 E.	13 10 E.

MADRAS TO LIVERPOOL.

Oct. 6	12 18		82 6				East	1 to 4								
7	10 51	10 51	81 15	81 22	East	17	West	3								
8	8 34	9 13	81 53	82 11	S. 67 W.	43	S. S. W.	4 to 1	— 2 0	0 45 E.	S. 2 E.	7 27 W.	8 12 W.	S. 14 E.	4 33 E.	3 48 E.
9	8 13	8 22	82 27	82 12	S. 59 E.	18	South	1	— 4 0	0 45	S. 26 E.	1 48	2 33	S. 45 E.	17 12	16 27
10	7 11	7 20	84 12	83 0	S. 83 E.	73	S. S. W.	4								
11	6 33	6 34	84 36	84 55	S. 86 W.	18	S. S. W.	3	— 6 0	0 45	W. by N.	0 0	0 45	N. W. by W.	22 30 W.	23 15 W.
											S. 35 E.	9 30	10 15	S. E. by E.	11 45 E.	11 0 E.
12	5 21	5 32	86 19	86 44	S. 65 E.	28	S. S. W.	3	— 7 30	1 0	S. 42 E.	9 25	10 25	S. 65 E.	13 35 E.	12 35 E.
13	4 25	4 18	87 30	86 40	N. 48 W.	50	S. S. W.	3	— 9 0	1 0	S. 7 W.	7 42	8 42	South	0 42 W.	1 42 W.
14	3 21	3 16	88 32	88 13	N. 47 E.	20	S. W. by W.	3								
15	2 52	2 47	89 18	88 46	N. 80 E.	30	West	1								
16	1 5	1 11	89 22	89 7	S. 68 E.	16	West	4								
	South.	*South.*														
17	0 30	0 27		89 20			Westerly	1 to 3								
18	1 43	1 28	89 58	89 10	S. 72 E.	50	Westerly	1	—20	0 40 E.	S. 14 W.	6 39	7 19	S. 10 W.	2 39 W.	3 19 W.
19	2 25	2 21	90 12	89 42	S. 82 E.	31	N. W.	2								
20	2 45	2 50	90 26	89 55	N. 80 E.	32	South	1								
21	3 45	3 54	89 28	89 16	N. 53 E.	14	S. S. E.	5								
22		5 28		87 45			East	5	—29	0 0	S. 67 W.	2 11	2 11	S. W. ½ W.	14 49 E.	14 49 E.
23	7 9	7 12	86 0	85 45	N. 77 E.	16	S. E.	5								
24	8 5	8 55	83 29	84 5	N. 85 E.	36	S. E. by S.	3	—34 0	0 50 W.	S. 65 W.	2 19	1 29	West	27 19 W.	26 29 W.
											S. 47 W.	4 0	3 10	W. S. W.	24 30	23 40
25	10 2	10 4	82 13	82 2	N. 75 W.	10	East	1	—37 30	1 20	S. 47 W.	4 0	2 40	S. 74 W.	31 0	29 40
26		10 31	81 8	81 43			Calm	0								
27	11 21	11 3	80 49	80 32	N. 49 E.	16	E. S. E.	1								
28	12 24	12 27	79 21	79 16	N. 70 E.	6.7	S. S. E.	5	—41 30	2 0	S. 58 E.	3 53	1 53	S. 84 E.	29 53	27 53
29	14 6	13 59	76 28	77 6	S. 75 E.	27	S. by E.	6								
30	15 23	15 53	74 30	74 44	S. 48 W.	23.5	S. S. E.	4	—47 30	3 20	S. 59 W.	5 19	1 59	West	36 19	32 59
31	16 46	16 50	71 46	72 24	N. 80 E.	21.5	S. by W.	6								
Nov. 1	17 58	18 16	69 20	69 35	N. 52 W.	29	S. by W.	5	—52 0	5 30	S. 66 W.	7 0	1 30	W. by N.	42 15	36 45
2	19 28	19 28	66 26	66 3	West	3	S. by E.	5	—53 0	7 0	S. 59 W.	10 0	3 0	West	41 0	34 0
3	20 17	20 26	64 13	63 58	N. 17 E.	9.4			—53 30	7 40	S. 77 W.	9 37	1 57	W. N. W.	45 7	37 27
							S. E. by S.	6			S. 77 W.	10 10	2 30	W. N. W.	45 40	38 0
4	21 32	21 12	61 9	61 9	S. 86 W.	18	South	5	—54 0	9 0						
5	22 0	22 32	59 17	59 5	N. 25 W.	35.3	S. E.	4	—55 0	10 20	S. 77 W.	12 13	1 53	N. 63 W.	52 13	41 53
6	23 3	23 2	57 27	57 15	N. 82 E.	7	S. E. by E.	4	—55 30	11 45						
7	23 56	23 59	55 42	55 34	N. 67 E.	8	E. S. E.	3	—56 30	13 15	S. 77 W.	17 17	2 2	N. 63 W.	54 17	41 2
8	24 38	24 28	54 33	54 33	South	10	E. S. E.	1	—57 0	13 45	S. 80 W.	15 52	2 7	N. 60 W.	55 53	42 8

Iron ship "Advance"—Madras to Liverpool—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1855.	*South.* ° ′	*South.* ° ′	*East.* ° ′	*East.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
Nov. 9	25 4	25 13	54 15	53 59	S. 72 E.	3	East...........	1	—57 0	14 20 W.	S. 69 W........	15 2 W.	0 42 W.	N. 67 W........	59 2 W.	44 42 W.
							S. W...........	3	....	....	....	....	....	....	....	....
10	25 46	26 13	51 50	52 52	N. 5 W.	27	S. S. E........	6	....	....	....	....	....	....	....	....
11	27 12	27 18	49 39	49 7	N. 79 W.	31	S. E...........	4	....	....	....	....	....	....	....	....
12	....	28 10	47 56	47 29	....	....	E. S. E........	3	....	....	....	....	....	....	....	....
13	28 39	29 3	45 4	45 6	N. 5 W.	24	S. S. W........	6	....	....	....	....	....	....	....	....
14	29 15	29 39	42 33	42 20	N. 24 E.	26	S. W. by W...	6	—58 0	23 15	S. 78 W........	22 42	0 33 E.	N. W...........	2 42	39 27
											S. 88 W........	20 43	2 32	N. W.W........	61 16	38 1
15	30 36	30 31	39 20	39 27	N. 67 W.	5	S.W. by S.....	5	—57 30	24 45	W. 6 S........	25 8	0 23 W.	N. 51 W........	70 0	45 15
16	31 58	31 49	37 12	37 14	S. 65 E.	2.3	South..........	2	—57 30	26 15	S. 76 W........	25 0	1 15 E.	N. 67 W........	62 0	35 45
											S. 82 W........	26 15	0 0	N. 54 W........	70 15	44 0
17	32 36	32 32	35 5	35 10	N. 47 W.	6	N. Easterly..	3	—57 30	27 15	N. 79 W........	25 46	1 29 E.	N.W. ½ W.....	65 23	37 8
											N. 87 W........	25 2	2 13 W.	N.W............	67 2	39 47
18	32 51	32 47	33 5	33 10	S. 51 E.	5.3	E. by N........	3	—57 30	28 0	N. 85 W........	27 53	0 7 E.	N. 44.5 W.....	68 23	40 23
											N. 68 W........	26 55	1 5	N. 34 W........	60 55	32 55
19	33 18	33 2	30 34	30 32	S. 6 E.	16	E. N. E........	2	....	....	....	....	....	....	....	....
20	33 48	33 40	29 30	28 54	....	....	East...........	3	—57 0	29 15	N. 70 W........	26 29	2 46	N. 34.5 W.....	61 59	32 44
21	34 16	34 1	27 46	27 17	S. 58 E.	28.4	S. W...........	4	—56 0	29 30	N. 69 W........	24 54	4 36	N. 35 W........	58 55	29 25
							S. E.									
22	34 19	34 22	25 6	25 50	N. 85 W.	33.5	S. E...........	3	....	....	....	....	....	....	....	....
							N. E...........	4								
23	35 13	35 6	23 7	23 1	....	....	S. E. by S.....	4	—55 0	30 0	N. 47 W........	23 56	6 4	N. 19 W........	51 56	21 56
											S. 88 W........	24 8	5 52	N. 49 W........	67 8	37 8
24	34 57	34 59	21 9	21 4	N. 65 E.	5	N.W. by W...	7	—54 30	29 50	N. 58 W........	24 48	5 2 E.	N. 27 W........	55 48	25 58
25	34 52	35 21	21 2	20 35	....	....	N.W. by W...	5	—54 30	29 50	S. 16 W........	39 35	9 45 W.	S. 44 W........	67 35	37 45 W.
26	35 35	35 33	20 37	20 8	S. 83 E.	16.5	N. N.W........	6	....	....	....	....	....	....	....	....
27	35 11	36 19	20 35	19 49	N. 78 E.	39	N.W. by W...	2	—54 30	29 50	N. 3 E........	14 45	14 5 E.	N. 14 E........	25 45	4 5 E.
28	34 50	35 0	20 14	20 0	N. 49 W.	15	W. S.W........	2	—54 30	29 50	S. 84 W........	30 18	0 28 W.	N. 54 W........	72 18	42 28 W.
29	34 43	34 45	18 39	18 34	N. 62 E.	4.3	S. E...........	5	—53 0	29 30	N. 15 W........	15 0	14 30 E.	N. 1 E........	31 0	1 30
							South..........	6								
											N. 0 W........	17 11	11 19	N. 4 E........	30 11	6 41

											N. 19 W.	19 11	10 19	N. 3 W.	35 11	5 41
Dec. 30	33 28	33 28	16 57	17 35	West	45.5	N. E. by E.	3	—52 0	20 20	N. 65 W.	26 47	2 33	…	…	…
1	31 59	31 50	15 28	15 33	S. 27 W.	10	S. S.W.	4	…	…	…	…	…	…	…	…
2	29 53	29 48	…	12 56	…	…	S.W. by S.	5	…	…	…	…	…	…	…	…
3	27 49	27 44	11 10	10 25	S. 83 E.	41	S.W. by S.	5	…	…	…	…	…	…	…	…
4	26 26	26 29	9 4	9 14	N. 73 E.	10	S. by W.	3	—41 0	27 40	N. 35 W.	22 0	5 40	N. 15 W.	42 0	14 20
											N. 30 W.	17 30	(Az.)			
													10 10			
5	25 18	25 20	7 27	7 30	N. 58 W.	4	S. by E.	4	—39 30	27 20	N. 32 W.	21 50	5 30	N. 13 W.	40 50	13 30
6	24 10	24 11	5 43	5 51	N. 83 W.	8.2	S. by E.	2	…	…	…	…	…	…	…	…
7	23 23	23 23	4 29	4 34	West	4.8	S. by W.	1	—35 0	26 45	N. 29 W.	20 59	5 46	N. 11 W.	38 59	12 14
8	22 21	22 34	3 25	3 25	North	12	W. S. W.	2	—32 30	26 30	N. 29 W.	21 23	5 7	N. 11 W.	39 23	12 53
											N. 29 W.	19 39	6 51	N. by W.	37 24	10 54
											N. 14 W.	18 39	7 51	North	32 39	6 9
9	21 11	21 30	2 24	2 21	N. 9 E.	9	S. S.W.	3	—30 0	26 20	N. 32 W.	19 35	6 45	N. 13 W.	38 35	12 15
10	20 16	20 14	1 2	1 15	S. 59 W.	3.9	S. by E.	3	…	…	…	…	…	…	…	…
			West.	*West.*												
11	19 25	19 12	0 12	0 18	S. 22 E.	14	S. by E.	3	—25 0	25 40	N. 34 W.	18 51	6 49	N. 15 W.	37 51	12 11
12	18 24	18 22	1 42	1 38	S. 64 W.	4.6	S. E. by S.	3	—22 30	25 20	N. 32 W.	20 23	4 57	N. 14 W.	38 32	13 12
13	17 41	17 32	3 2	2 55	S. 34 W.	10.9	S. S. E.	4	—20 30	24 45	N. 32 W.	20 9	4 36	N. 15 W.	37 9	12 24
14	16 41	16 40	4 28	4 23	S. 80 W.	5.7	…	…	—17 0	24 20	N. 32 W.	19 20	5 0	N. 14 W.	37 20	13 0
											N. 39 W.	21 51	2 29	N. 20 W.	39 51	15 31
14	16 41	16 40	4 28	4 23	S. 80 W.	5.7	S. S. E.	4	—17 0	24 20	N. 27 W.	19 47	4 33	N. 13 W.	33 17	8 57
											N. 10 W.	16 47	7 33	North	26 47	2 27
15	15 48	15 48	5 42	5 46	West	2.9	S. S. E.	2	—15 0	24 0	N. 30 W.	18 14	5 46	N. 15 W.	33 14	9 14
											N. 24 W.	19 14	4 46	N. 11 W.	32 14	8 14
16	14 54	14 54	6 45	6 41	West	3.9	S. E. by S.	4	—13 0	23 40	N. 26 W.	17 10	6 30	N. 11 W.	32 10	8 30
17	13 48	13 45	8 14	7 59	S. 74 W.	17.7	S. E. by S.	3	—10 30	23 0	N. 34 W.	19 20	3 40	N. 18 W.	35 21	12 21
											N. 32 W.	18 0	5 0	N. 16 W.	34 0	11 0
18	12 47	12 42	9 13	9 23	S. 63 E.	11.0	S. by E.	4	…	…	…	…	…	…	…	…
19	11 36	11 33	10 36	10 21	S. 81 W.	15.0	S. S. E.	4	— 4 0	22 15	N. 27 W.	18 30	3 45	N. 12 W.	33 30	11 15
20	10 21	10 41	11 59	12 8	S. 52 E.	11	S. E. by S.	4	…	…	…	…	…	…	…	…
21	8 37	9 2	13 4	13 14	N. 61 E.	11	S. E. by S.	4	2 0	21 20	N. 19 W.	15 43	5 37	N. 9 W.	25 43	4 23
22	7 40	7 35	14 19	14 24	S. 48 E.	7	S. E. by S.	4	4 0	21 0	N. 51 W.	20 50	0 10	N. 32 W.	39 30	18 50
23	6 8	6 5	15 24	15 24	South	3	S. E. by S.	4	…	…	…	…	…	…	…	…
24	4 35	4 35	16 28	16 22	West.	6	S. E. by S.	4	…	…	…	…	…	…	…	…
25	3 6	3 4	17 41	18 27	S. 84 W.	14	S. by E.	4	…	…	…	…	…	…	…	…
26	1 40	1 40	18 44	18 25	West	15	S. S. E.	3	17 30	18 30	N. 19 W.	14 1	4 29	N. 7 W.	26 1	7 31
27	0 29	0 27	19 9	19 14	N. 30 E.	9	S. by E.	1	20 0	18 0	N. 19 W.	12 41	5 19	N. 1 W.	24 41	6 41
											N. 19 W.	12 38	5 22	N. 1 W.	24 38	6 38
											N. 3 W.	11 21	6 39	N. 7 E.	21 21	3 21
											N. 2 E.	10 21	7 39	N. 11 E.	23 21	5 21
	North.	*North.*														
28	0 59	0 51	19 58	19 26	N. 76 W.	34	South	3	22 30	17 40	N. 11 E.	9 14	8 26 E.	N. 18 E.	16 14	1 26
29	…	2 34	…	19 58	N. 73 W.	45	Variable	3	…	…	…	…	…	…	…	…
30	3 16	3 3	20 44	20 1			Easterly	1	26 0	17 20	N. 61 W.	18 35	1 15 W.	N. 47 W.	32 35	15 15
31	…	3 25	20 50	20 49			Vble. S. E.	1	26 0	17 20	N. 62 W.	18 12	0 52 W.	N. 47 W.	33 12	16 52
1856. Jan. 1	…	4 18	…	20 53	S. 63 E.	37	Calm	0	…	…	…	…	…	…	…	…
2	5 2	5 19	20 33	21 6			Easterly	2	…	…	…	…	…	…	…	…
3	5 21	5 19	20 23	20 33	N. 73 E.	11	Calm	0	29 0	17 30 W.	N. 20 W.	12 21 W.	4 9 E.	N. 9 W.	23 21 W.	5 51 W.
4	5 37	5 36	20 18	20 30	N. 85 E.	12	N. E. by E.	1	…	…	…	…	…	…	…	…

Iron ship "Advance"—Madras to Liverpool.—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1856.	North. ° ′	North. ° ′	West. ° ′	West. ° ′	°	Miles.			° ′	° ′	°	° ′	° ′	°	° ′	° ′
Jan. 5	6 9	6 17	20 41	20 46	N. 32 E.	10	Easterly	2	30 0	17 15 W.	N. 10 W.	12 13 W.	5 2 E.	N. 1 E.	23 13 W.	5 58 W.
											N. 25 W.	14 13	3 2	N. 13 W.	26 13	8 58
											N. 35 W.	16 13	1 2	N. 21 W.	30 13	12 58
6	6 24	6 47	21 44	21 9	S. 41 E.	6	N. E. by E.	1 to 4	32 0	17 15	N. 25 W.	14 17	2 58	N. 13 W.	26 17	9 2
7	7 53	8 00	22 45	22 19	S. 74 W.	26	N. E. by E.	4	...	...	...	...	...	...	...	...
8	9 17	9 25	24 2	23 54	S. 45 W.	11	N. E. by E.	4	37 0	16 20	N. 23 W.	11 39	4 41	N. 11 W.	23 39	7 19 W.
9	10 37	10 36	25 2	25 13	N. 82 E.	11	N. E.	4	...	...	...	...	...	...	...	...
10	12 4	12 5	26 40	25 57	N. 89 W.	40	N. E. by E.	5	42 0	16 0	N. 3 W.	6 27	9 33	N. 6 E.	15 27	0 33 E.
11	13 37	13 47	27 52	27 48	S. 20 W.	10	N. E. by E.	6	44 0	15 50	N. 30 W.	12 16	3 34	N. 22 W.	20 16	4 26 W.
12	15 13	15 17	29 0	28 43	S. 70 W.	11	N. E. by E.	6	...	...	...	...	...	...	...	...
13	16 38	16 34	29 57	29 49	N. 62 W.	9	E. N. E.	4	48 0	15 15	N. 24 W.	9 32	5 43	N. 13 W.	20 32	5 17
											N. 10 W.	7 30	7 45	North	17 30	2 15
14	17 54	17 54	30 12	30 4	West	7	East	2	50 30	15 30	N. 6 E.	5 33	9 57	N. 16 E.	15 33	0 3
							S.W.	4								
											N. 12 E.	5 31	9 59	N. 20 E.	15 31	0 1
											N. 27 E.	6 59	8 31	N. 36 E.	15 59	0 29 W.
											N. 43 E.	7 41	7 49	N. 48 E.	12 41	2 49 E.
											N. 12 E.	4 31	10 59	N. 21 E.	13 31	1 59
											N. 26 E.	5 31	9 59	N. 34 E.	13 31	1 59
											N. 54 E.	8 31	6 50 E.	N. 57 E.	11 31	3 59
15	18 57	18 50	29 22	29 41	N. 70 E.	20	W. N.W.	4	51 30	16 20	S. 75 E.	21 26	5 6 W.	S. 87 E.	9 26	6 64 E.
							Northerly	2								
											N. 52 W.	14 16	2 4 E.	N. 40 W.	26 16	9 56 W.
16	19 39	19 45	30 13	30 4	S. 55 W.	11	N. Easterly	3	52 0	16 0	N. 21 W.	11 36 W.	4 24	N. 10 W.	22 36	6 36 W.
17	...	21 7	...	31 3	S. 87 W. (17–19)	40 (17–20)	N. E. by E.	3	...	...	...	...	...	...	...	...
18	22 7	22 17	...	31 35			E. N. E.	2	...	...	...	...	...	...	...	...
19	22 53	22 54	32 19	31 38			South	1	...	...	...	...	...	...	...	...
							W. N.W.									
20	23 40	23 40	32 6	32 10	S. 26 E.	9	W. N.W.	1	56 30	17 0	N. 15 E.	3 16 E.	20 16	N. 25 E.	6 44 W.	10 16 E.
21	24 39	24 45	32 2	32 10	S. 49 E.	9	N. E. by E.	4	57 30	18 0	N. 17 W.	1 51 W.	10 0	N. 7 W.	11 51 W.	6 9
							E. by N.									

	22	26 19	26 19	32 28	32 5	West......	21	East............	3	59 0	18 20	N. 2 W.......	6 50	11 24	N. 9 E.........	17 50	0 24
												N. 11 W........	7 28	10 44	North.	18 20	0 6
												N. 23 E........	4 8	14 12	N. 31 E.........	15 8	3 12
												N. 10 E........	5 8	13 12	N. 23 E.........	17 8	1 12 E.
												N. 26 W........	11 8	7 12 E.	N. 14 W.........	23 8	4 48 W.
												N. 21 W........	19 8	0 48 W.	N. 9 W.........	31 8	12 48 W.
	23	27 17	27 15	32 36	32 31	N. 67 W.	5	Vble. E. N. E.	1	60 0	19 0	N. 38 E........	7 22	11 38 E.	N. 47 E.........	16 22	2 38 E.
												N. 17 E........	5 22	13 38	N. 28 E.........	16 52	2 8
												North	6 54	12 6	N. 11 E.........	17 54	1 8 E.
	24	27 35	27 52	32 36	32 30	N. 71 W.	5	Variable S.E.	1	61 30	19 40 W.	N. 23 E........	5 4	14 36	N. 34 E.........	16 4	3 36
												N. 16 E........	4 7	15 33	N. 28 E.........	16 17	3 23
												N. 20 E........	5 29	14 11	N. 32 E.........	15 20	4 11
	25	28 43	28 48	....	32 23	....	....	S.W...............	2	61 30	20 0	N. 58 E........	11 4	8 56	N. 61 E.........	14 4	5 56
	26	30 45	30 51	31 57	31 41	S. 66 W.	15	S.W. by S.....	7	62 30	21 15	N. 13 E........	9 1	12 14	N. 27 E.........	23 1	5 40
	27	33 10	33 36	31 13	31 15	S. 6 E.	16	S.W. by S.....	8	64 30	22 45	N. 17 E........	9 44	13 1	N. 28 E.........	20 44	2 1
	28	34 42	34 58	30 18	30 17	S. 2 W.	16	W. N. W........	5	66 0	23 45	N. 28 E........	8 4	15 41	N. 38 E.........	18 4	5 41
												N. 28 E........	5 30	17 15	N. 40 E.........	17 30	6 15
		Double Alt.															
	29	35 36	36 32	29 12	29 15	N. 28 E.	5	S.W. by W...	4 to 7	63 30	24 45	N. 32 E........	7 22	17 23	N. 45 E.........	20 22	4 23
												N. 43 E........	10 22	14 23	N. 57 E.........	24 22	0 23
	30	....	38 13	....	27 45	....	....	S.W...............	8 to 10	67 0	26 0	....	....	....	W. by N.......	22 0	4 0
								Northerly	5 to 7								
	31	38 59	39 2	25 54	26 0	S. 57 E.	6	N. by W.......	5 to 6	....	....	....	....	....	....	....	....
Feb.	1	40 5	40 0	24 16	24 44	N. 77 E.	22	N. Westerly...	3	....	....	....	....	....	....	....	....
	2	....	40 54	23 23	23 30	....	....	Westerly......	4	67 30	26 30	N. 39 E........	11 12	15 18	N. 54 E.........	26 12	0 18
												N. 56 E........	14 12	12 18	N. 68 E.........	26 12	0 18
								South......									
	3	....	42 41	....	21 56	....	....	S.W.........	6 to 3	68 0	27 15 W.	N. 45 E........	15 37 W.	11 38 E.	N. 60 E.........	20 37 W.	6 38 E.
								North......									
	4	43 32	44 2	20 27	20 58	....	....	Southerly.....	2	....	....	....	....	....	....	....	....
	5	45 34	45 6	18 18	18 31	N. 18 E.	29	S.W...............	7	....	....	....	....	....	....	....	....
	6	47 52	47 42	....	14 51	....	....	S.W. by W...	8	....	....	....	....	....	....	....	....
									5								
	7	49 10	49 22	12 22	12 43	....	....	West....	4	....	....	....	....	....	....	....	....
	8	....	50 38	8 42	9 24	....	....	S.W. by W....	5	....	....	....	....	....	....	....	....
	9	52 29	52 28	....	5 54	....	....	S.W...............	....	....	....	....	....	....	....	....	....
								Calm, easterly.	....	....	....	....	....	....	....	....	....

NOTE.—On the outward voyage, besides general cargo, there were about 200 tons of iron on board, in the shape of hoop and rod iron and machinery. In the following voyage (outward) there were 260 tons of iron of the same description.

Iron ship "Advance"—Second voyage—Liverpool to Colombo.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1856.	North. ° ′	North. ° ′	West. ° ′	West. ° ′	°	Miles.			North. ° ′	° ′	°	° ′	° ′	°	° ′	° ′
May 9	41 24	41 27	12 41	13 13	......	......	N. E.	4	65 30	24 0 W.	S. 54 W	23 37 W.	0 23 E.	S. 56 W	25 37 W.	1 37
											S. 80 W	22 37	1 23 E.	West	32 37	8 37
10	38 52	38 53	14 25	14 34	S. 82 E.	7	N. E. by E.	4	......	......	......	......	......	......	......	......
11	36 41	36 44	15 56	15 51	S. 53 W.	5	N. E. by E.	3	......	......	......	......	......	......	......	......
12	34 47	34 55	......	16 54	......	......	E. by N.	3	......	......	......	......	......	......	......	......
13	32 44	32 38	18 29	18 2	N. 75 W.	23	E. variable	3	61 30	23 40	S. 46 W	24 0	0 20 W.	S. 51 W	29 0	5 20
							S. S. E.	4								
											S. 17 W	25 0	1 20	S. 14 W	22 0	1 40
14	31 0	30 32	20 41	20 19	N. 35 W.	34	Variable S.	4	61 0	22 0	S. 88 W	22 16	0 16 W.	N. 79 W	35 16	13 16
											N. 30 W	17 46	4 14 E.	N. 17 W	30 46	8 46
15	29 30	29 28	21 46	21 36	N. 77 W.	9	N. E	8	60 0	21 45	S. 45 W	24 0	2 15 W.	S. 48 W	27 0	5 15
											South	29 30	7 45	S. 5 E.	24 30	2 45
16	26 29	26 29	23 5	22 52	West	11	N. E	5	57 0	20 40	S. 41 W	22 33	1 53 W.	S. 45 W	26 33	5 53
											S. 85 W	20 0	0 40 E.	N. 85 W	31 0	10 20
17	23 54	23 50	24 20	24 57	S. 76 W.	21	East	4	55 30	20	S. 41 W	22 27	2 27 W.	S. 44 W	25 27	5 27
18	21 36	21 36	25 29	25 8	West	20	E. S. E.	2 to 4	......	......	......	......	......	......	......	......
19	19 37	19 31	26 30	26 14	N. 68 W.	16.5	E. N. E.	4	51 30	17 40	S. 44 W	19 11	1 31	S. 48 W	23 11	5 31
											S. 25 W	20 11	2 31	S. 23 W	18 11	0 31
											S. 5 W	23 23	5 43	South	18 23	0 43
											S. 37 W	18 23	0 43	S. 39 W	20 23	2 43
											S. 36 W	18 46	1 6	S. 38 W	20 46	3 6
											S. 60 W	17 46	0 6	S. 67 W	24 46	7 6
20	16 37	17 2	27 4	26 50	S. 30 W.	28	E. by N.	4	47 30	17 0	S. 25 W	20 30	3 30	S. 24 W	19 30	2 30
											S. 8 W	23 0	6 0	S. 1 W	16 0	1 0
21	13 25	13 27	26 24	26 6	S. 84 W.	18	E. by N.	4	42 30	16 15	S. 4 W	22 9	5 54	South	18 9	1 54
											S. 15 E.	24 9	7 54	S. 21 E.	18 9	1 54
22	11 4	11 0	25 16	25 11	S. 37 W.	8	East	3	40 0	16 0	S. 6 E.	25 12	9 12	S. 12 E.	19 12	3 12
23	9 15	9 13	24 22	24 14	S. 75 W.	8	......	2	......	......	......	......	......	......	......	......
24	6 48	7 10	23 21	23 21	South	22	E. by S.	3	......	......	......	......	......	......	......	......
25	4 44	4 54	23 15	22 50	S. 68 W.	27	Variable E.	3	30 0	16 30	S. 4 W	21 45	5 15	South	17 45	1 15

26		3 8		23 44			Calm and sq'lly S. E. by S.	5								
27	1 11 *South.*	1 4 *South.*	25 9	25 0	N. 40 W.	11	S. by E.	5	25 30	15 30	S. 45 W.	16 34	1 4	S. 52 W.	23 34	8 4
	0 28	0 34	27 30	26 44	N. 83 W.	47	S. by E.	4	23 0	13 15	S. 58 W.	14 20	1 5	S. 67 W.	23 20	10 5
											S. 82 W.	14 20	1 5	N. 87 W.	25 20	12 5
	2 14	2 24	28 42	28 29	N. 51 W.	17	S. S. E.	3	22 0	13 30	S. 42 W.	13 38	0 8	S. 49 W.	20 38	7 8
											S. 32 W.	14 17	9 47	S. 33 W.	15 17	1 47
30	3 54	3 50	29 50	29 10	S. 84 W.	39	S. E. by S.	2 to 4	18 30	12 30	S. 41 W.	13 21	0 51	S. 45 W.	17 21	4 51 W.
31	6 36	6 25	30 50	30 26	S. 65 W.	27	S. E.	4	16 0	11 30	S. 9 W.	15 6	3 36	S. 5 W.	11 6	0 24 E.
June 1	9 9	9 3	31 28	31 8	S. 73 W.	21	S. E.	4	11 0	10 45	S. 17 W.	14 22	3 37	S. 14 W.	11 22	0 37 W.
2	11 44	11 27	31 46	31 46	South.	27	S. E. by E.	4	6 0	10 30	S. 16 W.	11 12	0 42	S. 12 W.	10 12	0 18 E.
											S. 40 W.	12 0	1 30	S. 46 W.	18 0	7 30 W.
	14 12	13 54	32 7	31 59	S. 22 W.	20	Var'ble S. E.	3	+ 1 0	9 45	S. 19 W.	13 7	3 22	S. 17 W.	10 47	1 2
											S. 25 W.	12 0	2 15	S. 25 W.	12 0	2 15
											S. 39 W.	11 30	1 45	S. 45 W.	17 30	7 45
											S. 56 W.	11 0	1 15	S. 67 W.	22 0	12 15
											S. 75 W.	11 0	1 15	West	26 0	16 15
											N. 79 W.	11 0	1 15	N. 62 W.	28 0	18 15 W.
4	16 13	16 0	32 16	32 6	S. 35 W.	16	S. E. by E.	2								
5	17 13	17 5	32 21	32 11	S. 50 W.	13	E. S. E.	1	— 3 0	8 45	S. 3 E.	15 37	6 52	S. 14 E.	4 37	4 8 E.
6	18 15	18 15	31 57	31 51	West	5	N. E.	1	— 5 0	9 0	S. 30 E.	17 24	8 24	S. 46 E.	1 24	7 36
											S. 11 E.	16 24	7 24	S. 22 E.	5 24	3 36
											S. 6 E.	14 54	5 54	South	8 54 W.	0 6
7	19 17	19 18	31 7	30 52	N. 87 W.	16	Variable W.	2	— 7 0	9 30	S. 48 E.	17 11	7 41	S. 68 W.	2 49 E.	12 19
											S. 60 E.	16 41	7 1	S. 79 E.	2 19	11 49
											S. 75 E.	14 11	4 41	East	0 49	10 19
8	19 23	19 37	30 15	30 31			Calm	0								
							S. S. W.	2								
9	19 55	20 2	28 28	28 51			S. by E.	3	— 9 0	10 40	S. 72 E.	16 0	5 20	N. 89 E.	3 0 E.	13 40 E.
10	21 36	21 38	29 26	29 9	N. 84 W.	16	S. E. by S.	4	—11 30	10 0	S. 15 W.	22 24	12 24	S. 11 W.	18 24 W.	8 24 W.
							S. E. by S.				S. 38 W.	20 54	10 54	S. 45 W.	28 54	19 54 W.
											S. 8 E.	18 0	8 0	S. 21 E.	5 0 W.	5 0 E.
11	23 37	23 31	28 35	28 28	S. 45 W.	8	E. N. E.	4	—15 30	10 0	S. 46 E.	18 12	8 12	S. 67 E.	2 48 E.	12 48
											S. 26 E.	18 42	8 42	S. 44 E.	0 42 W.	9 18
											S. 9 E.	18 49	8 49	S. 22 E.	5 49	4 11 E.
		23 0		28 52							S. 5 W.	17 19	7 19	South	12 19	2 19 W.
											S. 20 W.	15 49	5 49	S. 21 W.	16 49	6 49
											S. 37 W.	14 19	4 19	S. 45 W.	22 19	12 19
											S. 55 W.	13 19	3 19	S. 70 W.	28 19	18 19 W.
12	25 50	25 56	26 1	26 11	N. 54 E.	11	N. N. W. N. W. S.W. by W.	5	—21 0	11 0	S. 40 E.	18 0	7 0	S. 59 E.	1 0 E.	11 0 E.
13	27 29	27 38	22 51	23 17	N. 68 E.	25	S. W.	5								
14	29 26	29 42	19 6	19 30			S.W. by W.	8 to 11								
15	31 7	31 9	15 56	16 3	N. 74 E.	7	W. by S.	9								
16	32 49	32 40	13 0	12 59	S. 84 E.	9	W. N. W.	6 to 8	—32 0	17 30	S. 22 E.	30 46	13 16	S. 51 E.	1 46 W.	15 44 E.
17	33 48	33 38	11 1	10 25			N. W.	2								
							South	3								
18	33 17	33 13	8 37	8 45	N. 58 E.	8	S. E. by S.	7								
19	32 43	32 43	6 17	6 51		28	S. E.	6								

Iron ship "Advance"—Second voyage—Liverpool to Colombo—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1856.	*South.* ° ′	*South.* ° ′	*West.* ° ′	*West.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
June 20	33 2	33 8	3 41	3 48	N. 50 E.	9										
21	34 38	34 32	0 12	0 13	S. 12 E.	6	S. S. W.	6	—42 30	24 0	S. 24 E.	34 10 W.	10 10 W.	S. 59 E.	0 50 E.	24 50 E.
			East.	*East.*												
22	36 17	36 17		2 54			S. W. by S.	5								
23	37 50	37 51	6 53	6 11	N. 88 E.	30	West	4	—49 30	25 45	S. 19 E.	36 21	10 36	S. 56 E.	0 39	26 24
24	40 56	41 1	10 42	10 58	N. 49 W.	17	S. W.	8 to 10								
25	41 1	40 3	15 15	14 46	N. 85 E.	23	S. W. by S.	6 to 7								
26	41 4	40 51	20 2	19 38	S. 56 E.	20	S. W. by S.	6 to 7 & 9	—56 30	30 15	S. 32 E.	41 24	11 9	S. 84 E.	10 36	40 51
27	40 56	41 1	24 58	24 51	N. 44 E.	7	S. W. by W.	8 to 11								
28	40 29	40 30		29 30			S. W. by S.	4								
29	40 5	40 27	31 31	31 53	N. 37 W.	28	V'ble, sq'ly.	4 to 1	—60 0	31 15	S. 52 E.	36 36	5 21 W.	N. 77 E.	17 24	48 39
											S. 82 E.	30 36	0 39 E.	N. 55 E.	12 24	43 39
											N. 77 E.	26 36	4 39 E.	N. 45 E.	5 24	36 39
30	40 21	40 21		34 27			V'ble W.N.W.	3 to 6								
							S. by E.	1 to 11								
July 1	40 10	40 14	37 11	37 15			North	5 to 6								
2	39 59	40 4	41 0	41 27			South	5								
3	39 54	39 50	45 37	45 23			S. W. by W.	6								
4	39 39	39 36	49 57	49 23			W. S. W.	5								
5	38 48	38 34	57 1	57 1			S. W. by W.	4	—65 0	25 0	S. 64 E.	35	10 0 W.	N. 61 E.	22 0 E.	47 0
											S. 89 E.	35	10 0	N. 50 E.?	4 0 W.	21 0
											S. 78 E.	35 38	10 38 W.	N. 55 E.	11 32 E.	36 32
7	38 6	37 50	6 58	60 45			South	4								
							N. N. W.	8								
8	36 55	36 46	65 32	65 1			S. W. by S.	9								
							W. S. W.	11								
9	34 35	34 37	67 15	67 50			W. by S.	6 to 3								
							W. N. W.									
10	32 45	32 38	69 3	68 30			N. Westerly.	3	—63 0	16 15	N. 21 E.	9 0	7 15 E.	N. 17 E.	5 0 W.	11 15
11	31 31	31 29	71 38	71 56			N. N. W.	6						N. 43 E.	21 38 E.	37 53

12	28 48	28 47	72 53	72 47	S. 79 W.	5	N. W. by W. S. S. W.	6	—61 0	12 0	N. 7 E	4 27	7 33	N. 10 E	8 27 W.	3 33
13	27 4	27 5	73 7	72 51	N. 86 E.	16	V'ble S. S. W. to S. S. E.	2	......	......	......	......	......	......	......	......
14	26 3	25 51	73 24	73 3	S. 53 E.	20	V'ble, sq'ly...	2	......	......	......	......	......	......	......	......
15	23 1	23 8	73 14	73 24	N. 53 W.	12	S. E. by S ...	4	—56 0	8 0	N. 2 E......	3 38	4 22	N. 5 E......	5 22	2 38 E.
							S. E. by E...	4 to 6								
16	19 46	19 53	72 54	73 7	N. 61 W.	14	E. by S......	6	......	......	......	......	......	......	......	......
17	17 0	17 0	72 52	72 57	East......	1	E. by N	5 to 6	—51 0	4 0	N. 3 W......	0 52 W.	3 8	N. 3 E......	6 52 W.	2 52 W.
18	14 16	14 22	72 48	72 51	N. 26 W.	7	E. by S......	5	......	......	......	......	......	......	......	......
19	11 7	11 20	72 54	73 2	N. 68 W.	9	E. S. E......	5	......	......	......	......	......	......	......	......
20	8 20	8 41	73 49	74 7	N. 40 W.	27	E. by S......	5	—35 0	1 50	N. 27 E......	3 43 E.	5 33	N. 22 30 E...	8 13 E.	10 23 E.
											N. 15 E......	2 43	4 33	N. 15 E	2 43	4 33
											N. 8 E......	3 55	5 45	N. 11 E	0 55 E.	2 45
											North	3 55	5 46	N. 5 E	1 5 W.	0 45 E.
											N. 10 W	3 40	5 30	North	3 20 W.	1 30 W.
21	5 17	5 11	74 15	74 17	S. 2 W.	6	S. E. by E...	5	—29 0	1 20	N. 7 E......	4 11	5 31	N. 8 E	3 11 E.	4 31 E.
											N. 6 W	3 11	4 31	North	2 49 W.	1 29 W.
											N. 13 W	......	......	N. 5 W	5 35	4 15
											N. 21 W	2 0	3 20	N. 11 W	8 0	6 40
											N. 31 W	......	......	N. 17 W	12 23	11 3
											N. 37 W	1 15	2 35	N. 23 W	12 45	11 25
											N. 43 W	......	......	N. 28 W	14 15	12 55
											N. 50 W	0 15	1 35	N. 32 30 W...	16 15	14 55 W.
22	2 22	2 37	74 36	74 40	N. 15 W.	16	S. E. by S....	5	—25 0	1 0	North......	4 49	5 49	N. 5 E......	0 11 W.	0 49 E.
							S. S. E......	4								
											N. 9 E......	4 49	5 49	N. 11 E......	2 49 E.	3 49
											N. 16 E......	4 49	5 49	N. 17 E......	3 49	4 49
											N. 26 E......	4 49	5 49	N. 22 E......	8 49	9 49
											N. 35 E......	4 19	5 19	N. 28 E......	11 19	12 19
											N. 45 E......	3 49	4 49	N. 34 E......	14 49	15 49
											?N. 51 W......	0 4	1 4	?N. 34 W......	?16 58	17 56 E.
																15 56 W.
											?N. 69 W......	0 4	1 4	?N. 47 W......	?21 56	22 56 E.
																20 56 W.
23	0 11	0 35	75 7	74 53	N. 59 E...	28	S. by W......	3	—20 0	0 40 W.	N. 2 E......	3 54 E.	4 54 E.	N. 7 E......	1 6 W.	0 26 W.
	North.	*North.*														
24	2 26	2 6	76 26	75 51	N. 61 E...	40	S. W. by W...	4	......	......	......	......	......	......	......	......
25	4 56	5 9	77 59	77 25	S. 57 E...	28	West......	4	......	......	......	......	......	......	......	......
26	6 37	6 52	79 2	78 50	......	......	S. W......	3	......	......	......	......	......	......	......	......

HOMEWARD VOYAGE.

Sept. 10	7 11	......	79 25	......	......	......	W.S.W......	6	— 6 0	0 20 E.	S. 5 E......	3 49 E.	3 29 E.	S. 10 E......	1 11 E.	0 51 E.
11	5 35	5 35	80 9	80 0	......	......	W. by S......	7	......	......	......	......	......	......	......	......
12	......	3 47	......	82 20	......	......	S. W. by W...	5 to 7	......	......	......	......	......	......	......	......
13	1 57	2 0	85 11	84 27	......	......	S. W. by S...	4	—14 0	0 30	S. 43 E......	4 10 W.	4 40 W.	S. 61 E......	13 50 E.	13 20 E.
14	0 41	0 31	87 13	87 7	N. 31 E...	12	S. W. by S...	4	......	......	......	......	......	......	......	......
	South.	*South.*														
15	......	0 9	88 23	88 20	......	......	V'ble S. W...	3	......	......	......	......	......	......	......	......

Iron Ship "Advance"—Second voyage, homeward—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1856.	*South.* ° ′	*South.* ° ′	*East.* ° ′	*East.* ° ′	°			*Miles.*	° ′	° ′	°	° ′	° ′	°	° ′	° ′
Sept. 16	1 12	1 6	89 13	89 20	S. 49 W.	9	V'ble S. W.	5 to 2	......	......	......	......	......	......	......	......
17	2 35	2 35	90 3	89 40	East	22	V'ble, southerly.	5	......	......	......	......	......	......	......	......
18	3 7	3 25	90 51	90 30	N. 48 E.	28	V'ble S. W.	5 to 6	......	......	......	......	......	......	......	......
19	......	4 31	91 36	91 23	......	......	V'ble W.S.W.	4	......	......	......	......	......	......	......	......
20	6 5	6 42	91 36	91 11	S. 47 E.	25	W.S.W. N.W.	3	......	......	......	......	......	......	......	......
21	6 36	6 40	91 36	91 28	N. 63 E.	9	V'ble N. W., calms.	1	—27 30	0 15 E.	S. 41 W.	......	......	S. 56 W.	15 40 W.	15 55 W.
											S. 33 W.	1 24 W.	1 39 W.	S. 44 W.	12 24	12 39
											S. 24 W.	......	......	S. 33 W.	10 9	10 24
											S. 20 W.	1 54	2 9	S. 22 W.	3 56	4 11
											S. 10 W.	......	......	S. 12 W.	4 9 W.	2 24 W.
											S. 1 W.	2 24	2 39	South	1 24 E.	1 9 E.
22	6 36	6 53	91 36	91 16	N. 47 E.	25	Calms	0	—27 30	0 15 E.	N. 76 W.	1 0	1 15	N. 53 W.	24 0 W.	24 15 W.
23	......	6 56	......	91 16	......	......	S. by E.	6	......	......	......	......	......	......	......	......
24	7 28	7 38	88 23	88 47	......	......	S. by E.	4	—31 30	1 0 W.	S. 47 W.	1 55	0 55	N. 80 W.	27 55	26 55
											S. 65 W.	1 55	0 55	West	36 55	35 55
25	8 45	......	85 39				S. S. E.	3	—34 0	0 45	S. 67 W.	1 11	0 26	West	34 11	33 26
											S. 78 W.	1 51	1 6	N. 78 W.	25 51	25 6
26	9 46	9 49	83 10	83 13	N. 42 W.	41	S. S. E.	5	......	......	......	......	......	......	......	......
27	10 59	10 50	80 5	80 7	S. 13 E.	9	South	6 to 7	......	......	......	......	......	......	......	......
28	12 12	12 15	77 4	77 11	N. 66 W.	7	South	6	......	......	......	......	......	......	......	......
29	......	12 53	75 12	75 15	......	......	Calm	0	......	......	......	......	......	......	......	......
30	14 4	14 1	72 46	72 57	S. 76 W.	12	S. by E.	6	......	......	......	......	......	......	......	......
Oct. 1	15 46	15 42	64 20	69 56	S. 86 W.	29	S. S. E.	7	......	......	......	......	......	......	......	......
2	17 33	17 21	66 46	66 36	S. 36 E.	16	S. E. by S.	6	......	......	......	......	......	......	......	......
3	19 11	18 43	63 12	63 33	S. 36 W.	35	S. E. by S.	4	—52 30	7 0	S. 64 W.	11 33	4 33	N. 82 W.	45 33	38 33
											S. 75 W.	11 14	4 14	N. 69 W.	47 14	40 14
4	19 58	20 8	60 22	60 30	N. 37 W.	13	S. E.	4	—53 0	8 30	N. 85 W.	11 44	3 14	N. 53 W.	43 44	35 14
											S. 83 W.	......	......	N. 60 W.	48 44	40 14

Nov.	5*																
	6	20 20		56 43				Easterly	2	—53 0	10 30	N. 83 W	13 33	3 3	N. 53 W	43 33	33 3
												S. 79 W	13 33	3 3	N. 68 W	46 33	36 3
												S. 62 W			N. 84 W	47 33	37 3
												S. 55 W			West	48 33	38 3
												S. 44 W			S. 77 W.	45 33	35 3
	7	20 39	20 34		55 27			E. N. E.	2								
	8	21 37	21 26	54 32	54 19			East	2								
	9	22 45	22 22	53 25	53 37	S. 27 W.	26	E. by S	2								
	10	23 26	23 35	52 28	52 26	N. 20 W.	5	N. E.	3								
	11	24 34	24 28		50 40			S. S. E	7								
	12	26 8	25 56	48 26	48 19			S. E. by S.	6								
	13	27 38	27 51		45 37					—57 30	20 0	S. 77 W.	23 20	3 20	N. 65 W.	61 20	41 20
												West	23 21	3 21	N. 56 W.	57 10	37 10
	14	28 49	28 19	43 38	43 41			S. W. by S.	2	—57 30	21 0	N. 84 W.	24 0	3 0	N. 50 W.	58 0	37 0
	15	29 12	29 13	42 8	42 21	N. 85 W.	12	S. W. by W.	3	—57 30	23 0	S. 74 W.	24 40	1 40	N. 67 W.	63 40	40 40
								S Easterly	1								
												West	24 40	1 40	N. 56 W.	58 40	35 40
												N. 75 W.	25 10	2 10	N. 45 W.	55 10	32 10
												N. 60 W.	25 10	2 10	N. 35 W.	50 10	27 10
	16	29 45	29 37	40 47	40 57	S. 45 W.	11	E. N. E.	3								
	17	30 18	30 9	39 28	39 38	S. 45 W.	13	S. Easterly	1								
								E. N. E.	3								
	18	30 52	30 55	37 46	36 59	N. 86 E.	43	N. Easterly	4								
								W. S. W.	6								
	19	30 43	30 57	35 36	35 43	N. 25 W.	16	W. S. W.	6 to 1								
	20	31 38	31 31	33 57	33 36	N. 69 W.	20	E. N. E.	6	—57 0	27 0	S. 81 W.	27 43	0 43	N. 60 W.	66 43	39 43
												N. 81 W.	27 43	0 43	N. 49 W	59 43	32 43
	21		31 52	32 18	32 17	N. 6 E.	8	W. S. W.	4								
	22	32 57	32 50	30 32	30 39			E. S. E.	5								
	23	34 7		28 51				S. E. by E.	4	—57 0	29 30	S. 43 W.	30 32	1 2	S. 81 W.	68 32	39 2
												S. 34 W.	30 32	1 2	S. 68 W.	64 32	35 2
												S. 22 W.	30 28	0 58	S. 45 W.	53 25	23 55
												S. 10 W.	30 25	0 55	S. 41 W.	52 25	22 55 W.
	24	33 58	33 51	27 23	27 31	S. 41 E.	9	Westerly.	7								
	25	34 8	33 59	26 3	26 41			S. E.	5	—56 0	29 45	N. 88 W.	31 38	1 53	N. 53 W.	66 38	36 53
	26	35 22	35 11	24 24	24 27	S. 16 W.	11	N. N.W	4	—56 0	29 45	S. 60 W.	31 6	1 21	N. 79 W.	72 6	42 21
	27		34 54		24 14			W. N.W.	11								
	28	34 59		23 26				W. N.W.	4								
	29	34 49	34 51	22 17	22 27	S. 77 W.	9	S. E.	5	—55 0	29 50	N. 88 W.	30 30	0 40	N. 53 W.	65 30	35 40
												N. 70 W.	32 43	2 53	N. 41 W.	61 53	32 3
	30	35 13	35 7	20 22	20 38	S. 66 W.	15	S.W. by S.	2	—54 30	29 50	N. 29 W.	31 56	2 6	N. 61 W.	46 56	17 6
Dec.	1	34 49	34 48	19 27	19 27	South	1	N.W	3								
	2	34 33	34 47	18 14	18 29	N. 33 W.	17	S. S.W	3	—52 30	29 30	West	31 17	1 47 W.	N. 55 W.	60 17	36 47
												N. 40 W.	29 30	0 0	N. 21 W.	48 30	19 0
		Sunset	34 7									N. 24 W.	29 0	0 30 E.	N. 11 W.	42 0	12 30
												N. 9 W.	27 0	2 30 E.	North	36 0	6 30
	3	32 35	32 48	15 11	15 28	N. 48 W.	19	South	6 to 7	—50 0	29 15	N. 42 W.	30 15	1 0 W.	N. 11 W.	43 15	14 0
								S. S.W	3			N. 13 W.	28 31 W.	0 44 E.	N. 4 W.	37 31	8 16 W.
	4	30 57	31 4	13 8	13 16	N. 45 W.	20	S. S.W	2	—49 0	28 40 W.	N. 29 E.	24 15 E.	4 25 E.	N. 22 E.	15 45 W.	12 55 E.

* Sailed from Port Lewis.

Iron ship "Advance,"—Second voyage, homeward—Continued.

Date.	Latitude. By observat'n.	Latitude. By dead reckoning.	Longitude. By chronometer.	Longitude. By dead reckoning.	Difference between position by observation and by dead reckoning. Direction.	Difference. Amount.	Winds. Direction.	Winds. Force.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Standard compass, (uncompensated.) Head by compass.	Standard compass. Total error.	Standard compass. Deviation.	Steering compass, (compensated.) Head by compass.	Steering compass. Total error.	Steering compass. Deviation.
1856.	*South.* ° ′	*South.* ° ′	*East.* ° ′	*East.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
Dec. 4											N. 11 E.	25 15 W.	3 25 E.	N. 11 E.	25 15 W.	3 25 E.
											N. 6 30 W.	26 15	2 25	North	32 45	4 5 W.
5	30 4	30 9	12 0	12 6	N. 46 W.	7	Variable S	1								
6	28 33	28 41	10 14	10 23	N. 48 W.	12	Variable S	3								
7	26 55	27 7	8 32	8 24	N. 31 W.	14	S. by E.	4	—41 30	27 30 W.	N. 20. W.	27 5	0 25	N. 10 W.	37 5	9 35
8	25 34	25 28	6 38	6 45	S. 47 W.	9	South.	3								
9	24 18	24 22	5 5	5 9	N. 45 W.	6	S. S. W.	3								
10	23 3	22 57	3 20	3 28	S. 51 W.	10	South	4	—33 0	26 30	N. 83 W.	28 10	1 40 W.	N. 57 W.	54 10	27 40
											N. 70 W.	28 10	1 40	N. 45 W.	53 10	26 40
											N. 55 W.	28 18	1 48	N. 34 W.	49 18	22 48
											N. 38 W.	28 18	1 48	N. 22 W.	44 18	17 48
		23 20		3 38							N. 21 W.	28 4	1 34	N. 11 W.	38 4	11 34
											N. 13 W.	28 41	1 34 W.	N. 5 W.	36 4	9 34
											N. 7 W.	26 12	0 18 E.	North	33 12	6 42
											North	25 32	0 58	N. 5 E.	30 32	4 2
											N. 8 E.	24 52	1 38	N. 10 E.	26 52	0 22 W.
											N. 28 E.	22 28	4 2	N. 24 E.	19 28	7 2 E.
11	21 46	21 46	1 41	1 40			S. S. E.	4								
12	20 33	20 25	0 2	0 15	S. 56 W.	14	S. by E.	4								
			West.	*West.*												
13	19 14	19 15		1 30	S. 80 W.	13	S. by E.	4 to 5								
14	17 55	17 57	3 14	3 1			S. by E.	4								
15		16 33	4 54	4 49			S. S. E.	4								
16							S. S. E.	4								
17							S. S. E.	4								
18	14 0	14 1	7 33	7 31			S. S. E.	5								
19	12 22	12 33	9 21	9 0		14	S. S. E.	5								
20	10 30	10 34	11 15	11 23	N. 63 E.	9	S. E. by S.	5	— 2 0	22 0	N. 20 W.	20 0	2 0	N. 11 W.	29 0	7 0 W.
											N. 6 W.	19 0	3 0	North	25 0	3 0 W.
21	8 41	8 41	12 58	13 0	East	4	S. E. by S.	4 to 5								
22	6 58	7 4	14 32	14 38	N. 45 E.	9	S. S. E.	4	+ 5 20	21 0 W.	N. 8 E.	15 W.	6 0 E.	N. 11 E.	18 0 W.	3 0 E.

											N. 6 W.	16	5 0	North	21 0	0 0
											N. 20 W.	17	4 0	N. 11 W.	26 0	5 0 W.
											N. 35 W.	17 24	3 36 E.	N. 24 W.	28 24	7 24
											N. 47 W.	22 30	1 30 W.	N. 33 W.	36 30	15 30
											N. 60.5 W.	21 50	0 50	N. 45 W.	47 20	26 20
											N. 73 W.	21 40	0 40 W.	N. 56 W.	38 40	17 40
												Amp.				
		6 30									N. 15 W.	19 30	1 30 E.	N. 6 W.	28 30	7 30
											N. 33 W.	20 0	1 0	N. 22 W.	31 0	10 0 W.
23	5 15	5 22	15 20	15 38	N. by E.	19	S. by E.	3	9 0	20 20	N. 40 E.	15 55	4 25	N. 35 E.	10 55	9 25 E.
											N. 23 E.	14 55	5 25	N. 22 E.	13 55	6 25
											N. 8 E.	14 33	5 47	N. 10 E.	16 33	3 47 E.
											N. 6 W.	15 23	5 57	North	21 23	1 3 W.
											N. 20 W.	17 20	3 0	N. 11 W.	26 20	6 0
											N. 33 W.	19 50	0 30	N. 22 W.	30 50	10 30
											N. 48 W.	20 14	0 6 E.	N. 33 W.	35 14	14 54
											N. 62 W.	21 14	0 54 W.	N. 45 W.	38 14	17 54
											N. 68 W.	21 44	1 24	N. 50 W.	39 44	19 24
24	3 41	3 49	17 5	16 43	N. 69 W.	23	S. by E.	3	12 30	19 30	N. 11 W.	18 27	1 3 W.	N. 5 W.	24 27	4 57 W.
25	2 18	2 22	18 21	18 0	N. 78 W.	21	S. by E.	3								
26	1 4	0 58	19 28	19 2	S. 77 W.	27	S. by E.	3								
	North.	*North.*														
27	0 46	0 56	20 17	19 32	S. 83 W.	45	S. by E.	3	22 0	17 30	N. 10 E.	13 31	3 59 E.	N. 13 E.	16 32	0 58 E.
28	2 53	2 42	21 0	20 17	N. 76 W.	44	S. by E.	3								
29		3 59	21 27	20 7			E. S. E.	1 to 3	27 30	17 0	N. 17 E.	12 45	4 15 E.	N. 18 E.	13 45	3 15 E.
30	5 30	4 55	21 13	21 7			E. S. E.	2								
31	6 29	6 17		21 24			East	5								
1857. Jan. 1	6 57	6 40	22 1	22 25			N. E. by N.	2	32 0	17 0	N. 29 W.	17 25	0 25 W.	N. 19 W.	27 25	10 25 W.
2	7 59	7 50	23 22	23 5	West	17	N. E.	4								
3	9 20	9 18	24 46	24 21	N. 66 W.	27	N. E. by E.	4	37 0	16 20	N. 18 W.	12 32	3 48 E.	N. 10 W.	20 32	4 12
4	10 57	10 53	26 11	25 44	N. 81 W.	26	N. E. by E.	4								
5	12 45	12 44	27 23	27 10	N. 85 W.	13	N. E. by E.	4	43 0	15 45	N. 10 W.	11 28	3 17	N. 4 W.	17 28	1 43
6	14 45	14 29	28 46	28 20	N. 57 W.	29	N. E. by E.	4								
7	16 41	16 44	30 5	29 39	N. 83 W.	25	N. E. by E.	5	48 30	15 15	N. 7 W.	9 48	5 27	N. 2 W.	19 48	4 33
											N. 30 W.	12 45	2 30	N. 22 W.	20 45	5 30
8	18 50	19 5	31 9	30 35	S. 79 W.	32	E. by N.	7	51 30	15 40	N. 1 W.	11 50	3 50			
9	21 9	21 0	31 58	31 37	N. 65 W.	21	Easterly	8	54 0	16 15	N. 11 W.	10 17	5 58	N. 3 W.	18 17	2 2 W.
10	23 19	23 20	33 41	32 12	S. 88 W.	29	E. by S.	7								
11	25 22	25 22	33 3	32 57	West	24	East	6	58 0	17 40	N. 12 E.	8 42	8 58	N. 16 E.	12 42	4 58 E.
											N. 8 W.	9 7	8 33	North	17 7	0 33
12	27 47	27 51	33 29	33 7	S. 78 W.	19	East	6 to 4								
13	30 5	30	33 35	33 10	N. 83 W.	22	E. S. E.	5	62 30	20 30	N. 27 E.	5 22	15 8	N. 31 E.	9 22	10 8
14	32 0	31 46	33 23	33 16	N. 17 W.	15	E. S. E.	3	64 0	21 40	N. 30 E.	10 50	10 50	N. 35 E.	15 50	5 50
											N. 15 E.	12 0	9 40	N. 22 E.	19 0	2 40
											N. 2 E.	12 20	9 20	N. 11 E.	21 0	0 40 E.
											N. 10 W.	13 15	8 25	North	23 15	1 35 W.
											N. 21 W.	13 40	8 0	N. 11 W.	24 40	3 0
											N. 31 W.	15 40	6 0	N. 22 W.	24 0	2 20
											N. 36 W.	17 0	4 0	N. 29 W.	24 0	2 20 W.
15	33 39	33 23	33 23	33 12	N. 30 W.	19	S. E. by S.	3	65 30	22 26 W.	N. 72 E.	21 24	0 56	N. 68 E.	17·24	4 56 E.
											N. 56 E.	19 24 W.	2 56 E.	N. 56 E.	19 24 W.	2 56 E.

Iron ship "Advance"—Second voyage, homeward—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
	North. ° ′	*North.* ° ′	*West.* ° ′	*West.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
1857. Jan. 15											N. 42 E.	16 10 W.	6 10 E.	N. 45 E.	19 10 W.	3 10 E.
											N. 26 E.	14 30	7 50	N. 33 E.	21 30	0 50
											N. 16 E.	14 20	8 0	N. 22 E.	20 20	2 0 E.
											N. 2 E.	14 12	8 8	N. 11 E.	23 12	0 52 W.
											N. 9 W.	14 12	8 8	North.	23 12	0 52 W.
16	34 23	34 27	33 5	33 6	S. 9 E.	4	S. E. by S.	1	66 0	23 0	N. 72 E.	22 26	0 34	N. 68 E.	18 26	4 34 E.
											N. 43 E.	17 6	5 54 E.	N. 45 E.	19 6	3 54
17	36 2	35 55	31 46	31 47	N. 56 E.	13	S. S. E.	3	67 0	24 15	S. 80 E.	33 39	9 24 W.	East	23 39	0 36
											N. 87 E.	27 9	2 53 W.	N. 80 E.	20 9	4 6
											N. 70 E.	22 30	1 45 E.	N. 68 E.	20 30	3 45
											N. 57 E.	19 30	4 45	N. 57 E.	19 30	4 45
											N. 40 E.	18 30	5 45	N. 44 E.	20 30	3 45
18		37 4		30 9			N. E.	8	67 0	25 0	N. 56 E.	21 0	4 0	N. 56 E.	21 0	4 0
19	37 41	37 50	30 29	30 17			E. N. E.	5								
20		38 46	31 34	31 21			E. N. E.	4								
21	40 20	40 19	32 29	32 8			E. by N.	4								
22	41 45	41 33	32 42	32 47	S. 18 E.	13	East	3								
23	42 34	42 42	32 57	32 24			S. E.	2								
24	43 15	42 32	32 39	32 40			Easterly	1								
25	42 58	43 8	31 44	31 34	S. 39 W.	16	N. E.	3	70 30	30 0	S. 66 E.	37 8	7 8 W.	N. 79 E.	24 8	5 52 E.
26	42 58	43 5	29 43	29 30	S. 53 W.	12	N. E. by N.	4								
27	42 34	42 27	27 58	27 46			Easterly	6								
28	43 9	43 24	28 6	28 2	S. 11 W.	16	N. by E.	3								
29	43 37	43 52	27 2	26 53	S. 22 W.	17	E. by N.	3								
30	43 14	43 30	25 33	25 10	S. 46 W.	23	N. E.	4	69 30	29 0	S. 58 E.	36 15	7 15	S. 72 E.	22 15	6 45
31	42 59	43 11	23 54	24 2	S. 26 E.	13	Calm	0	69 0	28 30	S. 39 W. ?	40 30	12 0 W.	S. 54 E.	25 30	3 0 E.
Feb. 1	44 4?	44 8	22 17	22 19	S. 20 E.	? 43	West	8								
2	44 31	44 47		20 35			N. N. W.	10 to 11								
3	44 10	44 3	20 21	20 4			North	8 to 9								
4	44 7	44 7	10 1	19 0			N. N. E.	4								

	5	44 25	44 25		18 57			Calm	0								
								Northerly	2								
	6	45 40	45 31	17 35	17 33			Westerly	4	68 30	27 30 W.	N. 55 E.	24 50 W.	2 40 E.	N. 63 E.	32 50 W.	5 20 W.

LIVERPOOL TO CALCUTTA—THIRD VOYAGE.

[N. B.—On the outward voyage the cargo consisted, in part, of 330 tons of rod, hoop, and bar iron, and machinery.]

May	15	52 16		5 11				S. W. by W.	2								
	16	52 20		5 55				W. by S.	3	70 0	25 0	N. 47 W.	14 40 W.	+10 20	N. 25 W.	37 40 W.	−12 40
	17	51 8	51 4	5 39	5 41			S. W. by W.	4								
	18	51 3	50 57	6 50	6 51			Westerly	4								
	19		51 0		8 53			W. S. W.	5								
	20	5 7	51 10	10 48	10 44			S. W. by W	7 2								
	21	50 4	50 11	9 53	10 13	S. 63 E.	16	S. W. by W	2 4	69 30	26 0	S. 22 W.	30 31	− 4 31	S. 6 W.	14 31	−11 29
	22	48 20	48 18	7 59	8 22	N. 83 E.	16	W. S. W.	4 1	68 0	24 30	S. 18 W.	28 53	− 4 23	S. 10 W.	20 53	+ 3 37
	23	47 33	47 38	8 39	9 6			Calm	0	68 0	24 30	S. 71 W.	15 40	+ 8 50			
	24	46 8	46 8	8 44	8 35	West	6	S. by W. N. W. S. W.	5 7 4								
	25	44 46	44 45	9 23	8 59			S. E. N. W.	8 10 to 9								
	26	44 0	44 27	8 37	8 26			Westerly S.	8 to 9								
	27	44 59	45 7	10 18	10 17			W. by S.	4								
	28	42 41	42 45	11 36	11 36			W. N. W.	4	66 0	23 45	S. 55 W.	21 49	+ 1 56	S. 56 W.	22 49	+ 0 46
												S. 38 W.	25 12	− 1 27	S. 30 W.	27 12	− 3 37
	29	41 15	41 11	11 17	11 26			S. westerly	3	65 0	23 15	S. 11 E.	31 30	− 8 15	S. 20 E.	22 30	+ 0 45
	30	40 27	40 25	10 30	10 43			S. W.	2	64 0	22 45	S. 14 E.	32 15	− 9 30	S. 22 W.	24 15	− 1 30
												S. 39 W.	22 39	+ 0 6	S. 36 W.	19 39	+ 3 6
	31	39 44	39 58	10 23	10 38			W. N. W. and calms.	1	63 0	22 30	S. 53 W.	20 46	+ 1 44	S. 54 W.	21 56	+ 0 34
June	1	38 10	38 36	11 6	11 2			W. by N.	2								
	2	36 39	36 59	12 2	12 5			N. W. Calm	3 0	62 30	22 20	S. 71 W.	18 8	+ 4 12	S. 78 W.	25 8	− 2 48
	3	36 28	36 26	12 12	12 16			Calm	0	62 30	22 20	S. 46 W.	20 49	+ 1 31	S. 44 W.	18 49	+ 3 31
												S. 63 W.	18 56	+ 3 24	S. 69 W.	24 56	− 2 36
												S. 83 W.	17 30	+ 4 50	West	24 36	− 2 16
	4	35 55	36 5	12 46	12 40			E. N. E.	1	62 30	22 30	S. 42 W.	20 52	+ 1 38	S. 40 W.	18 22	+ 4 8
	5	35 9	35 2	13 5	13 7			West	1								
	6	34 29	34 43	12 52	13 14			W. N. W. and calms.	1	61 30	22 0	S. 61 W.	18 38	+ 3 22	S. 64 W.	21 38	+ 0 22
	7	33 21	33 26	13 50	13 33			N. E. to N. W.	1 to 3								
		31 7	31 18	16 36	16 37			N. N. E.	6								
		28 53	28 45	19 31	19 22			E. N. E.	6	58 0	21 20	S. 50 W.	20 53	+ 0 27	S. 52 W.	22 53	− 1 33
												S. 72 W.	19 35	+ 1 45	S. 79 W.	26 35	− 5 15
	10	26 9	26 11	21 37	21 7			E. N. E.	6 by 4								

Iron ship "Advance"—Liverpool to Calcutta, third voyage—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1857.	*North.* ° ′	*North.* ° ′	*West.* ° ′	*West.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
June 11	24 9	24 19	22 58	22 35			N. E. by E	4	55 0	20 0 W.	S. 46 W	19 13 W.	+ 0 47	S. 44 W	17 13 W.	+ 2 47
											S. 29 W	20 26	− 0 26	S. 22 W	13 26	+ 6 34
12	22 0	22 13	24 8	23 49			N. E. by E	4	53 0	19 15	S. 42 W	18 28	+ 0 47	S. 42 W	18 28	+ 0 47
13	19 36	19 56	25 20	25 9			N. E.	5	50 30	18 0	S. 42 W	17 26	+ 0 34	S. 42 W	17 26	+ 0 34
											S. 64 W	16 17	+ 1 43	S. 70 W	22 17	− 4 17
14	16 49	16 49	26 44	26 28			N. E.	5	47 30	17 0	S. 39 W	15 0	+ 2 0	S. 35 W	11 0	+ 6 0
15	14 23	14 24	27 35	27 15			N. Easterly	4	46 0	16 0	S. 29 W	16 58	− 0 58	S. 24 W	11 58	+ 4 2
											S. 7 W	18 28	− 2 28	South	11 28	+ 4 32
16	11 47	12 0	27 47	27 41			E. N. E.	3	42 0	15 20	S. 16 W	16 12	− 0 52	S. 11 W	11 12	+ 4 8
17	9 41	9 40	27 56	27 47			E. N. E.	3	39 0	14 45	S. 6.5 W	18 19	− 3 34	S. 1 W	12 39	+ 2 6
											S. 17 W	17 14	− 2 29	S. 12 W	12 14	+ 2 31
											S. 26 W	16 9	− 1 24	S. 22 W	11 39	+ 3 6
											S. 44 W	15 0	− 0 15	S. 44 W	15 0	− 0 15
											S. 61 W	13 30	+ 1 15	S. 67 W	19 30	− 4 45
18	7 32	7 39	28 0	27 55			N. E. by E.	3								
19	6 32	6 31	28 1	28 0			Calm	0								
20	6 7	6 51	27 38	27 50			Variable	2								
21	5 27	5 13	27 29	27 49			S. E. to N. E.	2								
22	4 41	4 32	27 5	27 38			N. N. E. / S. and E.	3 / 4								
23	4 8	3 38	28 2	28 13			Southerly	3 / 4	32 0	14 0	S. 30.5 W	12 30	+ 1 30	S. 28 W	10 0	+ 4 0
24	3 10	3 0	28 36	28 30			S. Easterly	2	30 0	13 40	S. 10 W	14 26	− 0 46	S. 7 W	11 26	+ 2 14
											S. 26 W	13 26	+ 0 14	S. 24.5 W	11 56	+ 1 44
25		2 49	29 18	28 46			S. Easterly	1	30 0	13 15	S. 48 W	13 22	− 0 7	S. 52 W	17 22	− 3 42
26	2 29	2 2	30 14	29 34			S. E.	3								
27	0 15	0 58	30 58	30 29			S. E. by E.	4								
	South.	*South.*														
28	1 50	1 36	31 1	30 31			E. S. E.	3 to 5	23 0	11 45	S. 23 W	11 43	+ 0 2	S. 19 W	7 43	+ 4 2
29	4 2	3 53	32 31	31 33			S. E. by S.	4								
30	6 13	6 20	33 29	32 52			S. E.	4 to 5	17 0	10 0	S. 28 W	8 32	+ 1 28	S. 30 W	10 32	− 0 32

July	1	7 44	7 40	33 48	33 45			V'ble, S. E. by S.	4 to 6								
	2	9 11	9 4	34 16	33 44			V'ble, E. to S.	1 to 6								
	3	11 33	11 10	34 41	34 24			S. E. by E.	5								
	4	14 8	13 46	35 9	34 47			S. E.	4								
	5	17 8	16 44	35 33	35 11			E. S. E.	5	— 3 0	7 0	S. 25 W.	9 3	— 2 3	S. 24 W.	8 3	— 1 8
	6	19 43	19 34	36 10	36 0			S. E. by E.	4 to 5								
	7	22 34	22 36	37 10	36 43			E. S. E.	7								
	8	24 41	26 45	36 45	36 48			E. by N.	6								
	9	26 42	26 26	35 43	35 33			E. by N.	4								
	10	28 24	28 27	24 25	33 55			N. N. East'ly.	3			S. 4 E.	12 19	— 9 49	S. 9 E.	7 19 W.	— 4 49
												S. 11 E.	13 2	—10 32	S. 23 E.	1 2 E.	+ 3 32
												S. 19 E.	13 45	—11 15	S. 35 E.	2 15	+ 4 45
												S. 27 E.	13 35	—11 5	S. 44 E.	3 25	+ 5 55
			28 9		34 27					— 4 30	2 30	S. 35 E.	14 35	—12 5	S. 55 E.	5 25	+ 7 55
												S. 45 E.	13 25	—10 55	S. 65 E.	6 35	+ 9 5
												S. 59 E.	12 16	— 9 46	S. 80 E.	8 44	+11 14
												S. 73 E.	10 46	— 8 16	N. 88 E.	8 14	+10 44
												S. 81 E.	9 16	— 6 46	N. 78 E.	11 44 E.	+14 14
	11	28 23	28 38	32 52	33 12			N. Easterly / S. E. by S.	2 / 5								
	12	30 10	29 43	33 23	33 3			Vble. S. E.	5	—25 0	5 0	N. 31 W.	6 59	— 1 59	S. 35 W.	10 59 W.	— 5 59
	13	32 11	32 1	32 15	32 11			E. N. E.	5								
	14	34 24	33 52	29 43	29 50			N. E. by E.	5								
	15	35 37	35 36	27 27	27 33			N. E. by N.	3	—32 0	7 40	S. 48 E.	7 55	— 0 15	S. 67 E.	12 5 E.	+19 45
	16	36 21	36 24	25 29	25 47			N. by E.	2								
	17	36 38	37 2	22 51	23 4			South	2								
	18	37 31	37 28	18 31	19 17			N. by W.	7								
		Ex. Mer.															
	19	38 4	38 24		15 34			N. N. W.	3								
	20	39 13	38 53	11 9	11 9			N. W. by N.	8								
	21		40 9		6 58			N. W. by N.	8								
	22		1 29		4 5			N. N. W.	8								
	23	41 40	41 37	1 12	2 8			N. N. W.	5	—47 30	21 0	S. 62 E.	31 30	—11 30	East	3 30 W.	+17 30
				East.	*East.*												
	24	41 26	41 30	3 20	3 10			West	10								
	25	41 8	41 14	6 0	5 30			West	10	—51 0	25 15	S. 58 E.	36 44	—11 29	N. 89 E.	2 44	+22 31
								W. S. W.	2			S. 42 E.	36 10	—10 55	S. 73 E.	5 10	+20 5
	26		41 2	7 43	7 48			N. N. W.	1								
	27	40 55	40 56	10 59	10 28			W. N. W.	7								
	28	40 35	40 45	15 15	15 10												
	29		40 47		17 56												
	30		41 6		20 26												
	31		40 59		23 27			W. by S.	3	—57 40	31 0	S. 49 E.	42 24	—11 24	S. 88 E.	3 24	+27 36
Aug.	1	41 7	40 59	27 18	25 8			S. S. E.	2	—59 0	31 30	S. 6 W.	38 24	— 6 54	S. 6 W.	38 24 W.	— 6 54
	2		40 23		28 52			S. E. by E.	10								
	3	39 58	39 49	29 1	29 0			S. E. by E.	11 / 5								
	4		39 39		29 22			S. E. by S.	7								
	5	39 6	38 56	31 43	30 44			S. S. E.	6								
	6	39 23	39 15	35 37	34 17			Southerly	5	—61 0	30 30 W.	S. 17 E.	37 52 W.	— 7 22	S. 60 E.	5 18 E.	+35 48

Iron ship "Advance"—Liverpool to Calcutta, third voyage—Continued.

Date.	Latitude. By observat'n.	Latitude. By dead reckoning.	Longitude. By chronometer.	Longitude. By dead reckoning.	Difference between position by observation and by dead reckoning. Direction.	Difference between position by observation and by dead reckoning. Amount.	Winds. Direction.	Winds. Force.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Standard compass, (uncompensated.) Head by compass.	Standard compass, (uncompensated.) Total error.	Standard compass, (uncompensated.) Deviation.	Steering compass, (compensated.) Head by compass.	Steering compass, (compensated.) Total error.	Steering compass, (compensated.) Deviation.
1857.	*South.* ° ′	*South.* ° ′	*East.* ° ′	*East.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
Aug. 6	39 53	37 15	35 37	34 17			Southerly	5	—61 0	30 30 W.	S. 30 E.	37 44 W.	— 7 14	S. 77 E.	9 11 E.	+39 41
											S. 40 E.	37 46	— 7 16	N. 89 E.	13 14	+43 44
											S. 49 E.	37 32	— 7 2	N. 78 E.	15 28	+45 58
											S. 63 E.	37 18	— 6 48	N. 70 E.	9 42	+40 12
7	39 26	39 27	39 37	39 32			S. S. W.	6								
8	39 51	39 46	44 17	44 3			S. W.	6								
9		40 6		47 40			W. S. W.	9								
10	39 57	40 6	51 43	51 1			S. S. W.	3								
11	39 55	39 57	55 16	54 46			S. W.	7								
12	40 10	39 55	58 51	58 59			Westerly	3	—66 0	25 45	S. 45 E.	37 39	—11 54	N. 81 E.	16 21	+42 6
13		40 10		63 23			S. W. by W.	5								
14	40 24	40 10	66 10	65 52			W. S. W.	8								
15	39 42	39 50	69 59	69 57			S. W. by W.	7								
16	38 52	38 39	73 51	73 45			S. W. by W.	8								
17	37 28	37 37	76 55	76 52			S. W. by W.	6								
18	35 7	35 6	79 14	78 28			S. W. by S.	3	—65 0	16 20	N. 48 E.	14 51	+ 1 29	N. 30 E.	3 9 E.	+19 29
19	32 52	32 53	80 15	80 20			N. W. by N.	5								
20	30 34	30 33	81 39	81 14			N. W.	3	—62 20	12 30	N. 11 E.	9 41	+ 2 49	N. 11 E.	9 41 W.	+ 2 49
											N. 20 E.	7 11	+ 5 19	N. 22 E.	0 49 E.	+13 19
											N. 50 E.	5 11	+ 7 19	N. 33 E.	11 49 E.	+24 19
21	28 31	28 42	81 58	81 54			N. W. by W.	2								
							S. S. E.	4								
22	25 44	26 5	82 5	81 58			E. S. E.	4	—57 40	8 40	N. 10 E.	5 33	+ 3 7	N. 10 E.	5 33 W.	+ 3 7
											N. 7 W.	4 33	+ 4 7	N. 2 W.	9 33	— 0 53
23	22 18	22 17	82 8	82 5			E. S. E.	6								
24	18 56	19 8	82 11	82 8			E. S. E.	5	—52 0	4 0 W.	N. 10 E.	0 56 W.	+ 3 4	N. 10 E.	0 56	+ 3 4
25	15 33	15 36	82 5	82 11												
26	12 54	12 58	81 51	82 5												
27	9 35	9 36	81 37	81 40												
28	6 42	6 30	81 50	81 40												
29	4 47	4 28	81 28	81 25												

	30	3 46	3 52	81 15	81 28	...	...	...	...	...	...	...	...	...	...	...	...
		Ex.Mer.															
	31	2 50	2 59	...	81 15	...	...	...	...	...	...	...	...	...	...	...	...
Sept.	1	...	1 27	...	81 24	...	...	...	...	...	...	...	...	...	...	...	...
		North.	*North.*														
	2	0 50	0 41	82 39	81 49	...	...	...	...	...	...	...	...	...	...	...	...
	3	3 29	3 30	83 26	82 41	...	...	...	...	...	...	...	...	...	...	...	...
	4	6 27	6 14	84 13	84 34	...	...	...	...	...	...	...	...	...	...	...	...
	5	8 9	7 57	84 27	84 13	...	...	...	...	− 2 30	1 0 E.	N. 13 W.	5 40 E.	+ 4 40	N. 5 W.	2 20 W.	− 3 20
	6	10 28	9 50	84 12	84 16	...	...	...	...	...	...	...	...	...	...	...	...
	7	12 11	12 16	83 56	84 4	...	...	...	...	...	...	...	...	...	...	...	...
	8	...	14 59	84 8	84 4	...	...	...	...	+10 0	1 15	N. 0 30 E.	5 11	+ 3 56	N. 5 E.	0 19 E.	− 0 56
												N. 15 E.	0 47 E.	− 0 28	N. 15 E.	0 47	− 0 28
	9	18 31	18 11	85 4	84 38	...	...	...	...	+17 30	1 30 E.	N. 80 E.	4 18 W.	− 5 48	N. 69 E.	7 42	+ 6 12
												N. 65 E.	0 42 E.	− 0 48	N. 57 E.	8 42	+ 7 12
												N. 51 E.	3 57	+ 2 27	N. 45 E.	9 57	+ 8 27
	10	20 23	20 29	87 16	87 31	...	...	...	...	...	...	N. 44 E.	1 38 E.	+ 0 8	N. 39 E.	6 38 E.	+ 5 8
	11*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

CALCUTTA TO HONG KONG.

Oct.	25†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	26	...	19 20	...	88 43	...	...	...	...	...	...	...	...	...	...	...	...
	27	...	17 44	...	88 25	...	...	...	...	17 0	2 0 E.	S. 11 E.	3 13 W.	− 5 13	S. 18 E.	3 47 E.	+ 1 47
	28	...	16 48	...	87 36	...	...	...	...	...	...	S. 8 W.	?12 18 E.	? +10 18	S. 11 W.	9 18	+ 7 18
												S. 23 W.	?12 48	? +10 48	S. 23 W.	9 48	+ 7 48
	29	17 16	17 2	88 0	88 14	...	...	...	...	15 0	...	N. 15 E.	8 17	+ 6 17	N. 15 E.	8 17	+ 6 17
Oct.	29	...	...	...	...	...	...	...	...	...	...	N. 29 E.	7 45 E.	+ 5 45	N. 27 E.	9 45	+ 7 45
	30	17 0	17 5	88 33	88 46	...	...	...	...	15	2 0	N. 88 E.	1 8	− 0 52	N. 79 E.	10 8	+ 8 8
												N. 74 E.	3 10	+ 1 10	N. 67 E.	10 10	+ 8 10
												N. 60 E.	5 12	+ 3 12	N. 56 E.	9 12	+ 7 12
												N. 51 E.	6 37	+ 4 37	N. 46 E.	11 37	+ 9 37
												N. 36 E.	8 3	+ 6 3	N. 33 E.	11 3	+ 9 3
												N. 23 E.	10 11	+ 8 11	N. 22 E.	11 11	+ 9 11
												N. 12 E.	12 20 E.	+10 20	N. 13 E.	11 20	+ 9 20
	31	17 31	17 28	90 12	89 49	...	...	...	...	16	2 0	S. 78 E.	1 49 W.	− 2 49	East	10 11	+ 8 11
												N. 89 E.	1 11 E.	− 0 49	N. 79 E.	11 11	+ 9 11
												N. 74 E.	4 11	+ 2 11	N. 68 E.	10 11	+ 8 11
												N. 64 E.	5 32	+ 3 32	N. 58 E.	11 32	+ 9 32
												N. 50 E.	6 53 E.	+ 4 53	N. 45 E.	11 53	+ 9 53
Nov.	1	17 11	17 17	90 50	90 47	...	...	Calm	0	15	2 0	S. 34 E.	7 30 W.	− 9 30	S. 46 E.	4 30	+ 2 30
	2	...	16 35	91 52	91 20	...	...	S. W.	2	15	2 0 E.	S. 34 E.	6 3	− 8 3	S. 46 E.	5 57	+ 3 57
												S. 41 E.	5 31	− 7 31	S. 56 E.	9 29	+ 7 29
												S. 58 E.	5 3 W.	− 7 3	S. 65 E.	9 57 E.	+ 7 57

* 4 30 p. m. on Pilot Station, Sand Heads.
† 9 30 a. m. pilot left the ship; heavy swell from N. E., with quantities of rain; no observations.

Iron ship "Advance"—Calcutta to Hong Kong, third voyage—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1857.	North. ° ′	North. ° ′	East. ° ′	East. ° ′	°	Miles.			°	° ′	°	° ′	° ′	°	° ′	° ′
Nov. 3	15 0	15 9	92 29	92 20	......	......	N. E	4	......	......	......	......	......	......	......	......
4*	......	......	......	......	......	......	N. E	5	10	2 0 E.	S. 28 E......	6 22 W.	— 8 22	S. 38 E......	3 38 E.	+ 1 38
5	11 16	11 17	95 23	95 19	......	......	{ N. W...... West...... }	6	......	......	......	......	......	......	......	......
6	9 41	9 43	96 28	96 21	......	......	W. by N	4	......	......	......	......	......	......	......	......
7	8 45	8 39	97 4	97 1	......	......	W. by N	3	......	......	......	......	......	......	......	......
8	8 9	7 56	97 25	97 28	......	......	N. W......	2	......	......	......	......	......	......	......	......
9	7 9	7 17	97 59	97 54	......	......	West......	2	......	......	......	......	......	......	......	......
10	5 44	5 56	98 43	98 39	......	......	West......	3	......	......	......	......	......	......	......	......
11	......	......	......	......	......	......	N. W......	4	......	......	......	......	......	......	......	......
12	3 16	3 19	......	100 39	......	......	N. Westerly...	3	......	......	......	......	......	......	......	......
13	2 46	......	101 8	......	......	......	V'ble, W'ly...	3	......	......	......	......	......	......	......	......
14	1 56	......	102 20	......	......	......	Westerly......	4	......	......	......	......	......	......	......	......
15	1 11	......	103 26	......	......	......	Westerly......	4	......	......	......	......	......	......	......	......
16†	......	......	......	......	......	......	North......	3	......	......	......	......	......	......	......	......
17‡	......	......	......	......	......	......	E. N. E	4	......	......	......	......	......	......	......	......
20	0 4	......	107 2	......	......	......	Northerly......	2 to 5	......	......	......	......	......	......	......	......
21	0 49	......	......	......	......	......	N. Easterly...	1	—15	1 20	N. 57 W......	3 34 E.	+ 2 14	N. 45 W......	8 26 W.	— 9 46
											N. 30 W......	4 0	+ 2 40	N. 21 W......	5 0 W.	— 6 20
											N. 5 W......	5 25	+ 4 5	North......	0 25 E.	— 0 55
											N. 10 E......	6 25	+ 5 5	N. 11 E......	5 12	+ 3 52
											N. 22 E......	7 0	+ 5 40	N. 22 E......	7 0 E.	+ 5 40
Dec. 4	4 15	......	108 45	......	......	......	N. E. by E...	1 to 2	— 7	1 30	N. 22 W......	4 10	+ 2 40	N. 14 W......	3 50 W.	— 5 20
6	5 49	5 49	108 50	108 46	......	......	N. W......	3	— 3	1 40	N. 39 E......	8 12	+ 6 32	N. 36 E......	11 12 E.	+ 9 32
15	10 18	10 27	112 40	113 1	......	......	N. to N. E....	3	+ 7	1 30	N. 30 W......	6 28 E.	+ 4 58	N. 22 W......	1 32 W.	— 3 2
											S. 48 E......	6 0 W.	— 7 30	S. 62 E......	8 0 E.	+ 6 30
											S. 44 E......	4 55 W.	— 6 25	S. 56 E......	7 5 E.	+ 5 35
25	13 55	14 5	118 9	118 28	......	......	V'ble, East'ly	2	15	0 30 E.	N. 23 W......	5 20 E.	+ 4 50	N. 17 W......	0 40 W.	— 1 10
26	14 3	14 28	118 14	118 6	......	......	N. to N. E....	2	......	......	N. 27 W......	5 30	+ 5 0	N. 21 W......	0 30 W.	— 1 0
28	14 42	14 28	119 15	119 22	......	......	N. E......	2	16	......	N. 81 E......	0 9 E.	— 0 21	N. 72 E......	9 9 E.	+ 8 30

HONG KONG TO RANGOON.

1858. Jan. 28	15 53	16 21	113 40	115 9	....	....	N. E....	5	17	1 0 E.	S. 11 E........	6 17 W.	− 7 17	S. 19 E........	1 43 E.	+ 0 43
		15 23	113 49	....	....	....	....	....	....	....	S. 13 W........	2 21	− 3 21	S. 12 W........	1 21 W.	− 2 21
30	....	11 40	....	112 10	....	....	N. E............	5	10	1 30 E.	S. 46 W........	0 0	− 1 30	S. 56 W........	10 0	−11 30
											S. 39 W........	0 0	− 1 30	S. 45 W........	6	− 7 30
											S. 31 W........	0 0	− 1 30	S. 33 W........	2 0	− 3 30
											S. 22 W........	0 21	− 1 51	S. 22 W........	0 21 W.	− 1 51
											S. 14 W........	0 51 W.	− 2 21	S. 12 W........	1 9 E.	− 0 21
Feb. 2	*Sunrise.*	5 46	....	....	....	....	N. E............	4	− 5	1 40	S. 30 W........	0 28 E.	− 1 12	S. 33 W........	2 32 W.	− 4 12
Noon......	5 20	5 30	105 54	106 40	....	....	....	....	....	....	S. 77 W........	4 28	+ 2 48	West...........	8 32	−10 12
12	7 17	7 12	97 22	98 2	....	....	E. N. E. to N. N. E.	4	− 2 30	1 45	N. 38 W........	3 0	+ 1 15	N. 28 W........	8 0	− 9 45
13	7 55	....	97 26	....	....	....	{ N. E............ N. W............ }	2	0	1 50 E.	N. 6 W........	4 22	+ 2 32	N. 1 W........	0 38	− 2 28
14	7 51	....	97 59	....	....	....	N. N. W	....	....	....	N. 70 W........	4 30	+ 2 40	N. 60 W........	5 30 W.	− 7 20
											N. 68 E........	4 15 E.	+ 2 25	N. 63 E........	9 15 E.	+ 7 25

RANGOON TO HONG KONG.

April 15	15 43	....	96 5	....	....	....	W. S. W........	3	+13	2 15 E.	S. 4 30 W...	2 0 W.	− 4 15	South	2 30 E.	+ 0 15
											S. 5 E........	3 5	− 5 20	S. 11 E........	2 30	+ 0 15
											S. 13 E........	5 0	− 7 15	S. 21 E........	3 0	+ 0 45
16	14 16	....	96 10	....	....	....	West:	3	+12	....	S. 24 E........	7 30	− 9 45	S. 18 E........	2 30	+ 0 15
25	6 41	....	98 18	....	....	....	N. N. W	2	− 3	1 45	S. 27 E........	4 0	− 5 45	S. 37 E........	6 0	+ 4 15
											S. 34 E........	3 0	− 4 45	S. 45 E........	8 0	+ 6 15
May 3§	....	....	....	....	....	....	S. Easterly ...	2	....	1 30	S. 43 E........	3 41 W.	− 5 11	S. 57 30 E.....	10 50	+ 9 29
											N. 41 E........	6 40 E.	+ 5 10	N. 36 E........	11 40	+10 10
4‖	....	....	....	....	....	....	{ N. N. E........ S. W............ }	3	....	1 30	S. 55 E........	4 45 W.	− 6 15	S. 60 E........	9 15	+ 7 45
14	....	4 52	105 18	105 6	....	....	S. S. W........	3	− 5	1 40	N. 32 W........	3 36	+ 1 54	N. 22 W........	6 4 W.	− 7 44
											N. 17 W........	4 42	+ 3 2	N. 11 W........	1 18 W.	− 2 58
											N. 3 W........	5 20	+ 3 49	N. 1 E........	2 29 E.	+ 0 49
											N. 10 E........	6 0	+ 4 20	N. 11 E........	5 0	+ 3 20
											N. 24 E........	6 30	+ 4 50	N. 23 E........	7 30 E.	+ 5 50
15	5 2	....	105 15	....	....	....	S. W............	1	....	....	N. 77 W........	3 10	+ 1 30	West...........	16 10 W.	−17 50
20	8 40	....	107 8	....	....	....	S. W............	2	+ 2	1 50	N. 52 E........	7 18	+ 5 28	N. 48 E........	11 18 E.	+ 9 28
23	12 43	....	111 36	....	....	....	S. W. by S.....	5	+10	1 30	N. 26 E........	7 3	+ 5 33	N. 24 E........	9 3	+ 7 33
27	19 13	....	114 29	....	....	....	Southerly......	3	+24	0 40	N. 24 E........	6 0	+ 5 20	N. 23 E........	7 0	+ 6 20
											N. 9 E........	5 30	+ 4 50	N. 11 E........	3 30 E.	+ 2 50
											N. 4 E........	5 0	+ 4 20	N. 1 E........	0 0	− 0 40
											N. 16 W........	4 30	+ 3 50	N. 10 W........	1 30 W.	− 2 10
											N. 31 W........	4 0 E.	+ 3 20	N. 24 W........	3 0 W.	− 3 40

* Narcondam Isle, S. E. ¾ E. 8′. † Noon, Coney Island light-house S. W. by W. ¼ W. St. John's Island, outer part, N. E. ¼ N.
‡ Noon, Port Romana, N. E. ¼ E. Port Palan S. Working through Straits of Singapore.
§ Mount Formosa, E. by S. ¼ S., Mount Monar, E. by N. ¼ N. ‖ Mount Formosa, N. by W. ¾ W., Palo Pisang, E. by N.

Iron ship "Advance"—Hong Kong to Singapore, Penang, and Rangoon.

Date.	Latitude. By observat'n.	Latitude. By dead reckoning.	Longitude. By chronometer.	Longitude. By dead reckoning.	Difference between position by observation and by dead reckoning. Direction.	Difference between position by observation and by dead reckoning. Amount.	Winds. Direction.	Winds. Force.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Standard compass, (uncompensated.) Head by compass.	Standard compass, (uncompensated.) Total error.	Standard compass, (uncompensated.) Deviation.	Steering compass, compensated.) Head by compass.	Steering compass, compensated.) Total error.	Steering compass, compensated.) Deviation.
	North. ° ′	*North.* ° ′	*East.* ° ′	*East.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
1859. Jan. 2*									+29	0 30 E.				S. S. W.	2 50 W.	− 3 20
														S. W.	9 50	−10 20
Feb. 5	7 56		97 41				E. N. E.	4	− 1	1 50	N. 27 W.	3 40 E.	+ 1 50	N. 18 W.	5 20	− 7 10
6	9 13	9 5	97 23	97 28			E. N. E.	4	+ 1	2 0	N. 5 W.	6 8 E.	+ 4 8	North	1 8 W.	− 3 8
8	12 29		96 44				E. N. E.	3	+ 8	2 10 E.				N. by E. ¼ E.	6 33 E.	+ 4 23

RANGOON TO BOMBAY.

Date.	Latitude. By observat'n.	Latitude. By dead reckoning.	Longitude. By chronometer.	Longitude. By dead reckoning.	Difference Direction.	Difference Amount.	Winds. Direction.	Winds. Force.	Dip.	Variation.	Standard Head by compass.	Standard Total error.	Standard Deviation.	Steering Head by compass.	Steering Total error.	Steering Deviation.
Aug. 11	10 47		94 37				S. S. W.	2	+ 5	2 0 E.				W. ¼ N.	9 0 W.	−11 0
30	6 42		84 34				S. W. by W.	4	−13	0 45				S. 22 W.	6 0 E.	+ 5 15
Sept. 1	3 13		86 56				S. W.	4	−12	0 45				W. N. W.	*Approx.* 14 W.	−14 45
2	3 30	3 27	85 35	85 29			S. W.	3						W. by N.	18 25 W.	−19 10
	South.	*South.*														
8	9 40		83 15				W. to S. W.	3	−20	0 10				South	3 17 E.	+ 3 7
10	1 46		83 52				V'ble S. W.	1	−21	0 0				S. W.	10 0	+10 0
							Calms	0								
17	8 32		76 13				S. S. E.	6	−35	1 40				West	22 21	−20 41
18	9 4	8 46		73 22			S. E. by S.	6	−37 0	2 10				W. N. W.	25 0	−22 50
19	8 52	8 56	70 12	70 52			S. S. E.	5	−37 30	2 40				N. 89 W.	24 13	−21 33
														N. 77 W.	22 30	−19 50
														N. 64 W.	19 13	−16 33
														N. 46 W.	18 50	−16 10
														N. 34 W.	17 50	−15 10
20		8 22		67 27			S. E.	5 to 7	−36	2 50						
21		6 35	65 12	65 39			S. E. to S.	6	−32 30	2 40				N. 28 W.	13 8	−10 28
22	4 52	4 46	64 35	64 44			S. Westerly	5	−31 9	2 45	N. 69 E.	1 33	+ 1 12	N. 58 E.	7 37	+10 22
											N. 50 E.	0 3 W.	+ 2 42	N. 43 E.	6 57	+ 0 42

												N. 38 E.	1 27 E.	+ 4 12	N. 35 E.	4 27	+ 7 12
												N. 21 30 E.	2 27	+ 5 12	N. 22 E.	1 57 E.	+ 4 42
												N. 9 E.	0 20 E.	+ 3 5	N. 11 E.	1 40 W.	+ 1 5
												N. 5 W.	0 13 W.	+ 2 32	North	5 13	— 2 28
												N. 19 W.	1 43	+ 1 2	N. 11 W.	9 43	— 6 58
												N. 33 W.	2 50	— 0 5	N. 22 W.	13 50	—11 5
												N. 45 W.	2 50	— 0 5	N. 32 W.	15 50	—13 5
												N. 62 W.	2 50	— 0 5	N. 46 W.	18 50	—16 5
												N. 74 W.	2 53	— 0 8	N. 56 W.	21 23 W.	—18 38
	23	3 15	......	64 31	......	......	......	S.W.	4	—28 0	2 30	N. 106 W.	? 7 30	— 5 0	N. 80 E.	18 30 E.	+21 0
												N. 85 E.	2 0	+ 0 30	N. 70 E.	13 0	+15 30
												N. 70 E.	0 30 W.	+ 2 0	N. 58 E.	11 30	+14 0
												N. 55 E.	0 30 E.	+ 3 0	N. 48 E.	10 30	+13 0
												N. 41 E.	0 50	+ 3 20	N. 34 E.	7 50	+10 20
												N. 25 E.	2 50	+ 5 20	N. 22 E.	5 50 E.	+ 8 20
												N. 8 E.	1 40	+ 4 10	N. 10 E.	1 40 W.	+ 0 50
												N. 5 W.	0 30 E.	+ 3 0	North	4 30	— 2 0
												N. 34 W.	2 0 W.	+ 0 30	N. 23 W.	13 0	—10 30
	24	1 46	......	64 21	......	......	......	N.W. by W.	4	—25 0	2 15	N. 6 W.	1 14 W.	+ 1 1	North	7 14	— 4 59
												N. 13 E.	1 0 E.	+ 3 15	N. 15 E.	1 0 W.	+ 1 15
	25	0 13 *North.*	0 17 *North.*	65 36	65 21	......	......	W. N.W.	3	—22 30	1 50	N. 5 E.	0 53 E.	+ 2 43	N. 8 E.	2 7 E.	+ 3 57
	26	0 48	0 52	66 13	66 0	......	......	N.W. by W.	2	—20 0	1 40	N. 33 W.	1 15 W.	+ 0 25	N. 22 W.	12 15 W.	—10 35
												N. 20 W.	1 19	+ 0 21	N. 11 W.	10 19	— 8 39
												N. 5 W.	0 17 W.	+ 1 23	North	5 17	— 3 37
												N. 17 E.	0 45 E.	+ 2 25	N. 10 E.	2 15 W.	— 0 35
												N. 21 E.	0 45	+ 2 25	N. 21 E.	0 45 E.	+ 2 25
												N. 52 E.	0 0	+ 1 40	N. 46 E.	6 0	+ 7 40
												N. 65 E.	0 51 W.	+ 0 49	N. 56 E.	8 9	+ 9 49
												N. 78 E.	1 39	+ 0 1	N. 67 E.	9 21	—11 1
												S. 84 E.	2 20	— 0 40	N. 81 E.	12 40	+14 20
												S. 73 E.	4 40	— 3 0	East	12 20	+14 0
												S. 62 E.	5 40	— 4 0	S. 80 E.	12 20	+14 0
												S. 50 E.	6 40	— 5 0	S. 68 E.	11 20	+13 0
												S. 39 30 E.	6 20	— 4 40	S. 56 E.	10 10	+11 50
												S. 31 E.	6 0 W.	— 4 20	S. 45 E.	8 0 E.	+ 9 40
Oct.	1	9 9	......	67 11	......	......	......	W. N.W.	4	— 5 0	0 50	N. 16 E.	1 36 E.	+ 2 26	N. 18 W.	0 24 W.	+ 0 26
	3	13 49	......	67 58	......	......	......	W. N.W.	5	+ 5 0	0 30 W.	N. 8 E.	4 11	+ 4 41	N. 11 E.	1 11 E.	+ 2 41
												N. 21 E.	......	......	N. 22 E.	3 11	+ 3 41
												N. 33 E.	4 41	+ 5 11	N. 32 E.	5 41	+ 6 11
	5	17 33	......	70 31	......	......	......	N.W. by W.	5	13 0	0 0	N. 27 E.	3 10	+ 3 10	N. 26 E.	4 10	+ 4 10
												N. 46 E.	2 40 E.	+ 2 40	N. 43 E.	5 40 E.	+ 5 40

* Near Hong Kong.

Iron ship "Advance"—Bombay to Liverpool, third voyage.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1859.	*North.* ° ′	*North.* ° ′	*East.* ° ′	*East.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
Dec. 4	17 5	17 14	71 48	71 49	...	...	Northerly...	4	12 30	0 10 E.	S. 45 W...	1 47 E.	+ 1 37	S. 56 W...	9 13 W.	— 9 23
											S. 27 W...	1 17	+ 1 7	S. 33 W...	4 43 W.	— 4 53
											S. 10 W...	0 17	+ 0 7	S. 10 W...	0 17 E.	+ 0 7
5	15 37	15 47	71 14	71 6	...	...	N. by W...	3	9 0	0 0	S. 25 W...	0 30	+ 0 30	S. 31 W...	5 30 W.	— 5 30
6	14 30	14 28	70 31	70 35	...	...	N. N. W...	3	...	...	...	...	...	...	...	...
7	13 45	13 39	69 58	70 9	...	...	N. N. E...	2	7 0	0 15 W.	S. 26 W...	0 18	+ 0 33	S. 33 W...	6 42	— 6 27
8	12 22	12 19	69 17	69 10	...	...	N. E. by N...	3	...	...	...	...	...	...	...	...
9	10 54	10 56	68 35	68 30	...	...	N. E. by N...	3	...	...	...	...	...	...	...	...
10	9 36	9 30	67 43	67 50	...	...	N. E. by E...	3	...	...	...	...	...	...	...	...
11	8 20	8 19	67 5	67 4	...	...	E. N. E...	4	— 6 0	0 50	S. 25 30 W...	0 39	+ 1 29	S. 33 W...	6 51	— 6 1
12	6 46	6 42	65 55	66 3	...	...	N. E...	4	...	...	...	...	...	...	...	...
13	5 11	5 14	64 57	65 57	...	...	N. to N. E...	3	—12 0	1 20	S. 33 W...	0 55 E.	+ 2 15	S. 38 W...	7 5	— 5 45
14	4 15	4 27	64 19	64 29	...	...	N. to N. E...	2	—14 0	1 40	S. 29 W...	0 43 W.	+ 0 57	S. 37 W...	9 34	— 7 54
15	4 4	...	63 55	...	...	...	N. Easterly...	1	—15 0	1 40	S. 71 W...	0 30 E.	+ 2 10	S. 87 W...	15 30	—13 50
16	3 25	3 20	63 30	...	...	...	N. Easterly...	2	...	...	...	...	...	...	...	...
17	2 33	2 40	62 53	63 12	...	...	S. W...	1	—17 30	1 50	S. 26 W...	2 18 W.	— 0 28	S. 34 W...	10 18	— 8 28
							N. E...	2								
											S. 34 W...	1 48	+ 0 2	S. 45 W...	12 48	—10 58
18	1 58	2 6	62 54	62 40	...	...	E. N. E.	1	—18 0	2 0	S. 9 W...	3 36	— 1 36	S. 9 W...	3 36	— 1 36
							W. S. W.									
19	1 30	1 47	63 4	62 48	...	...	N. N. E...	1	...	...	...	...	...	...	...	...
20	0 43	0 47	63 15	63 35	...	...	N. N. E...	2	...	...	...	...	...	...	...	...
	South.	*South.*														
21	0 9	0 14	63 31	63 21	...	...	Westerly...	2	...	...	...	...	...	...	...	...
22	0 56	1 22	64 59	64 28	...	...	...	...	...	...	...	...	...	...	...	...
23	1 10	1 15	64 58	64 8	...	...	Calm...	0	...	...	...	...	...	...	...	...
24	1 19	1 34	65 13	64 56	...	...	S.W. to W...	1	...	...	...	...	...	...	...	...
							Calm...	0								
25	1 47	1 49	65 25	65 3	...	...	N. N. E...	1	—25 0	2 0	S. 20 W...	2 23	— 0 33	S. 20 W...	8 33 W.	— 6 33
26	3 23	3 29	65 22	64 49	...	...	W. N.W...	4	...	...	...	...	...	...	...	...
27	4 53	5 0	65 41	65 7	...	...	S.W to N.W...	6	...	...	...	...	...	...	...	...

28		6 26		65 13			W. N.W.	5								
29	7 6	7 0	65 22	65 5			Westerly	1								
30	8 17	8 15	65 8	65 1			Westerly	2	—37 0	8 10	South	5 10	— 2 0	S. 7 E.	2 50 E.	+ 6 0
											S. 60 E.	6 10	— 3 0	S. 81 E.	14 50	+18 0
31	8 48	8 46	65 24	65 18			Variable S. to S.W.	1	—37 30	8 10	S. 18 E.	8 10	— 5 0	S. 29 E.	2 50 E.	+ 6 0
1860. Jan. 1	9 13	9 13	65 44	65 41			Variable S. to S.W.	1								
2	9 35	9 33	65 47	65 34			W. S.W. / Calms	1 / 0	—38 0	8 15	S. 48 W.	1 18	+ 1 57	S. 67 W.	20 18 W.	—17 3
											S. 64 W.	0 49	+ 2 26	S. 86 W.	22 49	—19 34
											S. 75 W.	1 21	+ 1 54	N. 82 W.	24 20	—21 5
											N. 80 W.	1 53	+ 1 22	N. 59 W.	22 53	—19 38
											N. 48 W.	1 48	+ 1 27	N. 34 W.	15 48	—12 33
											N. 21 W.	0 48 W.	+ 2 27	N. 11 W.	10 48	— 7 33
									—38 0	8 15	N. 10 E.	0 20 E.	+ 3 35	N. 12 E.	1 40 W.	+ 1 35
											N. 39 E.	0 36 E.	+ 3 51	N. 34 E.	5 36 E.	+ 8 51
											N. 70 E.	0 41 W.	+ 2 34	N. 58 E.	11 19	+14 34
											S. 83 E.	4 58	— 1 43	N. 78 E.	14 2	+17 17
											S. 26 W.	1 38	+ 1 37	S. 36 W.	11 38	— 8 23
3	10 10	10 10	64 56	65 12			S. S. E.	3	—40 0	8 30	S. 38 W.	4 12	— 0 42	S. 56 W.	22 12	—18 47
											S. 46 W.	2 12	+ 1 18	S. 66 W.	22 42	—19 12
4	10 44	10 38	63 57	64 26			S. to S. E.	2								
5	11 27	11 24	62 51	63 17			S. E. by E.	2								
6	12 7	12 10	62 10	62 7			E. S. E.	2								
7	13 35	13 26	61 2	61 20			S. E.	2	—45 0	5 15	S. 39 W.	5 21	— 0 6	S. 58 W.	24 21 W.	—19 6
8	14 54	14 53	59 52	60 2			S. S. E.	3								
9		16 9	58 17	58 29			S. E.	3 to 5								
10	17 17	17 8	57 21	57 31			S. S. E. to E.	3 to 5	—50 0	8 0				S. 67 W.	32 2	—24 2
11	18 50	18 41	55 42	56—1			S. by W.	4	—52 0	9 30	S. 70 W.	10 7	— 0 37	N. 84 W.	36 7 W.	—26 37
12	19 8	19 11	53 27	53 53			S.W.	4								
13	19 12	19 8	51 19	51 42			S. Westerly	3								
	19 12		51 29						—52 0	11 30	S. 19 E.	16 17	— 4 47	S. 44 E.	8 43 E.	+20 13
											S. 40 E.	15 11	— 3 41	S. 68 E.	12 49	+24 19
											S. 61 E.	14 36	— 3 6	East	14 24	+25 54
											S. 89 E.	11 22	+ 0 8	N. 68 E.	11 37	+23 7
											N. 60 E.	8 27	+ 3 3	N. 46 E.	5 36 E.	+17 6
											N. 25 E.	7 14	+ 4 16	N. 22 E.	4 14 W.	+ 7 16
											N. 6 W.	7 46	+ 3 44	North	13 46	— 2 16
											N. 40 W.	10 6	+ 1 24	N. 23 W.	27 5	—15 36
											N. 68 30 W.	11 56	— 0 26	N. 46 W.	34 26	—22 56
											S. 86 W.	11 56	— 0 26	N. 67 W.	39 56	—28 26
14	19 22	19 17	49 57	50 25			V'ble, S.W.	3								
15	19 56	19 56	49 58	50 1			S. S.W.	1	—52 30	13 0	S. 7 W.	16 20	— 3 20	S. 6 W.	12 20	+ 0 40
											S. 18 W.	13 20	— 0 20	S. 27 W.	22 20	— 9 20
16		20 17		49 55			Calm	0								
17	22 4	21 44	49 21	49 34			S. E. by S.	3								
18	22 49	22 45	48 56	49 4			Calm	0								
19		23 11		48 51			Calm	0								
20	24 47	24 37	48 33	48 29			East	4								
21	27 23	27 12	46 2	46 38			E. S. E.	5	—57 30	19 45 W.	S. 62 W.	12 15 W.	+ 7 30	N. 83 W.	56 15 W.	—36 30

Iron ship "Advance"— Bombay to Liverpool, third voyage—Continued.

Date.	Latitude. By observat'n.	Latitude. By dead reckoning.	Longitude. By chronometer.	Longitude. By dead reckoning.	Difference between position by observation and by dead reckoning. Direction.	Difference between position by observation and by dead reckoning. Amount.	Winds. Direction.	Winds. Force.	Approximate magnetic. Dip	Approximate magnetic. Variation.	Standard compass, (uncompensated.) Head by compass.	Standard compass, (uncompensated.) Total error.	Standard compass, (uncompensated.) Deviation.	Steering compass, (compensated.) Head by compass.	Steering compass, (compensated.) Total error.	Steering compass, (compensated.) Deviation.
	South. ° ′	*South.* ° ′	*East.* ° ′	*East.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
1860. Jan. 22		28 35		43 28			Easterly	5								
23	29 44	29 43	40 15	40 19			S. E. by S.	6	—57 30	24 0 W.	N. 89 W.	24 53 W.	— 0 53	N. 57 W.	56 33 W.	—32 33
24	30 17	30 30	37 58	38 7			East	2	—57 0	25 15	West	25 28	— 0 13	N. 58 W.	57 38	—32 23
25	30 53	30 37	37 25	36 59			Calm	0								
26	31 25	31 19	36 16	36 16			South	3	—57 30	26 20	N. 88 W.	26 0	+ 0 20	N. 56 W.	58 0	—31 40
27	31 59	31 59	34 4	34 25			E. S. E.	3	—57 0	27 20	West	27 0	+ 0 20	N. 57 W.	59 0	—31 40
28	32 28	32 19	32 52	32 4			S. W.	6								
29	32 23	32 43	30 30	30 35			S. Easterly	2								
30	34 14	33 41	27 51	28 5			E. S. E.	6								
31	35 2	34 35	25 2	25 59			South	3								
Feb. 1	35 24	35 7	21 4	22 23	(*)	(*)	S. E. by E.	5	—55 0	30 0				N. by W.	42 6	—12 6
2	34 19	34 13	17 23	17 46			S. S. E.	6	—52 30	29 30				N. by W.	42 40	—13 10
3	32 6	32 23	14 41	14 47			S. S. W.	5	—50 0	29 0				N. ½ W.	45 0	—16 0
4	30 1	30 19	12 2	11 55			S. S. W.	4	—47 0	28 20	N. 22 W.	25 0	+ 3 20	N. 8 W.	39 0	—10 40
5	28 11	28 14	10 4	9 51			S. S. W.	3								
6	26 36	26 36	8 13	8 24			W. S. W.	4	—40 0	27 30	N. 21 30 W.	23 30	+ 4 0	N. 8 W.	37 0	— 9 30
7		24 53	5 57	6 7			South	3								
8		23 15		3 59			S. E.	4								
	Double alt.															
9	22 6	21 50	2 1	2 19			S. S. E.	3								
10	20 50	20 40	0 23	0 26			S. S. E.	3								
			West.	*West.*												
11	19 45	19 52	1 1	0 54					—25 0	25 30	N. 20 W.	23 52	+ 1 38	N. 11 W.	33 52	— 8 22
12	18 24	18 26	2 38	2 33			S. E. by S.	3	—22 30	25 10	N. 24 W.	23 29	+ 1 41	N. 12 W.	35 29	—10 19
13	17 18	17 19	4 6	3 54			S. E. by S.	3								
14	16 4	15 58	5 38	5 31												
15	15 12	15 6	6 47	6 37			S. S. E.	2								
16	14 7	14 4	8 5	8 2			S. E.	3	—10 0	23 10	N. 21 W.	21 15	+ 1 55	N. 11 W.	31 15	— 8 5
17	13 5	13 1	9 21	9 18			S. E. by S.	3								
18	11 52	12 0	10 27	10 31			S. E.	3	— 5 0	22 20	N. 18 W.	20 26	+ 1 54	N. 8 W.	?20 26	?+ 1 54

	19	10 51	10 58	11 26	11 19			S. E.	2								
	20	9 52	9 50	12 28	12 18			S. E.	2								
	21	8 46	8 43	13 44	13 27			S. E. by S.	3	+ 3 0	21 10	N. 15 W.	19 4	+ 2 6	N. 7 W.	27 4	— 5 54
	22	7 30	7 23	14 42	14 44			S. E. by E.	3								
	23	6 18	6 15	15 51	15 44			S. S. E.	3								
	24	4 58	5 4	16 56	16 53			S. E. by S.	3								
	25	3 59	3 52	18 15	17 59			S. E. by S.	2								
	26	3 0	3 1	19 25	19 14			V'ble S. E. by S.	2	16 0	18 0	N. 26 W.	17 25	+ 0 35	N. 15 W.	28 25	—10 25
	27	2 5	2 14	20 25	20 14			S. E. by S.	2								
	28	1 19	1 21	21 18	21 3			S. S. E.	2	19 0	17 0	N. 27 W.	17 25	— 0 25	N. 16 W.	28 25	—11 25
												N. 2 W.	16 25	+ 0 35	N. 4 E.	22 25	— 5 25
	29		0 21		20 44			V'ble N. E. to S. E.	2								
		North.	*North.*														
Mar.	1		0 42		21 45			East	2								
	2		1 50		21 45												
	3	2 35	1 55	22 13	21 45			Variable	1	26 0	16 40	N. 15 30 W.	15 10	+ 1 30	N. 18 W.	17 40	— 1 0
	4	3 12	2 51		22 28			Variable N. Easterly.	1	27 0	16 40	N. 59 W.	16 30	+ 0 10	N. 53 E.	10 30	+ 6 10
	5	3 50	3 47		23 4			N. to E.	3								
	6	4 22	4 14	23 2	23 15			N. W. / N. E.	2	29 0	16 30	N. 45 W.	15 48	+ 0 42	N. 33 W.	27 28	—10 58
												N. 75 E.	19 29	— 2 59	N. 65 E.	9 29	+ 7 1
												S. 47 E.	23 15	— 6 45	S. 61 E.	9 15	+ 7 15
												S. 28 E.	24 48	— 8 18	S. 39 E.	13 48	+ 2 42
												S. 17 E.	22 38	— 6 8	S. 25 E.	14 38	+ 1 52
												S. 1 W.	21 55	— 5 25	S. 1 E.	19 55	— 3 25
												S. 18 W.	19 26	— 2 56	S 22 W.	23 20	— 6 50
												S. 36 W.	16 40	— 0 10	S. 46 W.	26 40	—10 10
												S. 55 W.	16 7	+ 0 23	S. 67 W.	28 7	—11 37
												S. 76 W.	15 50	+ 0 50	N. 89 W.	30 50	—14 20
												N. 78 W.	16 35	— 0 5	N. 62 30 W.	32 5	—15 35
												N. 58 W.	15 50	+ 0 40	N. 45 W.	28 50	—12 20
	7	4 39	4 39	24 7	24 59			N. N. E.	3								
	8	5 38	5 37	25 15	24 59			N. E. by N.	3								
	9	7 8	7 3	26 49	26 25			N. E. by N.	3								
	10	8 28	8 18	28 25	28 8			N. N. E.	4								
	11	10 13	9 49	30 4	29 49			N. E. by N.	4	40 0	13 50				N. ¼ W.	14 12	— 0 22
	12	12 29	12 17	31 18	31 0			E. N. E.	4	43 0	13 30				N. ¼ W.	14 6	— 0 36
	13	14 27	14 29	32 24	32 9			E. N. E.	4								
	14	16 19	16 19	32 54	32 30			E. by N.	3								
	15	18 24	18 18	32 29	33 4			East	3	52 0	14 0				N. ½ E.	13	+ 1 0
	16	19 47	19 52	34 5	33 56			E. N. E.	2								
	17	20 57	21 3	35 2	34 45			N. E.	2	54 30	14 30				N. by W. ½ W.	18 42	— 4 12
	18	21 44	21 52	35 52	35 46			N. E. by E.	2								
			21 36	35 48						55 30	14 30 W.	N. 14 E.	10 36	+ 3 54	N. 18 E.	14 36	— 0 6
												N. 8. W.	9 30	+ 5 0	North	17 30	— 3 0
												N. 34 W.	10 38	+ 3 52	N. 24 W.	28 30	—14 0
												N. 57 W.	11 30 W.	+ 3 0	N. 45 W.	23 30 W.	— 9 0

* 6 P. M.—Lat. ☾ 35 2 18, Lon. Chr. 20 10 30.

Iron ship "Advance"—Bombay to Liverpool, third voyage—Continued.

Date.	Latitude.		Longitude.		Difference between position by observation and by dead reckoning.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
	By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Amount.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
	North. ° ′	*North.* ° ′	*West.* ° ′	*West.* ° ′	°	*Miles.*			° ′	° ′	°	° ′	° ′	°	° ′	° ′
1860. Mar. 18											N. 86 W.	13 8W.	+ 1 22	N. 71 30W.	27 38 W.	−13 8
											S. 74 W.	13 10	+ 1 20	S. 87 W.	26 10	−11 40
											S. 54 30 W.	13 40	+ 0 50	S. 67 W.	26 50	−12 20
											S. 36 W.	14 15	+ 0 15	S. 43 W.	21 15	− 6 45
											S. 18 W.	15 41	− 1 11	S. 20 W.	17 41	− 3 11
											S. 4 W.	19 54	− 5 24	S. 1 W.	16 54	− 2 24
											S. 14 E.	19 48	− 5 18	S. 22 W.	11 48	+ 2 42
											S. 18 W.	20 10	− 5 40	S. 27 E.	10 10	+ 4 20
19	22 20	22 15	36 11	36 0			Calm	0	56 0	14 40 W.				N. E.	9 36	+ 5 4
														E. N. E.	8 56	+ 6 4
20	22 53	22 48	36 11	36 8			Calm	0								
21		23 16	35 50	36 0			V'ble S. W.	1								
22	23 26	23 44	35 52	35 53			Variable	1	57 0	16 0				N. N. E.	10 44	+ 5 16
23	24 20	24 31	36 55	36 53			N. E.	3								
24	25 56	25 48	37 31	37 10			E. N. E.	3								
25	27 42	27 42	37 30	37 10			East	4								
26	29 57	29 50	38 2	37 30			E. by N.	4	63 0	18 45				N. ½ E.	13 18	+ 5 27
	31 55	31 48	37 59	38 2			E. by N.	4								
	32 57	33 15	37 24	37 27			E. by N.	3	66 0	21 15	N. 76 E.	22 29	− 1 14	N. 67 E.	13 29	+ 7 46
											N. 48 E.	16 54	+ 4 21	N. 45 E.	13 54	+ 7 21
											N. 7 W.	12 15	+ 9 0	North	19 38	+ 1 37
											N. 46 W.	13 31	+ 7 44	N. 34 W.	25 31	− 4 16
											S. 71 W.	11 57	+ 9 18	N. 86 W.	26 57	− 5 42
29	33 44	33 35	36 30	36 22			S. S. E.	3	66 0	22 0 W.	N. 78 30 E.	22 42	− 0 42	N. 68 E.	12 12	+ 9 48
											S. 76 E.	29 12	− 7 12	East	15 12	+ 6 48
											N. 48 E.	18 30 W.	+ 3 30	N. 45 E.	15 30 W.	+ 6 30
30	33 46		35 7				S. W.	4								
31	36 33	36 18	32 48	32 58			W. S. W.	8								
April 1		37 8		31 41			N. W. to N. E. / S. E.	3								

Iron ship "Advance"—Bombay to Liverpool, third voyage—Continued.

Date.	Variation by chart.	Latitude.		Longitude.		Winds.		Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
		By observat'n.	By dead reckoning.	By chronometer.	By dead reckoning.	Direction.	Force.	Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1860.	° ′	*North.* ° ′	*North.* ° ′	*West.* ° ′	*West.* ° ′			° ′	° ′	°	° ′	° ′	°	° ′	° ′
April 2	....	37 54	38 20	29 30	29 28	West.........	6	....	....	....	....	....	....	....	....
						North.........	7								
3	....	38 13	38 47	29 47	29 28	....	....	67 15	26 0 W.	N. 64 E.........	17 15 W.	+ 8 45	N. 56 E.........	9 15 W.	+16 45
		Position by bearings of Pico.													
4	16 40 W.	....	38 23	....	28 35	Variable and calms under lee of Pico.		67 15	26 0 W.	N. 30 30 W...	25 10	+ 0 50	N. 53 30 W...	19 40	+ 6 20
	16 40									N. 30 30 E....	24 10	+ 1 50	N. 53 30 W.?..	19 40	+ 6 20
	14 40									N. 76 E.........	26 10	— 0 10	N. 67 W.?......	17 10	+ 8 50
	13 10									S. 76 E.........	30 10	— 4 10	East............	16 10	+ 9 50
	13 40									S. 52 E.........	33 40	— 7 40	S. 69 E.........	15 40	+10 20
	15 40									S. 30 E.........	33 10	— 7 10	S. 45 E.........	18 10	+ 7 50
	17 40									S. 10 E.........	32 10	— 6 10	S. 20 E.........	22 10	+ 3 50
	22 40									S. 6 W.........	29 40	— 3 40	S. 2 W.........	25 40	+ 0 20
	25 40									S. 21 W.........	26 40	— 0 40	S. 23 30 W...	27 10	— 1 10
	30 40									S. 40 W.........	23 40	+ 2 20	S. 50 W.........	33 40	— 7 40
	32 40									S. 57 W.........	20 40	+ 5 20	S. 70 W.........	33 40	— 7 40
	32 40									S. 75 W.........	19 40	+ 6 20	N. 78 W.........	35 10	— 9 10
	32 40									N. 81 W.........	19 10	+ 6 50	N. 66 W.........	34 10	— 8 10
	30 40									N. 59 W.........	18 40	+ 7 20	N. 45 W.........	30 40	— 4 40
	23 40									N. 9 30 W...	15 40	+10 20	North...........	25 10	+ 0 50
	18 40									N. 17 E.........	15 10 W.	+10 50	N. 22 E.........	20 10	+ 5 50
	27 40 W.												N. 20 W.........	27 40 W.	— 1 40

REMARKS.—When these observations were taken for deviation, the ship lay close under the Peak of Pico, an azimuth observation was made at first and last observation, in order to obtain the true bearing of the peak, observed as the ship was wore round, there being very little wind at the time. In the column marked "variation by chart" is the deviation, &c., as obtained by bearings taken by after compass, which, as it differs from that found by comparison of the two compasses, leads me to suppose that there must be an error in the position of the lubber's lines, which I shall be better able to ascertain on arrival in port.

These observations close the log so far as compass observations are concerned.

Iron ship "Advance"—Liverpool to Colombo—Fourth voyage.

Date.	Latitude.	Longitude.	Approximate magnetic.		Standard compass, (uncompensated.)			Steering compass, (compensated.)		
			Dip.	Variation.	Head by compass.	Total error.	Deviation.	Head by compass.	Total error.	Deviation.
1860.	° ′	° ′		° ′	°	° ′	° ′	°	° ′	° ′
July 21	41 49 N.	12 1 W.	......	24 0 W.	S. 35 W...	17 58 W.	+6 2	S. 54 W...	16 58 W.	+ 7 2
24	34 3	17 30	......	23 0	S. 41 W...	17 26	+5 34	S. 41 W...	17 26	+ 5 34
28	25 41	23 19	......	20 20	S. 1 W...	19 52	+0 28	S. 3 W.?.	21 52	— 1 32
					S. 24 W...	14 40	+5 40	S. 22 W...	12 40	+ 7 40
					S. 45 W...	12 56	+7 24	S. 45 W...	12 56	+ 7 24
					S. 66 W...	12 4	+8 16	S. 67 W...	13 4	+ 7 16
30	20 55	24 46	......	18 50	N.73 W...	14 20	+4 30	N. 65 W...	21 50	— 3 0
					S. 86 W...	14 50	+4 0	West.......	18 50	0 0
					S. 65 W...	15 37	+2 13	S. 65 W...	15 37	+ 3 13
					S. 46 W...	15 20	+3 30	S. 44.30 W.	13 55	+ 4 55
					S. 26 W...	15 45	+2 5	S. 22 W...	11 45	+ 7 5
					S. 2 W...	19 32	—0 42	South......	17 32	+ 1 18
					S. 23 E...	22 48	—3 58	S. 23 E...	22 48	— 3 58
Aug. 2	15 28	26 4	......	17 0	S. 9 W...	16 18	+0 42	S. 6 W...	13 18	+ 3 42
					S. 4 E...	17 33	—0 33	S. 6 E...	15 33	+ 1 27
3	15 15	25 9	......	17 0	S. 13 E...	19 30	—2 30	S. by E....	18 0	— 1 0
9	5 27	16 29	......	19 0	....	....	....	S. E. by S. ½ S.	21 9	— 2 9
10	4 29 N.	17 21	......	18 40	....	....	....	W. ½ S......	20 47	— 2 7
23	20 78 S.	30 59	......	9 20	S. 42 E...	14 52	—5 32	S. 45 E...	11 52	— 2 32
					S. 25 E...	14 0	—4 40	S. 25 E...	14 0	— 4 40
					S. 1.5 W..	12 50	—3 30	S. 1 E...	10 20	— 1 0
					S. 38 W...	9 0	+0 20	S. 33 W...	4 0	+ 5 20
					S. 57 W...	6 15	+3 5	S. 55 W...	4 15	+ 5 5
					S. 88 W...	7 30	+1 50	West.......	9 30	— 0 10
					N.71 W...	7 30	+1 50	N. 65 W...	13 30	— 4 10
					N.55 W...	6 0	+3 30	N. 47 W...	14 0	— 4 40
					N. 6 W...	6 30	+2 50	North......	12 30	— 3 10
					N.23 E...	8 12	+1 8	N. 25 E...	10 12	— 0 52
24	21 49	30 10	......	9 30	S. 4 E...	13 0	—3 30	S. 8 E...	9 0	+ 0 30
28	28 42	27 44	......	9 30	S. 28 E...	13 56	—4 26	S. 33 E...	8 56	+ 0 34
					S. 58 E...	13 56	—4 26	S. 63 E...	8 56	+ 0 34
30	30 7	24 48	......	11 0	S. 40 E...	16 57	—5 57	S. 45 E...	11 57	— 0 57
Sept. 1	31 38	21 42	......	12 30	S. 23 W...	19 9	—6 39	S. 28 W...	14 9	— 1 39
3	35 0	14 7 W.	......	....	....	....	....	S. E.........	19 0	— 3 15
14	40 44	24 6	......	31 15	S. 38 E...	39 49	—8 34	S. 50 E...	27 49	+ 3 26
20	41 2	32 40	......	31 20	S. 45 E...	40 0	—8 40	S. 62 E...	22 0	+ 9 20
24	40 48	46 51	......	28 45	N. 84 E...	36 12	—7 27	S. 78 E...	17 32	+11 13
Oct. 2	33 40	69 33	......	16 20	N. 16 E...	11 0	+5 20	N. 20 E...	15 0	+ 1 0
3	30 18	70 12	......	14 0	N.10 W...	8 42	+5 18	North......	18 42	— 4 42
4	28 29	68 51	......	12 45	N.34 W...	9 4	+3 47	N. 20 W...	23 4	—10 19
5	28 16	71 14	......	12 45	N. 72 E...	13 30	—0 45	N. 60 E...	1 30	+11 15
8	26 44	75 30	......	10 0	N. 7 E...	6 0	+4 0	N. 11 E...	11 0	— 1 0
9	25 1	74 31	......	9 0	N. 5 E...	8 14	+0 46	N. 11 E...	14 14	— 5 14
10	22 0	75 44	......	6 30	N. 7 E...	2 30	+4 0	N. 12 E...	7 30	— 1 0
11	18 46	75 44	......	4 40	N. 7 E...	0 30	+4 10	N. 10 E...	3 30	+ 1 0
12	14 59	75 34	......	3 15	N. 2 E...	0 34 E.	+3 49	N. 6 E...	3 26	— 0 11
14	7 40	75 6	......	1 40	North.....	2 23	+4 3	N. 5 E...	2 37	— 0 57
15	5 52	75 6	......	1 20	N. 1 E...	2 58	+4 18	N. 5 E...	1 2	+ 0 18
16	2 59 S.	75 24 E.	......	0 50 W.	N. 2 E...	3 44 E.	+4 34	N. 5 E...	0 44 W	+ 0 6

Before sailing from Liverpool, on her fourth voyage, a short iron bar was placed before the steering compass of the "Advance," as shown in the sketch at page 93 of the report. The vessel lay in dock with her head to the north while loading, and no opportunity was afforded for trying the effect of the bar with her head to the east or west, so as to fix the bar in its proper position, except so far as could be judged from temporarily placing the bar at different distances to the east and west of the binnacle, and seeing what effect it produced. This was much regretted at the time, but the following letter from Captain Dalison will show that he acted both cautiously and skilfully, under the circumstances, and that the position chosen for the bar was so near to the proper one that the maximum observed error of the steering compass was only 11° 13′, under circumstances in which it was formerly out three points and upwards:

SHIP "ADVANCE,"
Colombo, October 29, 1860.

MY DEAR SIR: I received your kind favor of August 30 on my arrival and thank you much for the same, as well as for your kindness and attention before the ship sailed.

I found the bar before the compass to be most effectual in reducing the deviation; so much so that, although I had but small opportunity for observation, on account of rough weather, the deviation was so small and regular as not to cause one any inconvenience. Of the few observations I have made I annex a copy.

Coming down channel, I removed the bar, and placed the magnets in the old position, but on the 20th July, being a fine day, I replaced the bar, in lat. 44° 30′ N. and long. 10° W., and also turned the magnets end for end, placing the starboard one on the port side, and the port one on the starboard side; the magnet on the starboard side being 15½ inches nearer the compass, and 1¼ inches raised from the deck; the port magnet being 10½ inches nearer the compass, but on the deck. Before I leave this port I will take the magnets up again, and place them as you wish, and, if good opportunity offer, make the requisite observations. The "Advance" will partly load here and fill up at Tuticoreen for Liverpool or London, so that I do not expect to be absent so long as on my last voyage. In hopes that you will be satisfied with the few observations I have made, I remain, my dear sir, yours, faithfully,

F. L. DALISON.

Mr. W. W. RUNDELL, *Liverpool.*

"ASTRÆA," CAPTAIN SAMUEL NICKELS.

Liverpool to Isle of Mauritius and back.

WITH TRANSVERSE MAGNET.

Date.	Latitude.	Longitude.	Heel.—P, port, and S, starboard.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Steering compass. Ship's head by compass.	Steering compass. Total error.	Steering compass. Deviation.
	South. ° ′	*West.* ° ′		° ′	° ′		° ′	° ′
Aug. 1856, to Feb. 1857.	22 22	30 23	....	—13 0	11 0 W.	S. by E.	21 32 W.	10 32 W.
						S. S. E.	16 20 W.	5 20 W.
	24 32	28 42	....	—17 30	10 0	E. by S.	8 10 E.	18 10 E.
						E. S. E.	0 16 E.	10 16
						S. E. by E.	0 32 W.	9 28
						S. E.	7 22	2 38
						S. E. by S.	7 56 W.	2 4
	37 32	12 30	....	—38 0	16 20	N. E.	31 36 E.	47 56
						N. E. by E.	25 46	42 6
						E. N. E.	21 34	37 54
						E. by N.	15 12	31 32
						East	13 58	30 18
						E. by S.	10 40	27 0
						S. S. E.	4 30	20 50
	40 48	9 25	....	—43 0	17 0	N. E. by E.	25 46	42 46
		East.						
	39 44	31 35	....	—60 0	31 0	N. E. by E.	37 20	68 20
	40 5	33 39	....	—60 30	31 0 W.	N. N. E.	76 50 E.	107 50 E.

WITHOUT COMPENSATION.

Date.	Latitude.	Longitude.	Heel.	Dip.	Variation.	Ship's head by compass.	Total error.	Deviation.
	South. ° ′	*West.* ° ′		° ′	° ′		° ′	° ′
Aug. 1856, to Feb. 1857.	22 22	30 23	....	—13 0	11 0 W.	E. S. E.	7 32 E.	18 32 E.
						S. E. by E.	3 50	14 50
						S. E.	4 28 E.	15 28
						S. E. by S.	2 28 W.	8 32
						S. S. E.	5 54 W.	5 6
	24 32	28 42	....	—17 30	10 0	East	12 0 E.	22 0
						E. by S.	10 20	20 20
						E. S. E.	6 6	16 6
						S. E. by E.	5 48	15 48
						S. E.	4 32 E.	14 32
						S. E. by S.	0 50 W.	9 10
						S. S. E.	0 10 W.	9 50
	29 41	31 40	....	—24 0	6 20	East	13 0 E.	19 20
	37 32	12 30	....	—38 0	16 20	N. E.	12 10	28 30
						N. E. by E.	15 52	32 18
						E. N. E.	17 28	33 48
						E. by N.	17 34	33 54
						East	16 42	33 2
						E. by S.	7 3	23 23
		East.						
	38 49	39 23	....	—61 30	29 30	N. E.	26 22	55 52
						N. E. by E.	24 10	53 40
	40 5	33 39	....	—60 0	31 0	N. E. by E.	30 8	61 8
	37 44	43 38	....	—62 0	28 0	N. E. by E.	13 20	41 20
	36 30	48 18	....	—62 0	25 30	N. E. by E.	46 50 E.	72 20 E.
	35 23	45 20	....	—61 30	25 45	North	27 58 W.	2 13 W.
	33 44	57 38	....	—62 30	20 0	N. by E.	0 46	19 14 E.
						N. N. E.	5 32	25 32
	29 17	59 21	....	—60 0	16 15 W.	N. by E.	9 20 W.	6 55 E.

"Astræa"—Liverpool to Isle of Mauritius and back—Continued.

Date.	Latitude.	Longitude.	Heel.—P, port, and S, starboard.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Steering compass. Ship's head by compass.	Steering compass. Total error.	Steering compass. Deviation.
	North.	West.			West.			
1857.	° ′	° ′	°	° ′	° ′		° ′	° ′
August 15	53 28	4 34	0	70	24 45	S. W. by S.	8 42 W.	16 3 E.
			0	...	...	S. W.	8 0	16 45
			0	...	...	S. W. by W.	10 12	14 33
17	49 39	8 36	2 S.	69	25 20	S. W. by S.	11 18	14 2
			2 S.	...	...	S. W.	13 4	12 16
19	47 23	10 56	2 S.	68 30	25 40	W. S. W.	18 6	7 34
			10 S.	...	...	S. S. W.	10 42	14 58
			2 S.	...	...	S. W.	13 2	12 38
			2 S.	...	...	S. W. by W.	14 20	11 20
20	45 2	12 42	0	67 30	25 20	S. W. by S.	11 0	14 20
21	42 45	13 56	...	66 30	24 40	S. W. by S.	10 56	13 44 E.
22	40 40	14 18	5 S.	65 0	24 40	W. by N.	25 46	1 6 W.
23	40 4	15 0	...	65 0	24 40	W. N. W.	23 34	1 6 E.
24	37 40	15 49	0	64 0	23 40	North	29 24	5 44 W.
						East	23 40	0 0
						E. by S.	23 58	0 18 W.
						E. S. E.	24 12	0 32
						S. E. by E.	24 24	0 44 W.
						S. E.	21 32	2 8 E.
						S. E. by S.	20 48	2 52 E.
			5 P.	...	...	N. W. by W.	28 40	5 0 W.
			5 P.	...	...	N. W.	30 52	7 12
			5 P.	...	...	N. W. by N.	31 2	7 22
						N. N. W.	31 8	7 28
						N. by W.	29 36	5 56 W.
	35 28	18 59	5 P.	63 0	23 40	S. W. by S.	9 48	18 52 E.
30	31 31	19 48	0	60 30	23 15	N. by W.	28 50	5 35 W.
						North	30 16	7 1
						N. by E.	28 24	5 9
						N. N. E.	25 36	2 21
						N. E. by N.	24 14	0 59 W.
						N. E.	21 54	1 21 E.
						N. E. by E.	21 6	2 9
						E. N. E.	22 24	0 51
						E. by N.	22 30	0 45 E.
						East	23 58	0 43 W.
						E. by S.	22 30	0 45 E.
						E. S. E.	22 20	0 55
						S. E. by E.	20 28	2 47
						S. E. by S.	18 50	4 25
						S. E.	18 38	4 37
						S. S. E.	16 58	6 17
	31 39	19 50	0	60 30	23 15	S. W.	11 52	11 23
			0	...	...	S. W. by W.	14 30	8 45
			0	...	...	W. S. W.	17 16	5 59
			0	...	...	W. by S.	19 56	3 19
			0			West	21 44	1 31
31	30 42	18 17	...	60 0	23 0	S. S. E.	16 42	6 18
						S. E. by S.	19 40	3 20
Sept'r 1	30 13	17 18	...	59 0	21 35	S. by E.	13 52	7 43
						South	10 38	10 57
						S. by W.	9 52	11 43
						S. S. W.	9 8	12 27
4	23 33	21 17	0	54 0	20 0	S. W.	12 36	7 24
5	21 33	23 28	0	52 0	19 0	S. W. by W.	16 10	2 50 E.
			0	...	...	W. S. W.	19 50	0 50 W.
			0	...	...	West	24 36	5 36
6	19 46	24 11	0	50 30	18 15	W. by S.	19 28	1 13
			0	...	...	West	22 25	4 10 W.
			0	...	...	S. S. W.	16 20	1 55 E.
7	17 55	25 34	5 S.	48 0	17 30	South	10 46	6 44
						S. by W.	9 52	7 38
8	16 31	25 37	...	47 0	17 15	S. by E.	8 30	8 45
10	13 22	25 58	0	43 0	16 30	S. E.	11 54	4 36
			0	...	...	S. E. by S.	11 54	4 36
			0	...	...	S. S. E.	10 56	5 34
			0	...	...	S. by E.	10 4	6 26
11	12 54	26 45	0	43 0	16 20	South	13 30	2 50
18	4 51	19 41	5 P.	...	...	S. E. by E.	12 40	3 40
20	3 47	17 36	5 P.	33 0	13 20	S. E. by E.	13 2 W.	0 18 E.

"*Astræa*"—*Liverpool to Isle of Mauritius and back*—Continued.

Date.	Latitude.	Longitude.	Heel.—P, port, and S, starboard.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Steering compass. Ship's head by compass.	Steering compass. Total error.	Steering compass. Deviation.
	North.	*West.*			*West.*			
1857.	° ′	° ′	°	° ′	° ′		° ′	° ′
Sept. 20	4 1	17 2	5 S.	31 0	14 20	W. by S.	26 18 W.	11 58 W.
21	3 36	16 23	0	30 0	15 0	W. S. W.	23 28	8 28
						West	24 26	9 26 W.
	South.							
26	4 52	24 28	....	15 30	15 15	S. S. W	13 22	1 53 E.
28	11 23	24 52	5 S.	4 0	14 20	South	10 28	3 52
29	13 11	24 57	5 S.	0	14 0	S. by W.	11 14	2 46 E.
			5 S.	....	....	S. S. W.	14 4	0 4 W.
October 4	25 35	29 5	5 S.	—18 0	9 15	S. by E.	2 20	6 55 E.
8	27 32	26 36	0	—22 0	11 40	E. S. E.	0 18 W.	11 22
10	28 8	24 50	0	—24 0	11 0	E. by S.	7 40 E.	18 40 E.
17	32 3	6 12	....	—36 30	22 0	S. S. W.	29 8 W.	7 8 W.
18	32 30	5 12	....	—37 0	22 0	E. by S.	2 34 E.	24 34 E.
		East.						
20	34 0	2 45	0	—44 0	25 20	E. by S.	0 40 W.	24 40
Nov. 8	36 2	19 43	5 P.	—54 0	29 45	S. E.	4 16 E.	34 1 E.
9	37 6	21 8	0	—55 30	30 15	N. N. W.	53 20 W.	23 5 W.
			0	....	....	N. by W.	48 40	18 25
			0	....	....	North	42 6 W.	11 51 W.
10	38 8	21 12	....	—56 0	30 20	S. S. E.	7 42 E.	38 2 E.
11	38 47	22 16	0	—56 30	30 35	East	12 20	42 55
			0	....	....	E. N. E.	3 45	34 20
			0	....	....	E. by N.	8 12	38 47
13	39 12	26 52	0	—58 0	31 10	E. by N.	12 44	43 54
18	38 51	40 0	0	—59 0	31 0	N. E. by E	6 12	37 12
			0	....	....	E. N. E.	10 24	41 24
21	37 4	49 27	0	—62 30	25 45	N. E. by E.	14 26 E.	40 11 E.
29	23 13	59 9	0	—56 30	11 40	North	17 4 W.	5 24 W.
			0	....	....	N. by W.	39 18	27 38
			0	....	....	N. N. W	27 18	15 38
			0	....	....	N. W. by N	42 8 W.	20 28 W.
HOMEWARD.								
1857.	22 32	55 7	....	—55 0	12 30	West	48 16 W.	35 46 W.
						W. by N.	53 24	40 54
	27 41	49 0	....	—58 0	18 40	N. W	61 32	42 52
						N. W. by N.	58 16	39 36
	30 34	15 40	....	—50 0	29 0	N. by W.	45 2	26 2
		West.						
	17 27	5 24	....	—30 30	23 0	N. W. by W.	45 28	22 28
						N. N. W	39 32	16 32
						N. by W	38 10	15 10
	15 42	7 27	....	—13 0	23 30	North	30 0	6 30
	2 26	27 9	0	+20 0	14 20	North	21 26	7 6
						N. by W.	26 26	12 6
	0 38	28 28	....	25 0	13 30	N. by E.	17 56	4 26
						N. N. E.	13 54	0 24
	North.							
	15 30	39 35	....	47 30	15 20	N. W	27 42	12 22
						N. W. by W.	28 18	12 58
						W. N. W.	26 10	10 50
						W. by N.	24 2	8 42
			0	....	....	West	21 52	6 32 W.
	15 36	39 40	....	50 0	10 15	N. E. by N.	5 6	5 9 E.
						N. E.	2 56	7 19 E.
	16 0	41 17	0	50 0	9 0	N. by E.	18 58	9 58 W.
						N. N. E.	16 48	7 48
	17 53	38 18	....	51 30	11 15	North	13 44	2 29
						N. by E.	12 52	1 37 W.
						N. N. E.	10 2	1 13 E.
						N. E. by N	9 12	2 3
						N. E	7 20	3 55 E.
						N. N. W.	18 26	7 11 W.
						N. by W.	16 38	5 23 W.
	20 32	37 55	....	54 30	12 40	N. E. by E.	8 48	3 52 E.
						E. N. E.	8 46 W.	3 54 E.

"*Astræa*"—*Liverpool to Isle of Mauritius and back*—Continued.

Date.	Latitude.	Longitude.	Heel.—P, port, and S, starboard.	Approximate magnetic.		Steering compass.		
				Dip.	Variation.	Ship's head by compass.	Total error.	Deviation.
	North. ° ′	*West.* ° ′	°	° ′	*West.* ° ′		° ′	° ′
1857.						E. by N.	10 4 W.	2 36 E.
	52 7	(*)	5 P.	70 0	26 0	N. E.	27 48	1 48 W.
		(*)	5 P.			N. E. by E.	30 36	4 36
		(*)	5 P.			E. N. E.	33 48 W.	7 48 W.
LIVERPOOL TO CALCUTTA.								
1858.	50 54	8 13		69 30	25 30	North	28 18 W.	2 48 W.
	45 25	12 44	0	67 30	25 30	S. E.	24 22	1 8 E.
			0			S. E. by S.	21 34	3 56
			0			S. S. E.	20 0	5 30
			0			S. by E.	17 28	8 2
			0			South	15 46	9 44
			0			S. by W.	15 4	10 26
			0			S. S.W.	13 28	12 2
			0			S.W. by S.	12 48	12 42
			0			S.W.	14 46	10 44 E.
	44 37	12 48	8 S.	67 15	25 0	North	32 36	7 36 W.
			5 S.			N. by E.	31 40	6 40
			5 S.			N. N. E.	31 52	6 52
			5 S.			N. E. by N.	30 48	5 48
			5 S.			N. E.	30 44	5 44
			8 S.			W. N.W.	25 24	0 24
			8 S.			N.W. by W.	28 2	3 2
			8 S.			N.W.	29 48	4 48
			8 S.			N.W. by N.	30 34	5 34
			8 S.			N. N.W.	33 22	8 22
			6 S.			N. by W.	33 8	8 8 W.
	25 38	21 36	0	56 0	20 20	S.W.	9 0	11 20 E.
	18 43	25 29	0	50 0	17 45	S. S.W.	8 8	9 37
			0			S.W. by S.	7 36	10 9
	15 45	25 45	5 S.	46 0	17 0	S. S. E.	6 54	10 6
			5 S.			South	8 14	8 46
	4 23	23 43	4 S.	29 30	16 15	S. S.W.	9 26	6 49
			4 S.			S.W.	14 18	1 57 E.
	5 14	24 0	5 S.	31 0	16 0	S. S. E.	21 4	5 4 W.
	South.							
	1 19	27 13	5 S.	22 0	14 15	S.W. by W.	18 12	3 57 W.
	7 54	31 20	7 S.	12 30	11 0	S.W. by S.	7 10	3 50 E.
	9 19	32 7	0	10 0	10 20	North	13 36	3 16 W.
			0			N. by E.	10 26	0 6
			0			N. N. E.	6 14	4 6 E.
			0			N. E. by N.	3 32	6 48
			0			N. E.	1 28	8 52
			0			S.W.	9 24	0 56 E.
			0			S.W. by W.	11 14	0 54 W.
			0			W. S.W.	14 14	3 54
			0			W. by S.	15 58	5 38
			0			West	17 50	7 30
						W. by N.	20 38	10 18
						W. N.W.	21 32	11 12
						N.W.	22 22	12 2
						N. W by N.	22 10	11 50
						N. N.W.	19 58	9 38
						N. by W.	16 50	6 30 W.
	15 52	32 52	5 S.	0	8 30	S. E. by E.	2 30	6 0 E.
			5 S.			S. E.	4 24	4 6
			5 S.			S. E. by S.	6 50	1 40
			5 S.			S. S. E.	6 54	2 36
			5 S.			S. by E.	7 0	1 30
			5 S.			South	8 14 W.	0 16
	27 12	30 24	5 S.	—21 0	7 45	East	6 38 E.	14 23
			5 S.			E. by S.	4 56	12 41
			5 S.			E. S. E.	3 14	10 59
			5 S.			S. E. by E.	1 20 E.	9 5 E.

* Off the hook.

"Astræa"—Liverpool to Calcutta and back—Continued.

Date.	Latitude.	Longitude.	Heel.—P, port, and S, starboard.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Steering compass. Ship's head by compass.	Steering compass. Total error.	Steering compass. Deviation.
	South. ° ′	*East.* ° ′	°	° ′	*West.* ° ′		° ′	° ′
1858.	35 37	76 50	0	—65 30	17 0	N. by E..........	11 22 W.	5 38 E.
			0	....	....	N. N. E..........	2 22 E.	19 22
	10 56	83 7	5 P.	—39 0	1 20	N. by E..........	1 46	3 6
	2 5	83 26	0	—22 0	0 0	North..............	1 58	1 58
			0	....	....	N. N. E..........	6 50	6 50
			0	....	....	N. E..............	13 44	13 44
			0	....	....	E. N. E..........	16 34 E.	16 34 E.
			0	....	....	W. N.W..........	6 54 W.	6 54 W.
				HOMEWARD.				
Nov. 12	19 58	57 26	....	—53 0	9 45	W. S. W..........	34 50 W.	25 5 W.
						West..............	39 44	29 59
30	23 6	55 33	....	—55 30	12 45	W. by S..........	41 42	28 57
Dec. 1	24 12	54 34	....	—56 0	14 0	W. N. W..........	51 18	37 18
						N.W. by W......	49 12	35 12
						N.W	46 18	32 18
7	28 20	41 48	....	—57 30	22 30	N.W	57 10	34 40
13	31 45	30 36	....	—56 0	28 0	S.W. by S........	37 40	9 40
						S. W..............	44 4	16 4
						S.W. by W......	50 34	22 34
						W. S.W...........	57 40	29 40
						W. by S..........	60 56	32 56
						West..............	66 10	38 10
20	35 44	19 19	....	—53 30	29 40	N.W. by N	57 40	28 0
						N. N.W...........	54 4	24 24
						N. by W..........	43 16	13 36
21	34 22	16 26	....	—52 30	29 20	N. by W..........	40 6	10 46
1859. January 9	0	*West.* 29 16	....	+25 0	13 0	N. by E..........	14 38	1 38 W.
						N. N. E..........	10 38	2 22 E.
19	*North.* 16 24	37 17	....	50 0	11 15	N. by E..........	3 54 W.	7 21 E.

"SIMLA"—CAPTAIN W. WILLIAMS.

Liverpool to Calcutta, first voyage.

Date.	Latitude.	Longitude.	Heel: P, port, and S, starboard.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Standard compass. Ship's head by compass.	Standard compass. Total error: z, azimuth, and m, amplitude.	Standard compass. Deviation.	Steering compass. Ship's head, correct magnetic.	Steering compass. Ship's head by compass.	Steering compass. Deviation.
1858.	*North.* ° ′	*West.* ° ′	°		*West.* ° ′	°	° ′	° ′	°	°	° ′
Sept. 24	33 56	15 32	2 S.		22 30	S. 25 W.	z 7 12 W.	15 18 E.			
			3 S.			S. 27 W.	z 5 54	16 36			
			2 S.			S. 25 W.	m 7 6	15 24			
26	27 56	19 39	0		21 10	S. 48 W.	z 7 30	13 40			
27	25 26	21 36	0		20 30	S. 44 W.	z 9 54	10 36			
						S. 37 W.	m 9 42	10 48			
						S. 40 W.	z* 9 39	10 51			
						S. 42 W.	☽ 10 0	10 30			
28	23 38	22 49	0		20 0	S. 44¼ W.	z 11 0	9 0			
29	22 17	23 52	0		19 20	S. 40 W.	z 10 36	8 44			
30	20 39	25 8	0		18 30	S. 46¼ W.	z 10 20	8 10			
Oct. 1	15 54	26 56	1 S.		17 0	S. 40 W.	z 7 39	9 21			
2	15 16	28 37	5 S.		15 45	S. 30 W.	z 4 18	11 27			
						S. 25 W.	m 4 0	11 45			
3	13 29	29 5	0		15 0	S. 17 W.	z 4 48	10 12			
4	11 24	29 26	3 S.		14 10	S. 12 W.	z 4 34	9 36			
5	10 12	29 22	1 P.		14 0	S. 75 E.	z 12 45	1 15			
6	8 44	28 38	5 S.		14 10	S. 5 E.	z 7 42	6 28			
7	7 2	28 54			13 40	S. 5 E.	z 7 12	6 28			
						S. 17 E.	m 11 0	2 40			
8	6 41	29 7			13 30	S. 75 W.	z 12 15	1 15 E.			
9	5 46	30 44	0		12 40	N. 62 30 W.	z 23 0	10 20 W.			
						N. 61 W.	z 23 30	10 50			
						N. 45 W.	z 27 30	14 50 W.			
			2 S.			S. 42 W.	z* 0 4	12 36 E.			
11	4 30	31 28	0		12 10	S. 42 E.	z 12 33	0 23 W.			
						N. 47 E.	z 13 2	0 52 W.			
						N. 50 E.	z 12 0	0 10 E.			
						N. 79 W.	z 13 0	0 50 W.			
12	4 32	30 28	3 P.		12 10	S. 48 E.	z 12 41	0 31 W.			
14	3 44	39 20	0		13 10	S. 5 E.	z 6 19	6 41 E.			
						N. 54 W.	z 14 16	1 6 W.			
15	3 25	29 22	1 P.		13 10	S. 76 E.	z 13 40	0 30			
			6 P.			S. 45 30 E.	z 14 50	1 40			
16	2 30	29 0	3 S.		13 15	S. 81 W.	z 14 10	0 55 W.			

"*Simla*"—*Liverpool to Calcutta, first voyage*—Continued.

Date.	Latitude.	Longitude.	Heel: P, port, and S, starboard.	Approximate magnetic. Dip.	Approximate magnetic. Variation.	Standard compass. Ship's head by compass.	Standard compass. Total error: z, azimuth, and m, amplitude.	Standard compass. Deviation.	Steering compass. Ship's head, correct magnetic	Steering compass. Ship's head by compass.	Steering compass. Deviation.
1858.	North. ° ′	West. ° ′			West. ° ′	°	° ′	° ′	°	°	° ′
Oct. 17	0 54	30 50	6 S.		12 0	S. 40 W.	z 2 57 W.	9 3 E.			
18	South. 2 0	32 20	10 S.		11 0	S. 23 W.	m 1 30 W.	9 30			
			10 S.			S. 12 W.	z 0 8 E.	11 8			
						S. 7 W.	m 2 42 W.	8 18			
20	7 2	34 2	5 S.		9 30	S. 7 W.	z 2 1	6 29			
21	9 33	34 47	3 S.		8 50	S. 7 E.	z 3 0	5 50			
22	12 12	34 44	4 S.		8 15	S. 18 30 E.	z 4 56	3 19			
						S. 29 E.	m 6 0	2 15			
23	13 49	33 32	5 S.		8 30	S. 26 E.	z 4 36	3 54			
			2 S.		8 30	S. 24 E.	m 7 0	1 30			
24	16 8	32 38	0		8 45	S. 26 E.	z 6 14 W.	2 31			
26	18 37	34 16	7 S.		7 15	S. 21 W.	z 2 24 E.	9 39			
27	21 19	34 30	5 S.		6 30	S. 5 E.	z 0 33 E.	7 3			
28	24 32	33 59	5 S.		6 15	S. 22 30 E.	z 1 50 W.	4 25			
29	27 33	32 25	3 S.		6 20	S. 25 E.	z 4 45	1 35 E.			
30	28 39	30 43	0		7 20	N. 6 E.	z 13 45	6 25 W.	N. 0 25 W.	North	0 25 W.
			0			N. 31 E.	z 8 22	1 2	N. 29 58 E.	N. 24 E.	5 58 E.
			1 P.			N. 54 E.	z 8 28	1 8 W.	N. 52 52 E.	N. 44 E.	8 52
			1 P.			N. 63 E.	z 5 0	2 20 E.	N. 60 40 E.	N. 54 E.	6 40
			4 P.			S. 86 E.	z 8 42	1 22 W.	S. 87 22 E.	N. 83 E.	9 38
			4 P.			S. 58 E.	z 9 2	1 42 W.	S. 59 42 E.	S. 66 E.	6 18
Nov. 2	29 56	26 40	1 P.		10 0	S. 14 E.	z 6 6	3 54 E.	S. 10 6 E.	S. 12 E.	1 54 E.
			2 S.			South	z 1 53	8 7	S. 8 7 W.	S. 10 W.	1 53 W.
1	28 40	26 15	2 S.		10 30	S. 20 W.	z 2 5	8 25	S. 28 25 W.	S. 35 W.	6 35
			3 S.			S. 45 W.	z 3 16	7 14	S. 52 14 W.	S. 63 W.	10 46
			2 S.			S. 67 30 W.	z 6 41	3 49 E.	S. 71 19 W.	S. 83 W.	11 41
			2 S.			West	z 13 13	2 43 W.	S. 87 17 W.	N. 79 W.	13 43
			4 S.			N. 75 W.	z 19 13	8 43	N. 83 43 W.	N. 68 W.	15 43
Oct. 30	28 39	30 43	3 S.		7 20	N. 48 W.	z 18 36	11 16	N. 59 16 W.	N. 48 W.	11 16
			2 S.			N. 22 W.	z 17 58	10 38	N. 32 38 W.	N. 25 W.	7 38 W.
Nov. 6	35 0	17 6	2 P.		14 0	S. 61 E.	z 16 5	2 5			
			2 P.			S. 44 30 W.	z 15 30	1 30			
7	35 21	14 48	1 S.		15 30	S. 59 30 E.	z 16 36	1 6 W.			
8	36 47	10 55	2 S.		17 30	S. 51 0 E.	z 16 54	0 36 E.			
9	38 5	7 55	0		18 30	S. 40 E.	z 19 22	0 52 E.			
	38 35	6 43	4 P.		19 45	S. 45 E.	z 18 32 W.	1 13 W.			

	13	42 27	*East.* 6 5	The steering compass is out 2¼ points. A very heavy sea carried away the binnacle containing the steering compass, the skylight, and the companion doors. The ship has to be steered by the companion compass on the skids until the gale abates.							
	14	42 38	16 0								
	15	42 52	19 16	0		29 50	S. 51 E.	z·	27 25 W.	2 25 E.	Took off all the magnets from the steering compass, which reduced its error from 2¼ points to ¼ point on the S. E. course.
							S. 45 E.	m	29 42	0 8	
	16	43 31	22 13	0		31 0	S. 49 30 E.	z	30 57	0 3 E.	
	17	44 22	28 59	6 S.		32 15	S. 58 E.	z	32 54	0 53 W.	
	21	43 26	47 19	0		30 15	S. 75 E.	m	31 19	1 4	
	24	41 48	61 16			26 0	S. 84 E.	z	28 6	2 6	
	29	35 3	82 17	2 P.		16 0	N. 57 E.	z	15 31 W.	0 29 E.	

Dec. 2 The following are the deviations of the steering compass compared with the standard compass, which is very nearly correct. Without the compensating magnets.

3 21 59 84 51 Put in the magnets for steering compass, reversing their poles. The following are the deviations observed under different degrees of heel, and depending on the deviations obtained for standard compass, off Tristan D'Acunha; but it is rather singular that the deviation on N. 81 E. is nearly the same as when the ship was swung at Liverpool, only of a contrary name, east for west.

Ship's head by steering compass.	Deviation.	Ship's head by steering compass.	Deviation.
°	° ′		° ′
N. 2 E.	7 0 W.	West	18 30 W.
N. 10 E.	4 0	N. 84 W.	18 30
N. 23 E.	0 30	N. 72 W.	20 45
N. 32 E.	4 30 E.	N. 63 W.	24 0
N. 49 E.	10 30	N. 49 W.	26 0
N. 74 E.	15 0	N. 38 W.	28 30
*N. 81 E.	13 45	N. 29 W.	27 0
S. 78 E.	12 0	N. 20 W.	18 0
S. 68 E.	10 0 E.	N. 5 W.	14 30
		N. 20 W.	2 0
		N. 34 W.	1 30 W.
		N. 54 W.	0 30 E.
		N. 88 W.	3 0 W.
		N. 16 E.	0 53 W.
		N. 24 E.	0 20 E.
		N. 43 E.	1 21 W.
		N. 62 30 E.	3 44 E.

	4	18 41	84 38	5 P.		4 0	N. 16 30 E.	z	9 43 W.	5 43 W.	
		17 14	84 55	5 P.		3 0	N. 23 0 E.	z	7 6	4 6	
				7 P.			N. 20 0 E.	m	9 6	6 6	
	5	14 39	85 20	4 P.		2 0	N. 16 0 E.	m	7 1	5 1	
	6	12 0	85 50	4 P.		1 30	N. 26 E.	z	3 19	1 49	
		11 30	86 4	5 P.		1 15	N. 25 30 E.	m	3 30	2 15	
	7	9 0	86 50	0		0 45	N. 24 30 E.	z	1 48	1 3 W.	
				3 P.			N. 43 30 E.	z	0 13 W.	0 32 E.	
				3 P.			N. 62 30 E.	z	0 52 E.	1 37 E.	
				0			N. 30 0 W.	z	7 55 W.	7 10 W.	
	8	6 24	87 30	1 P.		0	N. 21 30 E.	z	2 36	2 36	
				0		0	N. 7 0 W.	z	7 6	7 6	

The upper end of all upright iron attracts the south end of a small compass, and the lower end repels the same. The top of the ship's side plates also attract the south.

NOTE.—All the azimuths were observed by me on the standard compass, and the altitudes by the second mate. The first mate noted the ship's head by the steering compass. The steering compass was accurately compensated at Liverpool by magnets, but is now out on some points more than a point.

* With 10° starboard heel.

"*Simla*"—*Liverpool to Calcutta, first voyage*—Continued.

Date.	Latitude.	Longitude.	Heel: P, port, and S, starboard.	Approximate magnetic: Dip.	Approximate magnetic: Variation.	Standard compass: Ship's head by compass.	Standard compass: Total error: z, azimuth, and m, amplitude.	Standard compass: Deviation.	Steering compass: Ship's head, correct magnetic.	Steering compass: Ship's head by compass.	Steering compass: Deviation
1858.	*East.* ° ′	*West.* ° ′	°		*West.* ° ′	°	° ′	° ′	° ′	° ′	°
Dec. 8			0			N. 19 W.	z 9 15 W.	9 15 W.			
			0			N. 46 W.	z 7 23	7 23			
9	5 33	87 19	0		0	N. 27 E.	z 2 28	2 28			
						N. 89 E.	z 0 55 W.	0 55 W.			
						S. 65 E.	z 2 12 E.	2 12 E.			
					East.						
10	4 34	88 1	0		0 15	N. 14 30 E.	m 1 0 W.	1 15 W.			
14	0 31	92 40	0		1 0	N. 1 30 W.	z 3 14	4 14	N. 5 40 W.	N. 3 0 W.	2 44 W.
						N. 15 30 W.	z 6 8	7 8	N. 22 38 W.		
						N. 35 0 W.	z 8 2	9 2	N. 44 2 W.	N. 40 0 W.	4 2
						N. 51 30 W.	z 7 23	8 23	N. 59 53 W.	N. 59 0 W.	0 53 W.
						N. 73 0 W.	z 2 51 W.	3 51 W.	N. 76 51 W.	N. 84 0 W.	7 9 E.
						S. 84 0 W.	z 2 0 E.	1 0 E.	S. 85 0 W.	S. 78 0 W.	7 0
						S. 44 W.	z 7 46	6 46	S. 50 46 W.	S. 44 30 W.	6 16
						S. 23 W.	z 7 33	6 33	S. 29 33 W.	S. 25 0 W.	4 33
						South.	z 4 24	3 24	S. 3 24 W.	S. 1 W.	2 24 E.
						S. 15 E.	z 2 0 E.	1 0 E.	S. 14 0 E.	S. 10 30 E.	3 30 W.
						S. 56 30 E.	z 0 3 W.	1 3 W.	S. 57 33 E.	S. 53 0 E.	4 33
						East.	z 0 57 W.	1 57	N. 88 3 E.	S. 89 0 E.	2 57
						N. 72 30 E.	z 0 51 E.	0 9	N. 72 21 E.	N. 73 0 E.	0 39
						N. 45 0 E.	z 0 58 E.	0 2	N. 44 58 E.	N. 47 0 E.	2 2
						N. 22 0 E.	z 0 41 W.	1 41 W.	N. 20 19 E.	N. 23 0 E.	1 41 W.

These azimuths were taken under the most favorable circumstances, the sea smooth, with just air enough to work the ship round on her keel. The longitude found from each altitude as a check on the work. They show considerable decrease in the deviations of the standard compass. The comparison of the steering compass with the standard is after having the magnets on the 2d instant, in Lat. 26 S., Long. 85 E., when I put them in end for end to what they were in Liverpool. I find it necessary in low latitudes to remove the magnets further off from the compass to obtain correct compensation. I think a scale could be fixed for moving them that would always preserve the compass in its true direction in different magnetic latitudes; changing the magnets end for end when the south end dips, or the contrary. Although I do not consider it safe to be always meddling with the magnets, especially when near land, for myself, I would rather keep them something near the mark while in the open sea, and find the deviations before coming in with the land, as I find it very bewildering to have the steering compass much out when the wind is flying about, and it is necessary to know in an instant on which tack to put the ship to go her course or the nearest course to it. I hope those who read these notes, and know better than I do, will excuse my rude way, and, perhaps, erroneous opinions on this, to me, a new thing that I never practised before this voyage. W. WILLIAMS.

Date.	Latitude.	Longitude.	Heel	Dip.	Variation.	Ship's head by compass.	Total error	Deviation.	Ship's head, correct magnetic.	Ship's head by compass.	Deviation
	North.										
17	8 29	91 5			1 0	N. 11 30 W.	m 3 45 W.	4 45 W.			
18	1 50	90 31	2 S.		1 0	N. 12 30 E.	1 19	2 19			
21	5 18	91 22	4 P.		1 20	N. 40 W.	4 7 W.	5 27 W.			
22	6 39	90 54	8 S.		1 20	N. 85 0 E.	2 13 E.	0 53 E.			
24	9 42	90 24	4 P.		1 35	N. 11 W.	2 2 W.	3 37 W.			

			6 P.		1 35	N. 34 30 W.	3 7	4 42			
25	12 19	88 27	8 P.		1 35	N. 33 0 W.	4 7 W.	5 42			
26	14 46	87 14	4 S.		1 40	S. 75 30 E.	z 0 12 E.	1 28			
27	16 7	86 25	8 P.		1 45	N. 31 30 W.	5 43 W.	7 28			
28	16 22	87 25	7 S.		1 45	S. 53 0 E.	m 1 12	2 57			
			4 P.			N. 13 0 W.	z 1 36	3 21			
30	18 13	88 3	3 P.		2 0	N. 20 W.	m 4 30 W.	6 30 W.			

The upper edge of top sheer plate on starboard side from aft to mainmast attracts the north point of a small compass strongly, but on the port side it is not so strong. The upper ends of iron stanchions and davits attract the North and repel the South point.

I find the steering compass getting out as we draw to the northward up the bay of Bengal; greatest error 9°; changed the magnet for north latitude end for end: reduced the error to 3° at greatest.

FROM CALCUTTA TO DEMERARA.

1859.					*East.*						
Mar. 11	18 54	91 28	0		2 10	South.	z 8 8 E.	5 58 E.			
13	17 26	91 11	0			S. 6 W.	z 8 11	6 1			
14	16 19	91 17	0		2 0	S. 21 W.	5 54	3 54			
						S. 7 W.	m 5 0	3 0			
15	15 14	91 42	0		2 0	S. 27 W.	8 59	6 59			
16	14 18	91 33	0		2 0	S. 19 W.	7 47	5 47			
19	10 28	90 12	0		1 40	S. 14 W.	z 7 55	6 15			
20	8 28	88 30	6 S.		1 20	S. 1 E.	z 7 6	5 46			
24	3 34	86 6	4 S.		1 0	S. 8½ E.	4 42 E.	4 42 E.			
25	3 24	86 13	0		1 0	N. 1 30 W.	z 4 30 W.	5 30 W.			
						N. 21 30 W.	7 7	8 7			
						N. 45 0 W.	8 13	9 13			
						N. 64 0 W.	5 48	6 48			
						N. 80 0 W.	1 50 W.	2 50			
						S. 79 30 W.	0 38 E.	0 22 W.			
						S. 60 0 W.	4 40 E.	3 40 E.			
						S. 35 0 E.	0 40 W.	1 40 W.			
						S. 57 0 E.	0 19 W.	1 19			
						N. 52 0 E.	2 40 E.	1 40 E.			
						N. 43 0 E.	2 34	1 34			
27	1 20	87 27	0		0 40	S. 24 E.	1 39	0 59			
						S. 1 W.	3 16	2 36			
						S. 24 30 W.	7 47	7 7			
						S. 43 30 W.	6 20	5 40			
	South.										
29	0 40	89 9	0		0 35	S. 49 E.	0 45	0 10	The steering compass is compensated with magnets, and is gradually increasing its deviations as we sail south. The standard compass, without magnets, retains the deviations found at sea nearly.		
			0			N. 56 E.	3 1	2 26			
			0			N. 24 E.	1 26	0 51			
			2 P.			N. 85 E.	1 49	1 14			
			2 P.			S. 76 E.	1 0	0 25			
30	1 24	89 50	4 S.		0 40	S. 36 W.	6 51	0 40			
April 2	3 58	88 13	2 S.		0 10	S. 13 3' W.	5 27	5 17			
4	6 0	87 7	3 S.		0	S. 26 W.	7 30	7 30			
					West.						
6	8 18	85 23	4 S.		0 40	S. 20 W.	6 18 E.	6 58 E.			

"*Simla*"—*Calcutta to Demerara, first voyage*—Continued.

Date.	Latitude.	Longitude.	Heel: P, port, and S, starboard.	Approximate magnetic: Dip.	Approximate magnetic: Variation.	Standard compass: Ship's head by compass.	Standard compass: Total error: z, azimuth, and m, amplitude.	Standard compass: Deviation.	Steering compass: Ship's head, correct magnetic.	Steering compass: Ship's head by compass.	Steering compass: Deviation.
1859.	*South.* ° ′	*East.* ° ′	°		*West.* ° ′	°	° ′	° ′	°	°	° ′
April 8	11 1	82 7	4 S.		1 30	S. 35 W.	8 14 E.	9 44 E.			
10	13 13	78 21	10 S.		2 30	S. 68 30 W.				S. 80 W.	
			8 S.			S. 56 30 W.				S. 67 W.	
			4 S.			S. 60 30 W.				S. 70 W.	
11	15 31	75 35	7 S.		3 30	S. 58 0 W.	1 7 W.	2 23		S. 67 W.	6 27 W.
			0			S. 59 W.				S. 66 W.	
			5 S.			S. 61 W.				S. 72 30 W.	
			6 S.			S. 66 30 W.				S. 77 30 W.	
			6 S.			S. 69 W.				S. 79 W.	
12	16 13	71 25	6 S.			S. 86¼ W.				N. 86 30 W.	
			6 S.			S. 84 W.				N. 88 W.	
			6 S.			S. 77 30 W.				S. 86 30 W.	
			6 S.			S. 79 30 W.				West	
13	17 3	67 14	4 S.			S. 75 0 W.				S. 86 0 W.	
			4 S.			S. 81 30 W.				N. 88 0 W.	
14	17 59	64 34	0		6 30	S. 56 0 W.	1 42	4 48 E.	S. 60 48 W.	S. 71 0 W.	10 18 W.
			0			S. 72 0 W.				S. 83 30 W.	
15	18 45	62 32	3 P.			S. 65 0 W.				S. 78 0 W.	
						S. 57 30 W.				S. 73 0 W.	
						S. 54 0 W.				S. 70 0 W.	
						S. 44 30 W.				S. 61 30 W.	
16	19 28	61 28	0			S. 48 30 W.				S. 59 0 W.	
			2 P.			S. 49 0 W.				S. 66 W.	
			0			S. 56 0 W.				S. 71 W.	
17	20 8	60 29	0			S. 55 30 W.				S. 70 W.	
			0			S. 57 30 W.				S. 72 W.	
			1 P.			S. 46 0 W.				S. 64 W.	
						S. 68 30 W.				S. 84 W.	
18	20 57	58 54	0			S. 64 W.				S. 80 W.	
			5 S.			S. 59 30 W.				S. 74 W.	
			3 S.			S. 59 0 W.				S. 75 30 W.	
			4 S.			S. 65 0 W.				S. 81 0 W.	
19	22 27	56 27	8 S.			S. 58 W.				S. 75 0 W.	
20	23 53	53 49	0			S. 61 W.				S. 78 W.	
21	25 8	52 11	0			S. 59 W.				S. 78 W.	
			0			S. 69 W.				S. 87 W.	
			0		10 20	S. 63 30 W.	9 5	10 15 E.	S. 73 45 W.	S. 83 W.	9 15 W.

	23	26 34	46 51	8 S.		19 20	S. 74 0 W.	16 49	2 31 E.	S. 76 31 W.	S. 92 0 W.	14 29
							N. 81 30 W.				N. 67 0 W.	
	24	27 27	42 43	4 S.			N. 76 30 W.				N. 62 0 W.	
				2 S.			N. 82 0 W.				N. 68 0 W.	
				4 S.		21 15	S. 85 0 W.	22 32	1 17 W.	S. 84 43 W.	S. 100 0 W.	15 17
	26	29 12	39 11	4 S.		24 0	N. 47 0 W.	m 33 0	9 0 W.	N. 56 0 W.	N. 38 0 W.	18 0
				0			S. 84 30 W.	z 23 42	0 18 E.	S. 84 48 W.	S. 103 30 W.	18 42
				0			N. 39 0 W.	27 55	3 55 W.	N. 42 55 W.	N. 31 0 W.	11 55
				3 S.			N. 32 0 W.	27 49	3 49	N. 35 49 W.	N. 31 30 W.	4 19 W.
				4 S.			N. 19 30 E.	31 32	7 22	N. 12 8 E.	N. 12 0 E.	0 8 E.
				4 S.			N. 24 30 W.	38 51	14 51	N. 39 21 W.	N. 19 0 W.	20 21 W.
		29 0	38 50	10 S.			N. 64 30 W.	m 29 30	5 30	N. 70 0 W.	N. 52 0 W.	18 0
				4 S.			North	35 5	11 5 W.	N. 11 5 W.	N. 1 0 E.	12 5
	27	28 50	36 29	4 S.			N. 87 0 W.				N. 72 0 W.	
	29	31 16	32 9	2 S.			N. 72 0 W.				N. 61 0 W.	
	30	32 0	31 0	0		28 0	S. 75 0 W.				S. 93 0 W.	
							S. 72 30 W.	22 49	5 11 E.	S. 77 41 W.	S. 90 0 W.	12 19
May	1	33 10	29 4	2 S.			S. 63 0 W.				S. 80 0 W.	
		33 43		2 S.		29 15	S. 63 0 W.	24 37	4 38 E.	S. 67 38 W.	S. 80 0 W.	12 22
	2	35 18	25 49	2 P.			N. 48 0 W.				N. 43 0 W.	
		35 28		2 P.			N. 38 0 W.				N. 34 0 W.	
	3	35 10	22 22	8 S.		29 45	N. 45 0 W.	38 44	8 59 W.	N. 54 0 W.	N. 35 0 W.	19 0
		35 45		10 P.		29 45	N. 46 0 W.				N. 36 W.	
	4	35 48	19 55	5 P.		29 50	S. 25 W.	19 44	10 6 E.	S. 35 6 W.	S. 38 W.	2 54
				10 S.			N. 12 W.	37 36	7 46 W.	N. 19 46 W.	N. 8 W.	11 46
	5	35 45		4 S.			N. 22 E.				N. 22 E.	
	6	34 59	17 46	0		29 30	N. 9 W.	38 18	8 48			
				4 S.			N. 15 W.				N. 10 W.	
				0			N. 11 W.	41 42	12 12			
							N. 6 W.				N. 8 W.	
	7	32 47	14 43	0		29 0	N. 11 W.				N. 12 W.	
							N. 12 W.				N. 12 W.	
							N. 17 W.				N. 18 W.	
							N. 14 W.				N. 15 W.	
	8	30 18	11 26	0		28 30	N. 11 30 W.				N. 10 W.	
							N. 11 30 W.				N. 15 W.	
							N. 8 30 W.	40 34	12 4	N. 20 34 W.	N. 11 W.	9 34
							N. 15 0 W.				N. 18 W.	
							N. 14 W.				N. 15 30 W.	
	9	28 13	8 2	0			N. 18 W.				N. 17 W.	
							N. 14 30 W.				N. 14 30 W.	
							N. 14 15 W.				N. 15 0 W.	
							N. 10 30 W.				N. 12 30 W.	
	10	26 26	5 36	0		27 0	N. 10 0 W.				N. 12 0 W.	
							N. 12 0 W.	38 53	11 53	N. 23 53 W.	N. 13 0 W.	10 53
							N. 9 0 W.				N. 10 30 W.	
				2 P.			N. 8 30 W.				N. 11 0 W.	
	11	24 15	3 9	3 P.		26 30	N. 3 0 W.				N. 7 30 W.	
				3 P.			N. 12 30 W.	39 14 W.	12 44 W.	N. 25 14 W.	N. 16 0 W.	9 14
				3 P.			N. 5 0 W.				N. 8 0 W.	
				3 P.			N. 4 0 W.				N. 7 0 W.	
				6 P.			N. 5 0 W.				N. 9 0 W.	

"*Simla*"—*Calcutta to Demerara, first voyage*—Continued.

Date.	Latitude.	Longitude.	Heel: P, port, and S, starboard.	Approximate magnetic: Dip.	Approximate magnetic: Variation.	Standard compass: Ship's head by compass.	Standard compass: Total error: z, azimuth, and m, amplitude.	Standard compass: Deviation.	Steering compass: Ship's head, correct magnetic.	Steering compass: Ship's head by compass.	Steering compass: Deviation.
1859.	*South.* ° ′	*East.* ° ′	°		*West.* ° ′	° ′	° ′	° ′	° ′	° ′	
May 12	22 11	1 8	2 P.		26 10	N. 8 0 W.				N. 12 0 W.	
			2 P.			N. 2 30 W.	37 24 W.	11 14 W.	N. 13 44 W.	N. 3 30 W.	10 14 W.
			2 P.			N. 4 0 W.				N. 6 0 W.	
			2 P.			N. 2 30 W.				N. 6 0 W.	
			0			N. 4 0 W.				N. 5 0 W.	
			1 S.			N. 3 0 W.				N. 5 0 W.	
			0			N. 2 0 W.	34 28	8 18	N. 10 18 W.	N. 3 30 W.	6 50
			0			N. 2 0 W.				N. 7 0 W.	
13	20 20	*West.* 0 29	0		25 30	N. 18 0 W.				N. 15 45 W.	
			0			N. 2 0 W.	34 26	8 56	N. 10 56 W.	N. 4 0 W.	6 56
			1 S.			N. 9 0 W.				N. 10 0 W.	
			1 S.			N. 12 0 W.				N. 12 0 W.	
						N. 14 30 W.				N. 16 30 W.	
14			1 S.			N. 16 15 W.				N. 18 45 W.	
			1 S.			N. 15 0 W.				N. 15 8 W.	
15			0			N. 22 0 W.				N. 22 0 W.	
			0			N. 11 0 W.				N. 12 0 W.	
16*			2 S.			S. 16 30 E.				S. 11 30 E.	
17	15 30	6 52	0			N. 24 15 W.				N. 23 30 W.	
			1 S.			N. 37 0 W.				N. 33 0 W.	
			2 S.			N. 35 0 W.				N. 34 0 W.	
			0			N. 34 0 W.				N. 33 0 W.	
18	14 23	8 42	0		23 0	North	z 32 52	9 52	N. 9 25 W.	N. 5 0 W.	4 52
			0			N. 24 30 W.	z 32 14	9 14	N. 33 44 W.	N. 23 30 W.	10 14
			0			N. 45 30 W.	z 31 50	8 50	N. 54 20 W.	N. 43 W.	11 20
	14 10	9 2			22 45	N. 71 30 W.				N. 66 0 W.	
						N. 34 30 W.	m 32 48	10 3			
			1 S.			N. 33 0 W.				N. 32 0 W.	
19	12 48	12 6	2 S.			N. 35 0 W.				N. 32 30 W.	
			2 S.			N. 32 0 W.				N. 30 0 W.	
20	11 54	15 33	3 S.			N. 42 0 W.				N. 41 W.	
			2 S.			N. 39 0 W.				N. 37 0 W.	
21	11 6	17 21	0		19 30	N. 37 0 W.	29 40	10 10	N. 47 10 W.	N. 36 0 W.	11 10
	10 59	17 45	3 S.			N. 44 30 W.				N. 43 30 W.	
			0			N. 35 0 W.				N. 35 45 W.	
						N. 40 0 W.				N. 40 0 W.	

22	9 57	20 3	0		17 50	N. 35 0 W.	z 29 20	11 30	N. 46 30 W.	N. 34 30 W.	12 0
	9 48	20 28	0			N. 36 0 W.				N. 36 0 W.	
			0			N. 38 15 W.				N. 37 45 W.	
			2 S.			N. 43 30 W.				N. 43 0 W.	
23	8 50	22 30	0			N. 45 0 W.	m 27 45	11 45			
	8 36	23 11	2 S.		16 0	N. 38 0 W.				N. 37 30 W.	
24	7 40	25 28	0			N. 47 0 W.				N. 47 0 W.	
25†	5 52	27 41	2 S.			N. 29 W.				N. 32 0 W.	
			0			N. 34 30 W.				N. 35 0 W.	
			2 P.			N. 44 0 W.				N. 43 45 W.	
26	5 7	29 15	0		12 30	N. 34 W.				N. 35 W.	
						N. 33 30 W.				N. 35 W.	
						N. 28 0 W.	m 24 0	11 30			
						N. 31 30 W.				N. 33 W.	
27	4 41	30 30	2 P.			N. 28 0 W.				N. 29 30 W.	
			6 P.			N. 22 0 W.				N. 25 0 W.	
28‡			2 P.			N. 17 0 W.				N. 22 0 W.	
			4 P.			N. 48 0 W.				N. 50 30 W.	
29	2 59	34 21	4 S.			N. 66 W.				N. 63 45 W.	
			4 S.			N. 68 0 W.				N. 67 15 W.	
30	2 0	38 34	4 S.		7 15	N. 65 0 W.				N. 63 30 W.	
			4 S.			N. 50 30 W.	14 14	6 59	N. 66 30 W.	N. 58 0 W.	8 30
31	0 30	41 10	2 P.		5 40	N. 6 30 W.	17 12	11 32	N. 18 2 W.	N. 9 30 W.	8 32
			0			N. 25 0 W.	18 20	12 40	N. 37 40 W.	N. 28 0 W.	9 40
			0			N. 43 30 W.	16 30	10 50	N. 54 20 W.	N. 48 0 W.	6 20
			0			N. 65 30 W.	10 42	5 2	N. 70 32 W.	N. 65 0 W.	5 32
			0			S. 85 0 W.	5 57 W.	0 17 W.	S. 84 43 W.	S. 85 0 W.	0 17 W.
			2 S.			S. 62 0 W.	2 26 E.	8 6 E.	S. 70 6 W.	S. 67 0 W.	3 6
			4 S.			S. 37 30 W.	5 15 E.	10 55	S. 48 25 W.	S. 40 0 W.	8 25 E.
	North.										
June 1	2 0	44 0	4 P.		4 30	N. 24 0 W.				N. 26 0 W.	
			8 P.			N. 22 30 W.	13 26 W.	8 56 W.	N. 31 26 W.	N. 29 W.	2 26 W.
			8 P.			N. 46 0 W.				N. 46 0 W.	
			4 P.			N. 38 30 W.				N. 45 30 W.	
			6 P.			N. 50 30 W.				N. 58 15 W.	
2	3 19	45 40	2 P.			N. 20 W.				N. 24 W.	
3	4 19	45 52	2 S.			N. 22 45 W.				N. 26 W.	
			0			N. 15 0 W.				N. 19 W.	
4	5 3	45 51	0			N. 63 30 W.				N. 64 0 W.	
			2 S.			N. 19 45 W.				N. 21 50 W.	
			0			N. 70 0 W.				N. 72 0 W.	
			6 P.			N. 50 0 W.				N. 53 0 W.	
5	5 42	46 8	2 S.		3 40	N. 45 0 W.				N. 51 30 W.	

* St. Helena, James Town Road.

† On taking our steering compass into the cabin to be dried, after the heavy rain, our spare compass, when placed in the binnacle, was found to point S. S. E., with the ship's head from N. W. by N. to N. N. W. The needle, by some means or other, must have had its polarity reversed.

‡ Fernando Noronha, N. W. by W. 20 miles.

§ The 8° port heel this morning's sight for azimuth shows a difference of 7° in the deviation of the steering compass, and 3¼ on the standard compass, from the deviations found yesterday, when the ship was upright, from N. N. W. The noon comparisons differ 5° from those taken on the same points in the morning, owing to our taking away the two soft iron cylinders that are placed close to the steering compass to compensate the error from heeling. On replacing them again in this former position, the compass showed the difference it had before they were taken away.

"Simla"—Calcutta to Demerara, first voyage—Continued.

Date.	Latitude.	Longitude.	Heel: P, port, and S, starboard.	Approximate magnetic: Dip.	Approximate magnetic: Variation.	Standard compass: Ship's head by compass.	Standard compass: Total error: z, azimuth, and m, amplitude.	Standard compass: Deviation.	Steering compass: Ship's head, correct magnetic.	Steering compass: Ship's head by compass.	Steering compass: Deviation.
	North. ° ′	West. ° ′			West. ° ′	°	° ′	° ′	°	°	° ′
1859. June 5			0			N. 44 30 W.	15 41 W.	12 1 W.	N. 56 31 W.	N. 49 30 W.	7 1 W.
			0			N. 61 0 W.				N. 64 0 W.	
						N. 83 0 W.				N. 81 0 W.	
			2 P.			N. 75 0 W.				N. 77 0 W.	
6	5 52	48 31	3 P.		2 30	N. 83 15 W.				N. 83 45 W.	
			3 P.			N. 85 0 W.	5 8 W.	2 38 W.		N. 85 0 W.	2 38 W.
			4 P.			N. 83 0 W.				N. 83 0 W.	
			0			N. 75 0 W.				N. 75 0 W.	
7	6 17	52 12	0			N. 75 0 W.				N. 75 0 W.	
			2 S.			N. 83 0 W.				N. 83 0 W.	
8	7 6	52 50	3 S.		0	S. 28 0 W.	z 10 43 E.	10 43 E.	S. 38 43 W.	S. 33 0 W.	5 43
			2 S.			S. 48 0 W.	10 4	10 4	S. 58 4 W.	S. 51 0 W.	7 4
			2 S.			S. 67 30 W.	7 34 E.	7 34 E.	S. 75 4 W.	S. 70 0 W.	5 4 E.
			0			N. 84 0 W.	0 56 W.	0 56 W.	N. 84 56 W.	N. 84 0 W.	0 56 W.
			0			N. 47 0 W.	8 55 W.	8 55 W.	N. 55 55 W.	N. 48 0 W.	7 55
	7 17	53 18	3 S.			S. 61 0 W.				S. 65 0 W.	
			2 S.			S. 63 45 W.				S. 65 30 W.	
9	6 57	55 36	2 S.			S. 59 38 W.				S. 65 25 W.	
			0			S. 61 30 W.				S. 66 0 W.	
						S. 76 30 W.				S. 81 0 W.	

DEMERARA TO LIVERPOOL.

Date.	Latitude.	Longitude.	Heel.	Dip.	Variation.	Ship's head by compass.	Total error.	Deviation.	Ship's head, correct magnetic.	Ship's head by compass.	Deviation.
	North.	West.			East.						
July 17	6 55	58 11	8 P.		2 10	N. 23 0 E.		1 15 E.			
18	7 7	57 56	10 P.		2 0	N. 15 0 W.		4 31 W.			
	7 10	58 0	10 P.		2 0	N. 9 0 W.		5 12			
20	9 50	58 22	9 P.		1 30	N. 7 0 E.		4 35 W.			
	9 25	58 0	0 P.		1 30	N. 10 30 E.		2 42 E.			
21	10 36	58 30	10 P.		1 25	N. 14 0 E.		0 5 E.			
					West.						
23	15 32	60 16	12 P.		0 35	North		1 5 W.			
26	22 13	62 19	9 P.		2 0	N. 4 W.		1 17 E.			
27	24 19	62 57	6 P.		3 0	N. 3 W.		0 45 E.			

	25 0	63 0	3 P.		3 30	N. 5 E.		2 42 W.			
	24 19	62 57	6 P.		3 0	N. 19 E.		1 23 E.			
			3 P.		3 0	N. 32 E.		2 37 W.			
			6 P.		3 0	N. 3 W.		0 45 E.			
28	25 58	63 16	2 P.		3 50	N. 29 E.		1 43			
			0		3 50	N. 58 E.		0 56			
	26 0	63 15	3 S.		4 0	S. 54 W.		8 52			
			3 S.		3 50	S. 63 W.		6 42			
•		63 17	2 S.		3 50	N. 78 30 W.		0 27 W.			
		63 17	2 S.		3 50	N. 54 0 W.		4 12			
			2 S.		3 50	N. 27 0 W.		7 22 W.			
29	27 28	63 0	3 P.		4 50	N. 20 E.		0 24 E.			
			0		4 50	N. 24 W.		5 29 W.			
			2 P.		4 50	N. 5 W.		4 20			
30	29 16	64 0	7 P.		5 30	N. 6 30 W.		2 54			
31	31 5	64 34	0		6 20	N. 1 W.		4 46			
	31 20	64 40	0		6 20	N. 18 E.		5 48			
Aug. 1	31 49	64 51	0		6 0	N. 55 E.		2 42			
	32 0	64 48	6 P.		6 0	N. 72 E.		0 52			
	32 10	64 48	6 P.		7 0	N. 82 E.		1 26			
	32 10	64 48	6 P.		7 0	East		4 35 W.			
	31 46	64 48	2 S.		6 30	S. 20 30 W.		12 50 E.			
	31 46	64 48	3 S.		6 40	S. 55 30 W.		13 28			
3	35 16	62 0	0		11 30	N. 27 0 E.		0 51			
			2 P.		11 30	N. 54 30 E.		2 29			
			3 P.		11 30	N. 84 30 E.		0 44 E.			
			3 P.		11 30	S. 58 30 E.		1 28 W.			
			3 P.		11 30	S. 47 30 E.		0 40			
			4 S.		11 30	N. 45 0 W.		4 45			
			3 S.		11 30	N. 26 0 W.		8 8			
			2 S.		11 30	N. 6 0 W.		8 59 W.			
4	35 18	60 9	0		12 15	N. 70 E.		3 6 E.			
5	36 31	58 13	3 S.		14 30	N. 20 E.		3 30 W.			
			0		14 30	N. 42 E.		1 7 W.			
			0		14 30	N. 71 E.		0 8 E.			
			0		14 30	S. 85 E.		1 10			
			2 P.		14 30	S. 71 E.		0 10 E.			
			3 P.		14 30	S. 33 30 E.		0 43 W.			
7	31 8	56 22	2 S.		17 36	N. 57 30 E.		0 12			
10	41 53	49 22	0		25 20	N. 31 0 E.		3 29			
			0		25 20	N. 53 0 E.		2 10 W.			
11	42 22	47 37	3 S.		26 40	S. 37 30 E.		5 33 E.			
			0		26 40	S. 11 0 E.		8 53			
			0		26 40	S. 13 30 W.		10 3 E.			
14	44 4	41 23	2 S.		31 5	N. 28 0 E.		2 11 W.			
			0		31 5	N. 78 30 E.		0 1 E.			
			0		31 5	S. 74 0 E.		0 31			
15	45 4	38 16	6 P.		33 0	S. 77 30 E.		0 19			
17	47 8	31 0	4 S.		34 25	N. 74 E.		1 51			
			0		34 25	S. 86 E.		3 20			
	47 10	30 10	0		34 25	S. 64 30 E.		2 19			
19	47 20	27 46	4 S.		33 30	S. 53 30 E.		6 56 E.			

30

"*Simla*"—*Demerara to Liverpool*—Continued.

Date.	Latitude.	Longitude.	Heel: P, port, and S, starboard.	Approximate magnetic: Dip.	Approximate magnetic: Variation.	Standard compass: Ship's head by compass.	Standard compass: Total error: z, azimuth, and m, amplitude.	Standard compass: Deviation.	Steering compass: Ship's head, correct magnetic.	Steering compass: Ship's head by compass.	Steering compass: Deviation.
	North. ° ′	*West.* ° ′		*East.*	° ′	°	° ′	° ′	°	°	° ′
1859. April 19			4 S.		33 30	S. 30 0 E.		7 37 E.			
			3 S.		33 30	S. 10 30 E.		11 1			
			2 S.		33 30	S. 11 0 W.		12 43			
			0		33 30	S. 28 0 W.		10 26			
			0		33 30	S. 37 30 W.		8 50			
21	45 15	23 57	8 P.		30 5	N. 44 0 E.		3 59 E.			
22	47 21	22 3	0		30 30	N. 2 30 W.		0 56 W.			
			2 P.		30 30	N. 20 0 E.		0 21 E.			
			2 P.		30 30	N. 54 30 E.		3 9			
	46 40	22 48	7 P.		30 50	N. 64 0 E.		2 26			
	47 21	22 3	0		30 30	N. 83 30 E.		1 26			
			0		30 30	East		0 8			
			4 S.		30 30	S. 0 30 W.		14 21			
			4 S.		30 30	S. 25 0 W.		16 30			
			4 S.		30 30	S. 60 0 W.		10 47			
			3 S.		30 30	N. 86 30 W.		1 40 E.			
			2 S.		30 30	N. 66 30 W.		3 5 W.			
			0		30 30	N. 37 0 W.		5 25			
			0		30 30	N. 22 30 W.		4 57 W.			
23	47 11	21 47	4 S.		30 50	S. 57 0 E.		4 50 E.			
			3 S.		30 50	S. 34 30 E.		7 32			
			3 S.		30 50	S. 17 30 E.		12 8			
			2 S.		30 50	S. 1 30 W.		14 37			
			2 S.		30 50	S. 24 0 W.		10 17			
25	46 28	17 12	9 S.		28 15	S. 73 30 E.		5 15			
Sept. 1	51 36	6 25	7 S.		25 5	N. 70 0 E.		0 5 E.			

"SIMLA"—CAPTAIN W. WILLIAMS.

Liverpool to Calcutta, second voyage.

Date.		Lat.	Long.	Heel.—P, port, S, starboard.	Approximate magnetic		Standard compass.		Steering compass.	
					Dip.	Variation.	Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.
						West.				
1859.		° ′	° ′	°		° ′	° ′	° ′	° ′	° ′
Sept.	20	Sandon Dock, Liverpool.		0	....	....	N. 65 30 W...	9 30 W.	....	....
Nov.	11	Victoria Channel, Liverpool.		0	....	....	N. 24 W........	16 0	N. 24 W........	16 0 W.
		Mid channel, between Holyhead and Kish L. V.		8 P.	....	25 30	S. 40 E........	2 22 W.	S. 32 30 E....	9 52 W.
				8 P.	....	25 30	S. 72 W........	8 20 E.	S. 68 W........	11 50 E.
	12	Off Holyhead...		8 P.	....	25 30	S. 46 E........	5 0 W.	S. 43 E........	11 0 W.
		North.	*West.*							
	13	53 0	5 20	2 S.	....	25 30	S. 67 30 W...	9 40 E.	S. 69 30 W...	7 40 E.
				0	....	25 30	S. 73 E........	3 44	S. 64 0 E....	5 16 W.
			5 0	0	....	25 30	S. 18 W........	21 45	....	....
				0	....	25 30	S. 21 W........	17 12	....	....
							S. 35 W........	16 5	....	....
			4 20	4 S.	....	25 30	S. 42 W........	19 10	S. 47 W........	14 10 E.
		52 40	5 0	2 S.	....	23 30	S. 10 E........	10 0	....	....
	14	52 49	5 8	3 S.	....	25 30	S. 14 30 E.. ..	7 33 E.	S. 10 30 E....	3 38 E.
		52 40	5 0	2 S.	....	25 30	N. 35 W........	12 0 W.	N. 44 W........	3 0 W.
(1)	17	50 4	8 28	2 S.	....	25 25	N. 3 E........	14 24	N. 2 W........	9 24
				0	....	....	N. 24 30 E....	7 12	N. 27 E........	9 42
				0	....	....	N. 38 E........	2 12	N. 41 E........	5 12
				0	....	....	N. 48 E........	1 25 W.	N. 54 E........	7 25
				0	....	....	N. 69 30 E....	1 21 E.	N. 75 E........	4 9
				0	....	....	N. 89 E........	0 32 W.	N. 94 E........	5 32
				0	....	....	S. 62 30 E....	0 13 E.	S. 59 30 E....	2 47
				0	....	....	S. 41 E	1 35	S. 37 E........	2 25 W.
				0	....	....	S. 22 E........	7 5	S. 18 E........	3 5 E.
				0	....	....	S. 3 W........	13 45	S. 9 W........	7 45
				0	....	....	S. 19 W........	16 2	S. 25 W........	10 2
				0	....	....	S. 52 W........	9 50	S. 51 W........	10 50
				0	....	....	S. 80 W........	3 28	S. 74 W........	9 28
				1 S.	....	....	N. 67 W.	7 45 W.	N. 77 W........	2 15 E.
				2 S.	....	....	N. 42 W........	15 26	N. 56 W........	1 26 W.
				2 S.	....	....	N. 18 30 W...	17 5 W.	N. 28 W........	7 35 W.
	22	44 50	17 9	6 S.	....	26 50	S. 18 W........	25 0 E.	S. 23 W........	20 0 E.
		45 0	18 0	6 S.	....	26 50	S. 24 W........	19 26	S. 28 W........	15 26
(2)	24	40 38	16 50	6 P.	....	24 20	S. 13 W........	9 30	S. 17 W........	5 30
	25	37 1	16 0	3 P.	....	23 35	S. 14 W........	10 2	S. 17 W........	7 2
	26	33 30	16 0	0	....	23 0	S. 10 W........	12 3	S. 12 30 W...	9 33
	28	29 44	17 22	5 S.	....	21 25	S. 47 30 W....	13 10	S. 48 30 W...	12 10
	30	24 52	21 55	6 S.	....	20 15	S. 25 W........	14 55	S. 26 W........	13 55
Dec.	1	21 38	23 16	3 S.	....	19 12	S. 39 W........	15 2	S. 42 W........	12 2
	2	18 48	25 22	0	....	17 45	S. 43 W........	11 7	S. 44 30 W...	9 37
	3	16 0	27 1	5 S.	....	16 35	S. 24 W........	12 15	S. 27 W........	9 15
	4	13 1	28 6	2 S.	....	15 25	S. 20 W........	11 36 E.	S. 20 W........	11 36 E.
	5	10 0	29 0	4 S.	....	14 10	N. 72 W........	6 16 W.	N. 76 30 W...	1 46 W.
				4 S.	....	....	N. 40 W........	13 28 W.	N. 44 30 W...	8 58 W.
	7	5 30	28 40	5 S.	....	13 30	S. 11 30 W....	7 33 E.	S. 13 W........	6 3 E.
	8	3 20	30 8	6 S.	....	12 41	S. 56 W........	6 0	S. 61 W........	1 0
	9	1 33	31 49	3 S.	....	11 40	S. 10 W........	9 50	S. 12 W........	7 50
	10	0 0	32 42	6 S.	....	10 55	S. 6 W........	8 10	S. 8 30 W...	5 40
		South.								
	11	2 19	33 7	4 S.	....	10 10	S. 4 E........	6 37	South........	2 37 E.
	12	4 5	33 21	7 S.	....	10 5	S. 7 E........	3 58	S. 3 E	0 2 W.
	13	6 42	33 41	6 S.	....	9 45	S. 4 W........	7 33	S. 8 W........	2 33 E.
(3)	14	10 51	33 53	5 S.	....	8 55	S. 17 E........	1 46	S. 14 E........	1 14 W.
		9 32	34 0	10 S.	....	9 5	S. 2 E........	6 9	S. 1 W........	3 9 E.,
	15	12 33	33 39	4 S.	....	8 55	S. 2 30 E....	4 43	S. 1 W........	1 13
	16	15 43	32 45	4 S.	....	8 55	S. 11 30 E....	4 20	S. 8 E........	0 50 E.
(4)	19	24 41	31 8	5 S.	....	8 35	S. 19 E........	2 1	S. 15 E........	1 59 W.
(5)	20	27 11	29 31	4 S.	....	8 40	S. 47 E........	0 30	S. 48 E........	1 30 E.
				2 S.	....	8 40	S. 26 E........	3 6 E.	S. 22 E........	0 54 W.
(6)	21	....	....	....	....	....	....	....	....	....
(7)	22	29 19	27 7	0	....	9 35	N. 3 E........	6 12 W.	N. 2 W........	1 12 W.
							N. 44 E........	2 49 E.	N 41 30 E....	5 19 E.

"*Simla*"—*Liverpool to Calcutta, second voyage*—Continued.

Date.	Lat.	Long.	Heel.—P, port, S, starboard.	Approximate magnetic Dip.	Approximate magnetic Variation.	Standard compass. Ship's head by compass.	Standard compass. Deviation.	Steering compass. Ship's head by compass.	Steering compass. Deviation.
1859.	*South.* ° ′	*West.* ° ′	°		*West.* ° ′	° ′	° ′	° ′	° ′
Dec. 22	...	...	2 P.	...	...	N. 78 E.	1 39	N. 75 E.	4 39 E.
			0	...	...	S. 48 30 W.	8 1	S. 57 W.	0 29 W.
			0	...	...	S. 52 W.	7 15 E.	S. 62 W.	2 45
			0	...	...	N. 63 30 W.	7 18 W.	N. 61 W.	9 48
			0	...	...	N. 30 W.	11 12 W.	N. 33 W.	8 12 W.
23	30 24	27 15	1 S.	...	9 20	S. 34 E.	1 10 E.	S. 34 E.	1 10 E.
			3 S.	...	...	S. 15 30 E.	3 5	S. 12 E.	0 25 W.
			3 S.	...	9 25	S. 19 W.	8 23	S. 26 W.	1 23 E.
	30 0	27 10	2 S.	...	9 25	S. 31 W.	7 59 E.	S. 38 W.	0 59 E.
	30 2	27 10	2 S.	...	9 25	West	2 35 W.	N. 86 W.	6 55 W.
24	31 49	26 50	2 S.	...	9 0	S. 72 E.	0 20 W.	S. 74 30 E.	2 10 E.
	31 17	27 3	2 S.	...	9 0	S. 61 E.	0 52 E.	S. 63 0 E.	2 52
			2 S.	...	9 0	S. 55 E.	0 25 W.	S. 59 E.	3 35
	31 49	26 50	1 S.	...	9 5	S. 48 30 E.	1 3 W.	S. 51 E.	1 27 E.
	31 17	27 3	2 S.	...	9 5	S. 22 30 E.	0 32 E.	S. 20 E.	1 58 W.
	31 49	26 50	1 S.	...	9 5	S. 25 30 E.	0 37 E.	S. 23 E.	1 52 W.
(8) 26	34 11	23 30	0	...	11 5	S. 44 E.	2 6 W.	...	...
27	31 8	21 50	2 S.	...	11 5	S. 44 E.	1 54	S. 47 E.	1 6 E.
29	39 0	18 30	10 S.	...	12 5	South	2 13 W.	S. 5 W.	7 13 W.
(9) 30	41 0	16 50	0	...	12 5	S. 3 E.	3 31 E.	S. 4 W.	3 29 W.
1860.		*East.*							
(10) Jan. 9	45 14	26 56	0	...	32 0	S. 55 E.	0 37	S. 62 E.	7 37
(11) 11	44 50	35 8	0	...	32 20	N. 70 30 E.	3 20	N. 61 E.	12 50
						N. 81 30 E.	3 40 E.	N. 70 E.	15 10
						S. 77 E.	0 0	S. 89 E.	12 0
						S. 65 E.	0 40 W.	S. 76 E.	10 20 E.
						S. 27 E.	0 14 W.	S. 27 E.	0 14 W.
(12) 12	44 30	37 48	2 S.	...	32 10	S. 71 E.	0 6 E.	S. 83 E.	12 6 E.
13	44 8	40 37	5 S.	...	31 40	S. 71 E.	1 40 W.	S. 84 30 E.	11 50
(13) 16	42 46	46 15	10 S.	...	30 30	S. 46 E.	5 18	S. 60 E.	8 42
	42 58	47 9	8 S.	...	30 30	S. 40 E.	7 26	S. 54 30 E.	7 4
20	41 28	65 32	3 S.	...	25 35	N. 88 E.	0 30	N. 76 E.	11 30
21	40 38	68 2	0	...	23 35	N. 87 E.	1 29	N. 75 30 E.	10 1
25	32 20	76 15	4 P.	...	14 40	N. 5 30 E.	3 48 W.	N. 1 E.	0 42
			4 P.	...	14 40	N. 25 E.	0 40 E.	N. 19 E.	6 40
(14) 28	28 12	73 30	0	...	11 40	S. 5 E.	3 52	S. 3 E.	1 52 E.
			0	...	11 40	S. 24 W.	12 24	S. 37 W.	0 36 W.
			0	...	11 40	S. 49 30 W.	12 50	S. 62 30 W.	2 30
			0	...	11 40	S. 82½ W.	3 0 E.	N. 85 W.	9 30
			2 P.	...	11 40	N. 62 W.	7 10 W.	N. 58 W.	11 10
			2 P.	...	11 40	N. 36 W.	12 35	N. 37 W.	11 35
			0	...	11 40	N. 19 30 W.	10 57 W.	N. 19 W.	11 27 W.
30	26 15	73 20	5 S.	...	10 40	N. 74 E.	2 35 E.	N. 67 E.	9 35 E.
	26 25	73 0	3 P.	...	10 40	N. 18 30 W.	9 33 W.	N. 18 30 W.	9 33 W.
(15) 31	24 46	75 12	1 S.	...	8 45	N. 6 E.	0 30 W.	N. 3 E.	2 30 E.
	25 24	75 0	2 S.	...	9 26	N. 17 E.	1 35 E.	N. 11 E.	7 35
			4 S.	...	9 26	N. 35 E.	3 48 E.	N. 30 E.	8 48
Feb. 6	16 12	76 35	10 P.	...	3 25	N. 17 E.	1 35 W.	N. 11 30 E.	3 55
	14 50	76 40	8 P.	...	3 0	N. 17 E.	2 30	N. 11 E.	2 30
(16) 8	10 1	77 15	2 P.	...	1 50	N. 17 30 E.	0 13	N. 15 E.	2 17
					1 50	N. 16 30 E.	0 20	N. 14 30 E.	1 40 E.
9	8 10	77 24	0	...	1 25	N. 2 E.	2 35	North	0 35 W.
			0	...	1 25	N. 25 W.	6 20 W.	N. 25 W.	6 20 W.
10	7 0	77 0	0	...	...	N. 20 E.	0 35 E.	N. 19 30 E.	1 5 E.
	7 9	76 50	0	...	1 20	N. 80 W.	1 3 W.	N. 76 30 W.	4 33 W.
			0	...	...	N. 65 W.	3 51	N. 63 W.	5 51 W.
11	6 30	77 14	0	...	1 15	N. 19 30 E.	1 15 W.	N. 19 E.	2 8 E.
(17) 15	3 31	81 35	0	...	0 22	N. 9 E.	1 10 E.	N. 5 30 E.	4 40 E.
16	3 0	82 16	0	...	0 10	N. 1 30 E.	2 20 W.	N. 0 30 W.	0 20 W.
(18) 17	2 22	82 29	3 S.	...	0 5	N. 2 E.	2 55 W.	N. 0 30 W.	0 5 E.
			2 S.	...	0 5	N. 23 E.	0 45 E.	N. 23 E.	0 45 E.
			2 S.	...	0 5	N. 25 W.	6 5 W.	N. 24 W.	7 5 W.
					East.				
(19) 18	0 22	82 44	8 S.	...	0 10	N. 1 30 E.	3 5	N. 2 E.	3 35
						N. 2 W.	4 0	N. 1 30 W.	4 30
	North.					N. 16 E.	1 40	N. 15 30 E.	1 10
19	1 16	84 10	0	...	0 25	N. 1 30 E.	2 22	N. 0 30 W.	0 22
		84 17	2 S.	...	0 25	S. 83 E.	2 45	S. 84 E.	1 54
(20) 20	2 9	84 28	0	...	0 30	N. 3 30 E.	1 56	N. 2 E.	0 41
						N. 3 30 E.	2 0	N. 1 30 E.	0 0
21	2 33	84 24	0	...	0 40	N. 43 W.	7 6	N. 43 W.	7 6
(21) 23	3 10	83 32	1 S.	...	0 30	N. 0 30 E.	2 32 W.	North	2 2 W.
			0	...	...	N. 34 E.	3 5 E.	N. 33 E.	4 5 E.

"*Simla*"—*Liverpool to Calcutta, second voyage*—Continued.

Date.	Lat.	Long.	Heel.—P, port, S, starboard.	Approximate magnetic: Dip.	Approximate magnetic: Variation.	Standard compass: Ship's head by compass.	Standard compass: Deviation.	Steering compass: Ship's head by compass.	Steering compass: Deviation.
	North. ° ′	*East.* ° ′	°		*East.* ° ′	° ′	° ′	° ′	° ′
1860. Jan. 23	......	......	0	......	......	N. 63 E.	3 36 E.	N. 64 E.	2 36 E.
			0	......	......	N. 84 30 E.	1 9 E.	N. 82 E.	3 39 E.
			2 S.	......	......	S. 42 30 E.	4 51 W.	S. 44 E.	3 21 W.
			2 S.	......	......	S. 22 E.	3 9 W.	S. 21 E.	4 9 W.
			1 S.	......	......	S. 1 30 E.	1 20 E.	S. 1 W.	1 10 E.
			1 S.	......	......	S. 46 30 W.	8 24	S. 53 W.	1 54
			1 S.	......	......	S. 74 W.	4 52 E.	S. 76 W.	2 52 E.
			0	......	......	N. 79 W.	1 28 W.	N. 77 W.	3 28 W.
			0	......	......	N. 46 30 W.	6 45	N. 48 W.	5 15
			0	......	......	N. 23 30 W.	7 11	N. 24 30 W.	6 11
			1 S.	......	......	N. 9 30 W.	5 11	N. 10 W.	4 41
March 1	5 48	82 20	0	......	0 35	N. 61 W.	4 27	N. 63 30 W.	1 57
						N. 40 W.	5 57	N. 43 W.	2 57
2	6 19	82 2	3 S.	......	0 30	S. 40 E.	2 39	S. 39 E.	3 39 W.
(22) 5	9 15	82 5	2 P.	......	0 50	N. 5 E.	0 18 W.	N. 4 E.	0 42 E.
			2 P.	......	0 50	N. 10 E.	0 17 E.	N. 8 E.	2 17 E.
6	10 32	81 50	0	......	0 55	N. 4 30 E.	0 55 E.	N. 4 E.	1 40 W.
						N. 3 E.	2 22 W.	N. 2¼ E.	1 52 W.
						N. 5 W.	3 28 W.	......	......
9	14 1	81 49	5 P.	......	1 8	N. 25 30 E.	3 6 E.	N. 26 30 E.	2 6 E.
						N. 26 E.	2 55	N. 26 E.	2 55
	15 3	82 6	0	......	1 10	N. 23 30 E.	1 32	N. 23 30 E.	1 32
	15 8	82 10	0	......	1 10	N. 19 30 E.	0 57	N. 20 E.	0 27
	14 25	81 51	4 P.	......	1 8	N. 29 30 E.	3 55	N. 29 30 E.	3 55
	15 3	82 5	0	......	1 8	N. 29 E.	1 52 E.	N. 29 30 E.	1 22 E.
13	20 10	86 54	2 S.	......	2 0	N. 2 E.	1 25 W.	North	0 35 W.
			2 S.	......	......	N. 25 E.	3 3 E.	N. 23 E.	5 3 E.
			2 S.	......	......	N. 42 E.	3 33	N. 45 E.	0 33 E.
			2 S.	......	......	N. 69 30 E.	1 32	N. 73 E.	1 58 W.
			1 S.	......	......	S. 86 30 E.	1 45 E.	S. 85 E.	3 15
			0	......	......	S. 43 30 E.	5 18 W.	S. 42 E.	6 48
16	21 50	88 0	0	......	2 0	N. 0 30 W.	3 22	N. 0 30 E.	3 22
			0	......	......	N. 22 W.	7 4	......	......
			0	......	......	N. 46 30 W.	7 27	N. 51 W.	2 57
			0	......	......	N. 67 W.	4 15 W.	N. 69 W.	2 15 W.
			0	......	......	S. 55 30 W.	7 52 E.	S. 59 W.	4 22 E.

CALCUTTA TO LONDON.

Date.	Lat.	Long.	Heel.	Dip.	Variation.	Standard: Ship's head by compass.	Standard: Deviation.	Steering: Ship's head by compass.	Steering: Deviation.
(23) May 20	22 0	88 0	2 P.	......	2 0	S. 25 30 W.	8 0 E.	S. 28 W.	5 40 E.
June 1	14 40	90 39	8 P.	......	2 0	S. 9 E.	3 52	......	......
9	5 56	91 44	12 P.	......	1 30	S. 21 E.	4 23	S. 22 E.	5 23
(24) 11	1 0	92 50	12 P.	......	1 10	S. 13 E.	6 56	S. 12 E.	5 56
	South.								
(25) 13	0 30	92 58	0	......	1 0	N. 16 30 E.	0 55	N. 16 E.	1 25
			0	......	1 0	N. 25 E.	1 30	N. 26 E.	0 30
			0	......	1 0	N. 69 E.	2 35	N. 68 E.	3 35
			0	......	......	N. 89 E.	2 10	N. 87 E.	4 10
			0	......	......	S. 67 30 E.	1 15	S. 70 E.	3 45
			2 P.	......	......	S. 43 E.	2 28	S. 45 E.	4 28
			2 P.	......	......	S. 21 E.	5 2	S. 19 30 E.	3 32
			0	......	......	S. 12 E.	6 15	......	......
			3 P.	......	......	S. 2 30 W.	8 8	S. 5 W.	5 38
			3 P.	......	......	S. 20 30 W.	8 0	S. 24 W.	4 30 E.
			3 P.	......	......	S. 42 30 W.	6 56	S. 50 W.	0 34 W.
16	3 56	91 20	3 S.	......	0 25	S. 20 W.	8 20	S. 25 W.	3 20 E.
			2 S.	......	......	S. 41 30 W.	6 53	S. 49 W.	0 37 W.
			2 S.	......	......	S. 71 30 W.	1 34 E.	S. 76 W.	2 56
			0	......	......	N. 84 W.	2 17 W.	N. 85 W.	1 17
			0	......	......	N. 55 W.	7 45 W.	N. 58 W.	4 45
					West.				
19	7 46	88 42	10 S.	......	0 15	S. 21 W.	7 15 E.	S. 30 W.	1 54
			7 S.	......	......	S. 48 W.	5 15	S. 59 W.	5 47
20	9 47	86 35	14 S.	......	0 55	S. 31 30 W.	6 52	S. 43 W.	4 36
22	13 13	79 32	4 S.	......	2 20	S. 58 W.	5 34	S. 66 W.	2 26
28	21 0	60 27	8 S.	......	9 5	S. 43 W.	5 43	S. 55 W.	6 17
	20 18	61 26	12 S.	......	8 25	S. 50 W.	4 22	S. 62 W.	7 38
	21 0	60 27	4 S.	......	......	S. 73 W.	1 49	S. 82 W.	7 11
(26) June 29	21 53	58 23	6 S.	......	8 25	S. 54 W.	4 47	S. 66 W.	7 13
			4 S.	......	10 50	S. 72 W.	1 43 E.	S. 80 W.	6 17 W.

"*Simla*"—*Calcutta to London, second voyage*—Continued.

Date.		Lat.	Long.	Heel.—P, port, S, starboard.	Approximate magnetic		Standard compass.		Steering compass.	
					Dip.	Variation.	Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.
		South. ° ′	*East.* ° ′	°		*West.* ° ′	° ′	° ′	° ′	°
1860. June	29	....	....	4 S.	....	10 50	S. 88 W.	1 5 W.	N. 84 W.	9 5 W.
				4 S.	....	10 50	N. 62 W.	8 10	N. 60 W.	10 10
				0	....	10 50	N. 34 W.	15 30	N. 37 W.	12 30
July	1	24 14	53 30	0	....	14 25	North	9 11	North	9 11
							N. 10 E.	7 39	N. 9 30 E.	7 9
							N. 45 30 E.	2 58	N. 44 E.	1 28
							N. 63 E.	2 21	N. 64 E.	3 21 W.
							N. 86 E.	1 7 W.	N. 83 E.	1 53 E.
							S. 71 30 E.	0 47 E.	S. 77 E.	6 17 E.
							S. 70 W.	2 17 E.	S. 80 W.	7 43 W.
				4 S.	....	....	N. 87 W.	1 11 W.	N. 79 W.	9 11
				0	....	....	N. 67 30 W.	6 32	N. 64 W.	10 2
							N. 42 30 W.	12 1 W.	N. 46 W.	8 31
	5	26 45	48 13	4 P.	....	18 35	S. 85 W.	0 54 E.	S. 93 W.	7 6 W.
(27)	6	28 6	45 18	0	....	20 50	S. 11 E.	12 0	S. 13 E.	14 0 E.
				0	....	....	S. 22 W.	13 7	S. 30 W.	5 7 E.
				0*	....	....	S. 34 30 W.	10 20	S. 58 W.	3 10 W.
				5 P.	....	....	S. 83 W.	1 25 E.	S. 92 W.	7 5
	8	28 48	42 28	10* S.	....	22 20	N. 46 W.	9 38 W.	N. 41 W.	11 38 W.
	9	28 31	41 50	0	....	22 40	S. 5 E.	14 33 E.	South	9 33 E.
				0	....	....	S. 23 W.	15 27	S. 30 W.	8 27 E.
				0*	....	....	S. 45 W.	9 42	S. 57 W.	2 18 W.
				0	....	....	N. 88 W.	0 25 E.	N. 81 W.	6 35
				0	....	....	N. 68 W.	5 50 W.	N. 66 W.	7 50
				0*	....	....	N. 41 W.	12 0	N. 44 W.	9 0
				0*	....	....	N. 47 W.	11 45	N. 51 W.	7 45
				0	....	....	N. 27 W.	12 57	N. 31 W.	8 57 W.
	10	29 30	40 43	10 P.	....	23 55	S. 5 W.	19 15	S. 4 W.	20 15 E.
		29 48	40 40	....	....	....	S. 5 W.	19 17	S. 3 W.	21 17 E.
	11	29 36	39 25	6 S.	....	24 20	N. 81 W.	1 35	N. 74 W.	8 35 W.
	12	30 13	36 28	2 P.	....	25 35	N. 93 W.	0 55	N. 82 W.	11 55
	13	31 21	33 57	2 S.	....	26 40	N. 4 30 E.	10 26	N. 5 E.	10 56
				2 S.	....	....	N. 47 E.	4 20	N. 44 E.	1 20
			34 7	2 S.	....	....	N. 72 W.	6 16	N. 69 W.	9 16
			33 57	0	....	....	N. 33 W.	14 18 W.	N. 34 W.	13 18
	15	31 32	31 6	0	....	28 0	S. 67 W.	6 30 E.	....	....
		31 46	30 37	0	....	28 10	N. 80 W.	0 10	N. 74 W.	5 50
	17	35 50	24 0	4 S.	....	30 0	N. 8 E.	7 0	N. 7 E.	6 0 W.
				4 S.	....	....	S. 24 W.	15 56 E.	S. 30 W.	9 56 E.
	22	34 58	16 53	6 S.	....	30 0	N. 5 W.	6 35 W.	N. 2 W.	8 35 W.
(28)	23	33 4	15 28	6 P.	....	29 30	N. 16 E.	10 41	N. 10 E.	4 41
		33 20	15 40	7 P.	....	29 15	N. 30 E.	8 15	N. 25 E.	3 15
		32 37	15 12	6 P.	....	29 10	N. 5 W.	12 20	N. 11 W.	6 20
	24	31 0	13 0	0	....	28 50	N. 14 30 E.	8 27	N. 9 E.	2 57
		31 18	13 27	5 S.	....	28 50	N. 8 30 W.	10 34	N. 11 W.	8 4
				7 S.	....	....	N. 7 30 W.	10 34	N. 9 W.	9 4
	25	29 48	11 58	4 P.	....	28 30	N. 25 E.	6 11	N. 21 30 E.	2 41
							N. 51 E.	3 32	N. 49 E.	1 32
				0	....	....	N. 64 E.	3 0	N. 63 E.	2 0 W.
				0	....	....	S. 81 E.	0 52	S. 84 E.	2 8 E.
				0	....	....	S. 69 E.	0 21	S. 75 E.	5 39 E.
				0	....	....	N. 44 W.	9 19 W.	N. 46 W.	7 19 W.
	26	29 31	11 59	4 S.	....	28 30	N. 58 E.	1 50 E.	N. 55 E.	1 10 E.
				7 S.	....	....	N. 60 E.	2 4 W.	N. 58 E.	0 4 W.
				13 S.	....	....	N. 62 E.	0 40	N. 60 E.	1 20 E.
				11 S.	....	....	N. 64 E.	0 48	N. 62 E.	0 22 E.
	27	28 26	10 30	6 P.	....	28 30	N. 47 W.	11 20	N. 52 W.	6 20 W.
				10 P.	....	....	N. 45 W.	12 32	N. 50 W.	7 32
				6 P.	....	....	N. 37 W.	14 7	N. 42 W.	9 7
	28	28 18	10 32	4 S.	....	....	N. 11 30 W.	11 13	N. 15 W.	7 43
	31	23 6	7 22	2 S.	....	27 5	N. 20 W.	11 4	N. 22 W.	9 4
Aug.	1	22 2	5 25	2 S.	....	26 45	N. 16 W.	10 50	N. 19 W.	7 50
	2	29 36	4 59	4 S.	....	26 40	N. 32 30 E.	2 45	N. 32 E.	2 15
				3 S.	....	....	N. 44 30 E.	2 30	N. 44 30 E.	2 30
	3	19 51	4 50	2 S.	....	26 30	N. 1 30 E.	6 46	N. 2 W.	3 16
				2 S.	....	....	N. 49 W.	7 7	N. 52 W.	4 7
				2 S.	....	....	N. 43 W.	9 15	N. 49 W.	3 15
			West.							
	5	17 50	0 30	8 S.	....	25 45	N. 35 W.	9 39	N. 41 W.	3 39
	6	16 55	2 45	3 S.	....	24 55	N. 38 30 W.	9 15	N. 42 W.	5 45
	7	15 58	4 51	0	....	24 10	N. 48 W.	8 29	N. 52 W.	4 29
(29)	9	13 6	8 37	0	....	23 0	N. 8 W.	8 53	N. 10 30 W.	6 23
	10	10 58	10 38	0	....	22 20	N. 15 W.	10 10 W.	N. 18 W.	7 10 W.

"*Simla*"—*Calcutta to London, second voyage*—Continued.

Date.	Lat.	Long.	Heel.—P, port, S, starboard.	Approximate magnetic — Dip.	Approximate magnetic — Variation.	Standard compass — Ship's head by compass.	Standard compass — Deviation.	Steering compass — Ship's head by compass.	Steering compass — Deviation.
	South.	*West.*			*West.*				
1860.	° ′	° ′	°		° ′	° ′	° ′	° ′	° ′
(30) Aug. 11	9 59	11 32	0	....	22 0	N. 15 W.	9 30 W.	N. 18 W.	6 30 W.
12	9 1	12 43	0	....	21 40	N. 13 W.	10 1	N. 16 W.	7 1
(31) 13	7 57	13 46	0	....	21 10	N. 31 E.	3 19	N. 31 E.	3 19
			0	....	....	N. 32 W.	10 12	N. 37 W.	5 22
						N. 8 30 W.	8 53	N. 12 W.	5 23
(32) 16	3 0	18 29	0	....	18 40	N. 42 30 W.	9 47	N. 48 W.	4 17
			0	....	....	N. 8 W.	9 57	N. 12 W.	5 57
(33) 17	1 52	19 40	0	....	17 50	N. 9 W.	9 58	N. 13 W.	5 58
	1 22	20 0	0	....	17 45	N. 10 W.	10 31	N. 13 30 W.	7 31
(34) 18	0 33	20 45	2 S.	....	17 20	N. 8 W.	10 25	N. 10 30 W.	7 55
	North.								
21	7 6	27 5	9 S.	....	15 25	N. 1 W.	10 21	North	11 21
	8 10	27 3	8 S.	....	15 25	N. 25 E.	6 45	N. 29 E.	10 45
	7 6	27 5	*9 S.	....	15 20	N. 7 W.	11 14	N. 7 30 W.	10 44
22	9 4	26 30	*0	....	15 30	N. 30 W.	10 0	N. 41 W.	3 0
23	9 38	26 33	2 S.	....	15 30	N. 9 30 W.	8 58	N. 11 W.	6 58
24	10 30	26 41	6 S.	....	15 35	N. 83 E.	1 51 W.	N. 87 E.	5 51 W.
			2 P.	....	....	S. 47 W.	6 35 E.	S. 51 W.	2 35 E.
			4 P.	....	....	S. 85 W.	0 27 E.	S. 82 W.	2 27 E.
			0	....	....	N. 72 W.	3 32 W.	N. 75 W.	0 32 W.
	10 20	26 39	*2 S.	....	....	N. 8 W.	8 39	N. 10 W.	6 39
27	12 29	27 29	2 S.	....	15 30	N. 17 30 E.	3 10	N. 17 E.	2 40
						N. 21 E.	4 33	N. 23 30 E.	7 3
			2 S.	....	....	N. 38 E.	3 51 W.	N. 33 E.	7 51 W.
		27 26	2 P.	....	....	S. 45 W.	5 2 E.	S. 41 W.	3 2 E.
(35) 28	13 23	27 42	0	....	15 45	N. 8 W.	10 28 W.	N. 12 W.	6 28 W.
29	14 10	28 15	*8 P.	....	15 35	N. 30 W.	9 26	N. 40 W.	0 34 E.
		28 11	3 P.	....	15 35	N. 8 30 W.	8 36	N. 14 W.	3 6 W.
(36) 30	15 15	30 6	13 P.	....	15 0	N. 40 W.	6 57	N. 52 W.	5 3 E.
			14 P.	....	....	N. 30 W.	6 28	N. 42 W.	5 32
31	16 5	31 46	5 P.	....	14 20	N. 41 W.	9 14	N. 52 30 W.	2 16 E.
	16 20	32 20	3 P.	....	14 20	N. 37 30 W.	10 30	N. 48 W.	0 0
			3 P.	....	14 20	N. 39 W.	10 2	N. 49 W.	0 2 W.
	16 0	32 0	0	....	14 20	N. 44 W.	11 23	....	....
Sept. 1	16 25	33 1	0	....	14 15	N. 3 E.	7 40	N. 6 30 E.	11 10
			0	....	14 15	N. 19 30 E.	5 45	N. 21 E.	7 15
	16 24	33 1	0	....	14 15	N. 31 30 E.	4 12	N. 38 E. ?	10 42 ?
	16 25	33 1	0	....	14 15	N. 35 W.	10 12	N. 44 W.	1 12
3	19 0	33 39	6 P.	....	14 15	North	7 30	N. 6 W.	1 30 W.
5	23 18	36 12	9 P.	....	15 5	N. 5 W.	7 40	N. 14 W.	1 40 E.
6	24 7	37 3	0	....	15 5	N. 1 W.	10 3	N. 6 W.	5 3
						N. 27 30 E.	2 57 W.	N. 33 E.	8 27
						S. 40 E.	2 58 E.	S. 35 E.	2 2
						S. 15 E.	4 28	S. 10 E.	0 32 W.
						S. 5 W.	8 27	S. 9 W.	4 27 E.
						S. 12 W.	9 10	S. 14 W.	7 10
						S. 24 W.	9 20	S. 25 W.	8 20
						S. 50 W.	7 50	S. 50 W.	7 50
						S. 59 W.	5 47 E.	S. 58 W.	6 47
						S. 71 W.	4 23	S. 67 W.	8 23
						S. 85 30 W.	1 2 E.	S. 80 W.	5 32
						N. 48 W.	8 20 W.	N. 60 W.	3 40
						N. 25 W.	10 12	N. 36 W.	0 48 E.
7	24 20	37 5	....	....	....	North	4 50	N. 5 W.	9 20 W.
						N. 24 30 E.	3 42	N. 28 E.	7 12
						N. 45 E.	3 50	N. 53 E.	11 50
						N. 64 E.	4 30	N. 72 E.	12 30
						N. 83 E.	3 30	N. 89 30 E.	10 0 W.
12	32 36	38 9	8 P.	....	20 35	N. 15 E.	2 47	N. 12 E.	0 13 E.
13	33 24	38 30	6 P.	....	25 31	N. 14 E.	3 45	N. 11 E.	0 35 W.
	33 56	38 35	5 P.	....	....	N. 10 30 W.	6 55 W.	N. 25 W.	6 35 E.
14	37 27	39 48	*10 P.	....	22 20	N. 13 30 E.	0 10 E.	N. 5 E.	8 40
(37) 15	36 54	39 6	*3 P.	....	23 35	N. 8 E.	3 25 W.	N. 4 E.	0 35 E.
		39 2	4 P.	....	....	N. 45 E.	0 21 W.	N. 55 30 E.	10 51 W.
		39 2	4 P.	....	....	N. 59 E.	0 18 E.	N. 70 30 E.	11 12
			4 P.	....	....	N. 73 E.	0 30 W.	N. 85 E.	12 30
16	37 26	39 25	*0	....	24 0	N. 41 E.	2 50	N. 52 E.	13 50
						N. 64 30 E.	1 15	N. 75 E.	11 45
						N. 87 E.	2 3	S. 81 E.	14 3
						S. 66 E.	1 30	S. 57 30 E.	10 0
						S. 48 E.	0 30 W.	S. 39 E.	9 30
17	37 24	38 36	*6 P.	....	24 20	N. 40 E.	1 25 E.	N. 50 E.	8 35 W
	37 34	38 46	0	....	....	S. 20 W.	11 40 E.	S. 23 W.	8 40 E.

"*Simla*"—*Calcutta to London, second voyage*—Continued.

Date.	Lat.	Long.	Heel.—P, port, S, starboard.	Approximate magnetic		Standard compass.		Steering compass.	
				Dip.	Variation.	Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.
	North. ° ′	*West.* ° ′	°		*West.* ° ′	° ′	° ′	° ′	° ′
1860.									
Sept. 18	38 0	38 50	4 P.	....	24 25	N. 22 30 E....	2 22 W.	N. 24 E.........	3 52 W.
20	40 22	35 43	0	....	27 0	N. 84 E.........	0 50	N. 96 E.........	12 50
21	42 0	32 48	0	....	28 50	N. 88 E.........	0 59	S. 79 30 E....	13 29
22	41 20	29 35	5 P.	....	28 0	N. 12 E.........	2 8 W.	N. 7 E.........	2 52 E.
			7 S.	....	....	S. 45 E.........	7 50 E.	S. 39 E.........	0 50
			10 S.	....	....	S. 30 E.........	11 44	S. 20 E.........	1 44 E.
23	41 34	29 17	6 S.	....	28 0	S. 86 E.........	0 0	S. 75 30 E....	10 30 W.
24	42 0	28 0	12 S.	....	28 25	S. 88 E.........	1 25	S. 78 E.........	8 35
			9 S.	....	....	S. 65 E.........	2 55 E.	S. 67 E.........	5 5
25	42 43	24 31	5 S.	....	28 10	N. 89 E.........	0 8 W.	N. 78 E.........	11 8
27	44 36	15 59	8 S.	....	26 50	N. 83 E.........	0 27 E.	N. 94 E.........	10 33
28	45 16	12 40	8 S.	....	25 10	S. 84 E.........	1 3	S. 73 E.........	9 5
			8 S.	....	....	S. 73 E.........	4 18 E.	S. 64 E.........	3 42 W.
30	45 20	9 38	10 P.	....	24 15	N. 57 W.........	3 35 W.	N. 76 W.........	15 35 E.
	45 24	9 38	7 P.	....	....	N. 25 W.........	9 36	N. 41 W.........	6 24 E.
Oct. 1	45 28	11 7	0	....	24 45	N. 2 30 W....	10 55	N. 9 W.........	4 25
						N. 28 E.........	6 25	N. 37 30 E....	8 55
						N. 47 E.........	4 25	N. 53 E.........	10 55
						N. 54 E.........	3 0	N. 62 E.........	11 0
						N. 74 30 E....	2 7	N. 87 E.........	14 37
						S. 88 E.........	0 8 W.	S. 77 30 E....	10 38
						S. 65 30 E....	2 32 E.	S. 57 E.........	5 58
						S. 50 E.........	3 33	S. 40 E.........	6 27 W.
						S. 22 30 E....	7 42	S. 16 E.........	1 12 E.
						S. 1 30 W....	11 35	S. 4 W.........	9 5
			(?)	....	....	S. 19 W.........	13 15	S. 20 30 W....	11 45
						S. 45 W.........	9 45	S 45 W.........	9 45
						S. 66 W.........	5 45	S. 59 W.........	12 45
						S. 90 W.........	0 15 E.	S. 70 W.........	13 15
						N. 62 W.........	5 15 W.	N. 80 W.........	12 45
						N. 45 30 W....	10 24	N. 65 30 W....	8 36
						N. 23 W.........	11 56	N. 39 W.........	4 4
4	47 12	7 50	0	....	23 50	N. 19 30 W....	11 34 W.	N. 35 W.........	3 56 E.

NOTES ON THE SWINGING OF THE "SIMLA."

Liverpool to Calcutta.—Second voyage.

(1.) Nov. 17.—It will be seen by the azimuths obtained by this morning's swing, and the previous observations since we left Liverpool, that both compasses have increased and altered their deviations considerably. The fact of our having upwards of 2,000 tons of railway machinery and other iron on board, no doubt, is the cause of this, or it may be that the jerking and tremor in taking in and stowing the cargo has imparted to the ship an increased power of attraction. It is rather singular that the deviations of the standard compass are now nearly the same as they were when the ship was swung three weeks after launching, although during our last voyage the deviation had much decreased, even in high latitudes, as may be seen by referring to the register of my last voyage. Our compasses are and have been undisturbed since we left the Bay of Bengal, last voyage. We took in the whole of our cargo on the south side of Sandon Dock with our head to W. N. W. by standard compass. Our standard azimuth compass is not compensated; it is 10 feet 10 inches from deck to card, and rests over the foremost skidd, which has two iron stanchions for supporters. The centre of card is distant 5 feet 9 inches from upper end of stanchion on each side; 20 feet 2 inches from top of shell plate; 21 feet from ends of deck beams under the compass; 13 feet 6 inches from ends of boat davits abreast and on a level (one pair on each side and generally canted in;) 24 feet from nearest part of mizzen-mast, and 24 feet from after part of main mast. The masts and lower yards are iron, wooden bulwarks, and wire rigging. The after part of iron cargo is 30 feet abaft the compass, and extends to 129 feet before the compass. I have a fancy to take away the iron supporters under the skidd, and substitute wooden ones, for I think they cause this compass to alter as much as anything else, although I do not anticipate more than about 8° maximum change during the voyage in the standard. I corrected to-day 3° error in central line of standard compass, and made the alterations required in bearing of ship's head for standard and in the deviations of the steering compass which were obtained by comparison with the standard.

(2.) Nov. 24.—The difference in the deviation of both our compasses with different degrees of heel to port and starboard on this course is very apparent, amounting to about 1° of deviation for each degree of heel; the easterly deviation being increased with starboard heel and diminished with port heel; but I am inclined to think it will not have the same effect in a high southern latitude—perhaps the contrary. I shall endeavor to get an opportunity to try it. It is a rare chance to have the shift of wind of sufficient strength to put the ship over to 6° or 8° port and starboard on the same course in the same latitude and longitude, or nearly so, and it is also too much risk to trim cargo for the purpose in the open ocean.

(3.) Dec. 14.—The error from heeling is not so apparent here as it was in high north latitude. The deviations of both compasses have decreased gradually on these courses.

(4.) Dec. 19.—The top of shell plate (topsides) slightly attracting the south point of a small compass-needle. The upright iron supporters under the skidd that the standard compass is on still attract the north point, so do the upper ends of the boat's davits. Loose iron, such as loose bolts, windlass, normans, &c., their upper ends attract the south end of the needle slightly, and the lower ends repel the same.

(5.) Dec. 20.—Upper ends of skidd supporters still attracting the north end of the needle. Took a small hammer in my hand, and gave one of them two or three raps with it, and on applying the compass to it afterwards, the upper end, instead of attracting the north point, now attracted the south point, and the lower end repelled it; while the other three stanchions that were not hammered remained the same. I shall treat the second stanchion the same to-morrow, and leave the two that are under the foremost skidd (where the standard compass is fixed) untouched, to change their polarity without any help, and I shall watch the time and place they will give in to the southern law.

(6.) Dec. 21.—Gave the second stanchion under the after skidd several strokes with a wooden serving mallet. This neutralized its polarity. A few strokes more gave the upper end a very slight attraction for the south point of the needle, but not so decidedly as the one which was struck with the iron hammer yesterday.

(7.) Dec. 22.—The azimuths observed to-day were taken under very favorable circumstances, only they were not all taken at the same time, but some were A. M. and some P. M. azimuths, which I have sometimes found not to agree within a degree or so. They show a considerable decrease in the deviations of the standard compass. The change is about 8° on the maximum. They have decreased gradually, according to latitude, since we left Liverpool. I think it is worthy of note that the curve obtained from the observations made on this voyage coincides so exactly with the curve obtained from observations made nearly in the same spot last voyage; and as I noted elsewhere the deviations on leaving Liverpool were much about the same last voyage and this. So it appears that our having iron cargo does not affect the compasses, (in this locality at least,) although the taking it in at Liverpool had something to do with the curves. There is another point connected with it, viz., the error on the same point in the same latitude here in the South does not correspond on the outward with the homeward passage, though the two outward deviations agree exactly, (that is, within the probable error of a degree, and no more, in observing;) but if we were to retrace our track backward from the Bay of Bengal, the deviations I think would be different. For instance, last voyage, on the homeward voyage, on the 26th April, 1859, in latitude 29° 16′ S., longitude 39° 10′ E., the deviation on the standard compass was 14° 31′ W., with ship's head E. 24° 30′ W.; whereas, on this voyage, and on the last outward passage, in the same latitude, the deviation on the same point was 8° 30′ W., the discrepancy arising no doubt from the tenacity with which some of the upright iron that affects the compass retains its changing magnetism after the ship has been sailing or remaining for some time in the opposite latitude.

(8.) Dec. 26.—Upper edge of mizzenmast-head slightly attracting the south end of the needle; so does the upper end of 'tween-deck stanchions under every beam, (they are only three feet apart the whole length of the ship, except in the cabin,) and also the upper end of vertical iron ribs (ship's frame) in 'tween decks. The other iron supporters under the skidd still retain their attraction of the north end of the needle; so do the upper end of the boat's davits, as well as the four crutches under the ends of the skidds in main rails.

(9.) Dec. 30.—It appears, by comparing to-day's azimuths with the previous ones, and especially with the amplitude of last evening, that both steering and standard compasses are affected with heeling in a contrary way to what they were in the northern hemisphere. At sunset yesterday the sun's amplitude gave the deviation of the standard compass 2° 13′ W., with 10° starboard heel, the last azimuth this afternoon gave 3° 31′ E., ship's head south and S. 3° E., respectively, which shows 5° 40′ due to 10° starboard heel, (the ship to-day being upright.) The above 2° 13′ W. deviation with 10° starboard heel would have been 9° 15′ E. in that part of the northern hemisphere in which the upright iron has the same amount of attraction for the north point of the needle that it has in this latitude for the south point. The steering compensated compass is affected about 4½° by heeling in the same way as the standard. It appears that the attraction of the upright iron on the port side draws the south point of the needle to the upper side in this hemisphere, and repels the same in the northern hemisphere, with ship's head on the same point, causing in this ship an increase of easterly deviation in the northern and a decrease in the southern hemisphere, with ship's head south. This change of error from heeling in different latitudes is another difficulty in the way of contriving a compensation for correcting the error from heeling, by making it necessary to have a movable corrector to correct for change of hemisphere in the way contrived by tne Astronomer Royal for suiting the magnets to correct the general deviation when the ship is upright. Something that would counteract this error from heeling in the two hemispheres on otherwise compensated or uncompensated compasses would be very valuable. It would be the cure for the most difficult and perplexing error the shipmaster has to allow for in squally and changeable wind and weather, when trying to steer a good course to make the land. I have no doubt it has been the cause of the loss of many an iron ship, if not wooden ships also.

(10.) Jan. 9, 1860.—The upper ends of the two upright stanchions under the standard compass are now neutral; they affect the N. and S. points of the small movable compass alike. The lower ends of the stanchions to the height of about three feet from the deck have a slight attraction for the north. The stanchions, as well as the very *ends* of the boat's davits, held their attraction for the north end of the needle until within the last two or three days, but now the upper ends of the davits have a decided attraction for the south. The only iron I can find about the ship retaining attraction for the north are the fancy cast-iron stanchions that support the hand-rail down to the cabin; these are five feet from the steering compass, the upper ends on a level with it and that distance forward. The steering compass has about 5° more easterly deviation than it had on the same point when I had the ship swung on the 24th ultimo. The magnets have not been moved since I corrected them, so as to make the Sandheads last voyage. It is probable that this compass will be again nearly correct when we get there this voyage, and also that the standard will show the same deviations as then, or not far from it.

(11.) Jan. 11.—By to-day's azimuths it appears that the steering compass has increased its easterly deviations (on the points observed this afternoon) on the maximum more than a point since the 24th ultimo. No difference of note is taking place in the standard. On the 14th of August, 1859, in the North Atlantic, latitude 44° N., longitude 41° W., the deviation of the steering compass on the same point (correct magnetic) was 11° 34′ West. We were then on our passage home from Demerara. To-day the deviation on the same point is 15° 10′ E., the extreme change from 44° N. latitude to 45° S. latitude being 26° 44′, showing that there would be no deviation either E. or W. about 12° to 13° S. latitude. The extreme change was the same last voyage, only then the compass was correct when we left Liverpool, and showed so much the more error when we got off the Cape here, where I took the magnets off and afterwards put them in end for end, as recorded in the register of my last voyage. The iron stanchions under the skidds at their upper ends have a decided attraction to-day for the south point of the needle, equal in force to that of the Earth.

(12.) Jan. 12.—The attraction of the upper ends of the two stanchions alluded to above is stronger to-day than that of the Earth, as is shown by their drawing the south point of the needle when the compass is placed on their south side.

(13.) Jan. 16.—By this morning's azimuths the standard compass has 5° 18′ W. deviation on the S. E. course. On the 11th instant it had little or no W. deviation on that point when the ship was upright. Although to-day's azimuths were not the best, on account of the swing of the card, they were correct within less than 2° of error at the furthest, and probably within 1°. I therefore attribute 4° or 5° of this westerly deviation as due to the 10° starboard heel, which the ship has to-day, and which affects the compass in the same way as was observed December 30, 1859, viz., contrary to the way the compass was affected by heeling in the northern hemisphere. The steering compass does not appear to be affected by to-day's heel, but as this compass is more liable to change of deviation on this course than the other, I cannot decide without more observations in this locality with the ship upright. The afternoon azimuth shows even more error from heeling. The mean of the two observations will be near the mark.

Jan. 17.—On examining the record of azimuths taken on my last voyage, to find whether the heeling of the ship affected our compass in this hemisphere in the same manner as it does on this voyage, I found the following observations, which prove that it did. For instance, on November 30, in lat. 33° 25′ S., long. 84° 13′ E., the deviation of the standard on N. 15° E. was 1° 10′ E., the ship heeling 2° to port only. On the following day, December 1, in lat. 29° S., long. 85° 25′ E., the deviation of the same compass on N. 16° E. was 5° 27′ W., the ship then having 8° port heel, being 6° more deviation than on the preceding day, showing that the upright iron of the starboard or upper side drew the south point of the compass 6° 37′ toward it. These observations are recorded in my returned Board of Trade Register for the last voyage.

(14.) Jan. 28.—The azimuths to-day show an increase in the deviation of the standard compass since I put the ship round for the deviations in the South Atlantic on the 22d December, nearly on the same parallel as we are to-day. Had circumstances permitted to put her round somewhere about the Crozet Islands, it is probable the deviations on the S.W. and N.W. quarters would have been found still greater than they now are. A chart or a table of the dip of the needle in different latitudes over the globe would be very useful. I think with the original error (or the error at any other time at a certain place) of the compass it would be possible to find approximately the change that would be likely to take place both on the error when upright as well as that caused by heeling in different latitudes.

(15.) Jan. 31.—The deviation found this morning for both compasses differs more than 7° from what it was last voyage on the same point, in nearly the same latitude, on the passage home from Calcutta. It was April 26, 1859, lat. 29° 16′ S., long. 39° 11′ E., when the deviations were by the standard compass 3° 30′ W., ship's head N. 32° E., heel 3° to starboard, and by the steering compass 3° 0′ W., ship's head N. 31° 30′ E., heel 3° to starboard. To-day the deviations are, by the standard compass, 3° 48′ E., ship's head N. 35° E., heel 4° to starboard; by the steering compass, 8° 48′ E., ship's head N. 30° E., heel 4° to starboard. The cause of this difference is probably the ship having in the first case been sailing for a long time to the S.W., and in the latter case to the East. However the deviations are very perplexing and ever varying, and cannot be trusted for being exactly right at any time, at least when at sea.

(16.) Feb. 8.—To-day's azimuths, compared with those taken on the 6th on the same point, show but little effect from difference of heel but what there is in the same direction that was observed further south. The polarity of all upright iron much more sluggish to-day than when I put the pocket compass to them further south.

(17.) Feb. 15.—At noon to-day tried the polarity of different vertical iron; found the mizzenmast-head to have changed; so have the two stanchions under the fore skidd which were so obstinate in changing on coming south in the South Atlantic. The aftermost under the after skidd are neutral. 'Tween-deck stanchions still retain their southern polarity, so do the boats' davits, the top of shell-plate and frames, as well as the loose iron about the decks slightly.

(18.) Feb. 17.—The southern polarity of vertical iron almost vanished. The only way I have to try it is the following: A bolt 3¼ feet long by 2¼ inches diameter held vertically on deck, and a small pocket compass (having its needle free of the card) applied to the upper end of the bolt on one side, and then on the other side across the magnetic meridian, or on the east and west sides of the bolt. The deflection caused by shifting the compass from one side to the other to-day at noon was only two points and then I turn the bolt end for end and apply the compass again.

(19.) Feb. 18.—To-day at noon the iron bolt made use of above was as near neutral as possible when held vertical and the needle trembling. The bolt held fore-and-aft, or as near as could be north and south, and parallel with the horizon, attracted the north point of the needle with its south end, the north end drew the south point, both nearly at right angles. Exactly in the middle the needle was parallel with the bolt. Our ship is too deep to try this on the hull. I should like to have a swing of the ship just here to compare with those I had here going out and coming home last voyage, to see whether this horizontal magnetism changes, as I take it to be the only source of error that affects our compasses here where the other is neutral.

(20.) 4 P. M., Feb. 18.—After writing the above the wind increased, and as it afforded a good opportunity for trying how far the heel affected our compasses in these latitudes, I took three azimuths as recorded, and, contrary to my expectations, I find them affected by the northern polarity, although but little to what it would be in high latitudes. The two stanchions under the standard compass were perhaps the cause of the standard deviating that way, as they had previously changed, as noted on the 15th. On applying my small compass to the top of the shell-plate round the stern, I found it drew the north point quite round, the ship's head at the time being north. Our steering compass is only 12½ feet from this round stern, and within a few inches of the same distance from the ship's sides. The card is only 2 feet 10 inches from the deck, 7½ feet before the stern-post, 5½ feet before the spindle of the wheel, and 8 feet before the rudder stock, which is 2½ feet high from the deck. The stern-post is cut short. The wheel-spindle is 2 feet 6 inches high from the deck.

(21.) Feb. 20.—Put the ship round as far as I could this morning early, to obtain a good set of azimuths while the sun was low, the sea being smooth, with a very light air of wind. Although I got what I considered very good azimuths, they do not agree with the previous ones; but they agree with one another. Something wrong about the compass; cannot find out what. It is very provoking, after all the trouble and a good chance to obtain the deviations. To prove which was right, I took two other azimuths in the afternoon, when the sun had the same hour angle, and the ship's head exactly on one of the points observed in the morning, the ship in the meantime having made only 4 or 5 miles more northing than the sun. The true azimuth would be nearly as much west as the other was east in the morning, therefore the observed azimuths should be the same also, but they were not. The A. M. one was S. 78° 30′ E., and the P. M. one was S. 80° 15′ W. The sun's true azimuth in the morning was S. 78° 30′ E., and in the afternoon S. 78° 34′ W., only 4′ difference, whereas the observed difference is 2°. I therefore come to the conclusion that the A. M. observations should have 2° correction, making the deviations less in the southwest quarter and more in the northwest quarter, as that would make them nearly correspond with those taken previously. The deviations of the steering compass are taken by comparison with the standard compass, and cannot, perhaps, at any time be quite so exact as those of the standard, which is always fixed in its place on the bridge. It is a Board of Trade compass, and a beautiful instrument. I think this compass could not be better placed, but the position of our steering compass is very objectionable, being so low.

(22.) Feb. 23.—Not being quite satisfied with the deviations obtained on the 20th, I put the ship right round this morning early, and had as good a set of azimuth observations as I could wish for, the ship only just steering, and the sea quite smooth. She was quite steadied on each point for a short time. I need not make any further remark on them than that they are suitable for comparison with my previous swings in this locality, as well as with others further north and south, especially with those of Messrs. Towson and Rundell in Liverpool when the ship was new. This swing shows more deviation in the N.E. and S.E. quarters than I have noticed before.

(23.) March 5.—To-day at noon the northern polarity begins to show itself in neutral iron. It was quite neutral from the equator to the S. E. end of Ceylon. To-day the iron bolt deflected the small needle 4 points, therefore, taking the mean of latitudes 2° 13′ S., longitude 82° 29′ E., our position on the 17th February, where the upper end of the bolt attracted the south as much as it now attracts the north end of the needle, and lat. 8° 50′ N., long. 82° 21′ E., would give mean lat. 3° 21′ N. for the position of the magnetic equator in long. 82° 16′ E. Those who know better where it is than I do, no doubt will smile at my makeshift way of finding the magnetic equator; however, it answers my purpose, and I shall expect an error from heeling accordingly. The ship herself has been as perplexing in her polarity as anything could be for the last fortnight. With her head east or west, the top of shell-plate on both sides could not be discovered to have any attraction for the small compass applied to them from inboard, the same fore-and-aft; but to-day, with her head north, the fore end from mainmast forward on both sides attracted the south point, and the after end attracted the north end of the compass needle round the stern very strongly. Our masts have very strong attraction already.

Calcutta to London.

(24.) Left the pilot at the Sandheads on the morning of the 24th May. The same evening I was taken ill of fever, and have been unable to take any observations for ten days.

(25.) June 11.—To-day I was too late with my experiments for the magnetic equator, for the spare norman attracted the S. point of the needle those points, so that we are in south dip. There is considerable difference in the deviations on S. by E. to what was observed going up the bay. Whether the change is due to the 12° heel we had to-day I cannot find until I get observations without heel on the same point in this locality.

(26.) June 13.—By the azimuths this morning it appears the difference of deviation referred to above does not arise from the 12° heel, but from a change having taken place since we were going up the bay. Both compasses are affected in the maximum 8° in the S.E. quarter, decreasing gradually to N.N.E. by the east and to S.S.W. We discharged our cargo in Calcutta with our head to the south, except eight days we were at Howrah with our head to the north. Can it be that our iron cargo had an influence on our compasses in this part going up, and had no effect in the South Atlantic; or can it be the increased power that may have been imparted to the ship's iron while discharging machinery, &c., with the accompanying jerks, in the northern hemisphere? They are continually on the move, however little, in one way or another. The influence exerted is so varied by the different circumstances and conditions a sailing vessel is subject to, more especially the change of latitude and the error from heeling and remaining for some time in port in one position, as well as sailing on the same tack in the same course across the Trades, that they require continual watching, and then the courses steered, after applying all the corrections that can be got at, will not be the correct course actually made, probably, in nine cases out of ten in high latitudes.

(27.) June 29.—By this morning's azimuths the compasses appear to have altered their deviations considerably in the N.W. quarter. The same disturbing force affects both alike, increasing their west deviation.

(28.) July 6.—The error from heeling is apparent by comparing the observations marked * with one another; the weather side drawing the south, is contrary to its effect in the northern hemisphere, as noted in several places in this register.

(29.) July 23.—Two days' azimuths on N. ¼ W., compared with the one yesterday on the same point, with heel on different tacks, show a difference of 6° in the deviation of the standard compass.

(30.) Aug. 9.—At noon to-day, on applying my small compass to the iron bolt, as usual, I find the north end drawing the south 3¼ points on the east and west side of it. Iron standards under skidds neutral. Top of shell-plate drawing the south end of needle rather strong as yet. I find the upright iron that retained the northern polarity longest also receives it the soonest on the return voyage; so I suppose the opposite pole at any time in its own latitude cannot be so strong in that iron as in neutral iron, when the magnetic current is free.

(31.) Aug. 11.—The upper end of my bolt to-day at 2 P. M., latitude 9° 52′ S., longitude 11° 53′ W., only deflected the needle one point on each side.

(32.) Aug. 13.—At 3 P. M. this day, in latitude 7° 40′ S., longitude 14° 5′ W., I could not discern any attraction in the upper end of the bolt for either point of the compass. The standard under the skidd attracts the north end 2 points on each side. The starboard top of shell-plate, between the main and mizzen masts, attracts the south end slightly; the same iron abaft the foremast is stronger by 2 points. The port side (lee side) forward attracts the north end of the compass slightly, and the port quarter attracts it strongly. The starboard side the same, but not so strong. Ship's head, correct magnetic, N. 16 W., no heel.

Aug. 14.—Bolt neutral.

Aug. 15.—Bolt neutral.

(33.) Aug. 16. Lat. 2° 49′ S., long. 18° 38′ W.—I tried to find to-day how high a compass would have to be so as not to be affected with the ship's iron on this course. The place chosen was immediately over the standard compass. The following is the result:

Height from card of standard compass.	Ship's head by trial compass.	Ship's head by standard.
	°	° ′
10 feet 2 inches.	N. 17 W.	N. 10 0 W.
7 " 2 "	N. 8 W.	N. 12 30 W.
3 " 9 "	N. 13 W.	N. 11 30 W.

The ship at the time being upright. This shows 3° 0′ W. deviation at the 1st height,
5° 30′ W. " 2d "
8° 30′ W. " 3d "

The deviation of the standard compass is taken at 10° W.

(34.) Aug. 17.—The bolt begins to attract the north end of the needle about ¾ of a point on each side.

(35.) Aug. 18. Lat. 0° 12′ S., long. 21° 3′ W.—My bolt to-day at noon drew the north end of the needle fully 1¼ points, so that I think I may now put the ship down as in northern dip. By taking means I make the magnetic equator in about lat. 5° S., long. 16° W. Can this be anything near the mark? I have no means of ascertaining. Our steering compass is considerably affected by the starboard heel which the ship has to-day. The standard is also affected slightly. This no doubt arises from the port side having a stronger attraction than the starboard side, (as I have observed coming on from St. Helena,) but I think if we were to heel over as many degrees to port to-day in this place, it would not alter the upright deviation of the standard anything; it might the steering compass. What is the cause of our port side having so much more polarity that the other in these latitudes? Can it be that it was the south side of the ship all the way from the equator in the Indian Ocean to this, and therefore becoming the north pole of the ship? The ship was also built with her head to the westward. I expect when we come to steer from the Western Islands home, turning the starboard side of the ship to the south, this deviation on the north point will dwindle away and show itself on some points in the south the same as it did last voyage. The deviations have kept remarkably steady since we entered the southeast Trades on this side, the forces as it were counterbalancing or sustaining each other. Had our course been to the N.E. after rounding the cape, I think the effect would have been different. Sailing for some days with the same side of the ship towards either pole causes not only a difference in the deviations on the different points with the ship upright, but also a difference in those which arise from heeling, increasing them when heeling to one side, and decreasing them on the other; for example, steering from the edge of the S.E. Trades in the South Atlantic toward the Cape, showing the starboard side of the ship to the south for a number of days or weeks, the wind comes out east, ship's head south, on the port tack, heeling 10° to starboard, bringing the port side more on a level with the compass, which side having a stronger attraction for the south point of the needle than the starboard side, owing to the growing tendency in the ship to show dissimilar poles, according to hemisphere and dip, causing the south point to deviate westerly (from the upright error) towards the upper side *more* than it would easterly, (from the upright error,) were the starboard side the upper side with port heel, as the attractive power of that side has been weakened by the induced polarity of the Earth. The difference in error arising from heeling 10° to port to 10° to starboard, found when swinging ship in Liverpool, may, I think, be accounted for in the same way. But this is of minor consequence, compared with the other sources of error, as it cannot make much difference in the course by allowing the same *amount* of error (+ and — of the upright) for heeling to port or starboard on the point in question. By far greater in importance is it to allow the error from heeling in the southern hemisphere in the *right way* with a contrary sign to what it was in the northern hemisphere, or in north dip. The omitting this in our ship would cause an error of nearly two points off the Cape with 10° of heel.

The observations which I have recorded may be relied upon as correct within a degree at the most, the majority within less, although showing apparent discrepancies; these arise from varied magnetic influences under differing circumstances. Any fresh error from any cause is easily detected in the working out the observations from day to day, and should I find any apparent discrepancies, I generally take another sight to prove them, or I do not put the observation down until I am satisfied of its correctness. Should any doubt arise about the correctness of any observation, it would be a pleasure to me to give any information or to supply the materials for examination, as I preserve all in pen and ink.

(36.) Aug. 28. Lat. 13° 34′ N., long. 27° 42′ W.—The port and starboard sides of the ship appear to attract the needle with equal force here. My bolt experiment is out of limit some days since, drawing the north end of the needle at right angles to its true direction.

(37.) Aug. 30. Lat. 15° 25′ N., long. 30° 20′ W.—To-day's and yesterday's azimuths are affected by the heeling of the ship, according to north dip. The weather side of the ship drawing the north end of the needle and diminishing westerly deviation. It is also observable that the heeling from 0° to 8° does not affect the compasses as much as the heeling from 8° to 14° does. This is easily explained, were it necessary. Our steering compass does not show so much difference as the standard does, because it is so low, although the total error from heeling by it is more than on the standard on this course. Were the ship's head north, the error of the standard would be still more, but I question if the error of the steering compass would increase to that point; indeed, I think it would be less, as the upright iron (now on the points observed to-day) round the starboard or weather quarter acts upon the north end of the needle with the greatest leverage. I should also expect the maximum error from heeling to show itself on different points in different places, perhaps in the two hemispheres changing quarters S.E. for S.W. and N.E. for N.W.; but I have not sufficent suitable observations to prove this. Does heeling affect the compass most, under all changes of dip, when the iron that attracts is on the same horizontal level with the needle? If we were to continue our course north to the neighborhood of the magnetic pole, would the effect of heeling gradually increase to that point? If so, in what ratio, or by what rule? Can it be found without observation?

I think this error from heeling might be corrected in our steering as well as in our standard compass by fixing a bolt of neutral iron vertically on each side of the compass, with their centre or neutral part on the same level as the needle when the ship is upright; say their length to be from 3 to 5 feet, at a distance from the compass determined by the amount of error to be corrected. For example, steering north here in the northern hemisphere, with the wind on the starboard side heeling us over say 10° to port, would cause the weather side to attract the north end of the needle, drawing it to the east. But by introducing the bolt to windward of the compass, fixed as above stated, its lower half being now risen by the ship heeling, would repel the north end of the needle so as to balance the attraction of the ship's side. Perhaps one bolt would answer, but the joint effect of two, one to leeward and one to windward, would be best and safest. There are several slight objections that might be raised against this plan, but I am persuaded that it would cure nine-tenths of the error from heeling in any part of the globe. If we had them in this ship, and a vertical iron pillar amidships, and before the compass, with its upper end at the same angle below the compass as the mean angle of the general attractive force abaft, and with the Astronomer Royal's magnets fixed correctly on the magnetic equator, our steering compass, I think, would perform all the voyage round without much alteration; but now it has regular circular rotation of error right round the compass in the course of the voyage. To explain myself, I mean that "no deviation" and "greatest deviation" visits all points of the compass in some part of the voyage out or home. Mr. Rundell was kind enough to suggest and was prepared to fix the midship pillar before we left Liverpool this voyage, had we not been in such a hurry to get away when the ship floated after being neaped and a fine fair wind blowing. I may here again remark that this error from heeling is the worst of the whole to correct for and to guard against its effect. It is not so much the difficulty of correcting the different courses *after* they have been steered. This can be done with tolerable correctness, if care has been taken by the officer of the watch to note down every hour the mean course made by the compass, and also the mean degree of heel the ship has taken while being steered on that course. (A column for that purpose should be upon the log-slate and log-book of every iron ship; there should also be some simple contrivance in a conspicuous position to show the heel. The best place to fix it would be in the binnacle before the helmsman, that it might be read by the light of the binnacle lamp in the night.) The chief difficulty is to keep the ship on a given true course from headland to headland, or from light to light; indeed, it is impossible so to do, as the course cannot be altered continually and simultaneously with every puff and squall that comes to put a crank ship over from 0° to 5° in this puff, from 0° to 10° in the next, may be, and so on to 16° or 20° heel, and that many times in a watch, thereby throwing the ship from her real course in a zigzag manner. Great care and watchfulness are necessary here, not only on the part of the master but also the officers, and they should be as conversant in it as the master, as he cannot be always on deck. Fortunately, our course up the English channel is on those points on which heeling does not affect our standard compass. I cannot say this, perhaps, of the steering compass.

I have laid down the following rule for my own guidance *in this ship*, to assist the memory to guard against error from heeling, so as to be in a better position to apply it, so as to preserve a given set course in narrow channels or near land.

Northward.—*Keep away* on BOTH TACKS to preserve a straight course when the ship *increases* her *heel* on either tack.

Ship's head southward.—*Luff* on both tacks to preserve a straight course with increasing heel.

2d. In the southern hemisphere, or with south dip.—Reverse the order. Ship's head northward, *luff*. Ship's head southward, *keep away*.

Or thus, in north magnetic latitude, with ship's head northward, the ship comes up or to windward of the point or light steered for as the ship heels over on either tack. With her head southward she goes to leeward of her port, therefore luff to fetch it, if she increases her heel.

The above is the rule when the course has been set for upright or even beam sailing, but if the course has been set for sailing with a certain degree of heel on either tack, and the ship as she is steered on that course *decreases* her heel, it is obvious that the reverse of the rule must be adopted, "luff" for "keep away," and "keep away" for "luff."

(38.) Sept. 15. Lat. 36° 57′ N., long. 39° 2′ W.—Those azimuths marked * show the effect of heeling to be more on the steering compass than I had anticipated; on this course it amounts to 1° for every degree of heel, and to half a degree to each degree of heel by the standard compass.

NOTE.—The following is an approximate statement of the cargo on board during the second outward voyage and on the third outward voyage from London, in November, 1860.

Second Voyage.

About 100 tons large machinery, fore-and-aft, on the orlop deck.
About 200 tons railway bars, fore-and-aft.
About 130 tons railway wheels and axles; the axles athwart ship and between decks.
About 1,100 tons railway bars in hold, fore-and-aft.
About 200 tons large girders, bridge work, fore-and-aft.
About 200 tons small iron, in cases.

Third Voyage.

About 800 tons railway bars, fore-and-aft.
About 600 tons small iron, in cases.
About 500 tons machinery, small.

With the first-named cargo the mean quadrantal deviation of the standard compass on the four-point courses was about 6° with second iron cargo, and without iron cargo it is about 3°.

NOTE RESPECTING THE "SIMLA."

It is worthy of record, as illustrating some of Captain Williams's remarks on the magnetism of the "Simla," as well as various statements made by other observers, that the deviation of the standard compass towards the stern was about 9° greater after she was loaded in London, November, 1860, than had previously been observed; while loading, she lay with her head to the northward. The steering compass does not show the same effect, but the attraction to the stern was greater by about 4° than when she was loaded at Liverpool, in the previous year, with her head to the westward.

W. W. R.

"APHRODITA"—CAPTAIN HUGH STEWART.

Liverpool to Calcutta, first voyage.

Date.	Lat.	Long.	Dip.	Heel.—P, port, and S, starboard.	Admiralty compass. Ship's head. By compass.	Admiralty compass. Ship's head. Correct magnetic.	Admiralty compass. Observed deviation.	Admiralty compass. Deviation at Liverpool.	Admiralty compass. Difference.	Compass over companion. Observed deviation.	Compass over companion. Deviation at Liverpool.	Compass over companion. Difference.	Compass under companion. Observed deviation.	Compass under companion. Deviation at Liverpool.	Compass under companion. Difference.
1858.	*South.* ° ′	*West.* ° ′		°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Aug. 30	1 21	19 29	....	10 S.	S. 34 0 W......	S. 34 30 W......	0 30 E.	3 45 W.	4 15 E.	4 30 E.	1 45 E.	2 45 E.	8 30 E.	2 30 E.	6 0 E.
31	3 48	20 29	....	5 S.	S. 17 0 W......	S. 14 0 W......	3 0 W.	9 30	6 30	3 0	0 15 E.	2 45	11 0	0 30	10 30
Sept. 2	8 16	22 30	....	6 S.	S. 17 0 W......	S. 12 0 W......	5 0	10 15	5 15	2 0	....	2 0	10 0	0 15	9 45
3	10 35	23 28	....	5 S.	S. 11 0 W......	S. 7 30 W......	3 30	10 30	7 0	3 30	0 30 W.	4 0	6 30	....	6 30
4	12 59	24 32	....	5 S.	S. 17 0 W......	S. 13 30 W......	3 30	9 30	6 0	2 30	....	2 30	5 30	0 30	5 0
5	14 47	25 0	....	3 S.	S. 22 0 W......	S. 18 0 W......	4 0	8 30	4 30	2 0	0 15 E.	1 45	5 0	0 45 E.	4 15
6	16 50	25 34	....	1 S.	South............	S. 12 30 E......	12 30 W.	16 0	3 30	0 30	3 0 W.	3 30	2 30	2 0 W.	4 30
9	20 25	26 6	....	6 S.	S. 45 0 W......	S. 47 0 W......	2 0 E.	0 30 W.	2 30	6 0 E.	3 30 E.	2 30 E.	9 0	3 45 E.	5 15 E.
10	21 37	28 10	....	....	S. 73 9 W......	S. 72 30 W......	0 30 W.	5 0 E.	5 30	8 30 W.	4 0 E.	12 30 W.	2 30	4 30 E.	2 0 W.
11	22 29	29 20	....	2 P.	S. 28 0 E......	S. 43 30 E......	15 30	21 0 W.	5 30	0 30 E.	6 30 W.	7 0 E.	0 30 E.	3 30 W.	4 0 E.
13	23 28	26 37	....	6 P.	S. 45 0 E......	S. 61 0 E......	16 0	21 0 W.	5 0 E.	2 0 W.	7 45 W.	5 45 E.	2 0 W.	3 0 W.	1 0
14	23 37	25 17	....	....	S. 79 0 W......	S. 76 30 W......	2 30	5 45 E.	8 15 W.	12 30	4 15 E.	16 45 W.	1 30 E.	4 45 E.	3 15
					S. 22 0 E......	S. 38 30 E......	16 30	20 30 W.	4 0 E.	2 30 W.	6 0 W.	3 30 E.	1 30 W.	3 30 W.	2 0
15	23 42	24 18	....	4 P.	S. 34 0 E......	S. 50 30 E......	16 30 W.	21 30 W.	5 0 E.	0 30 E.	7 0 W.	7 30	1 30 W.	3 30 W.	2 0 E.
17	25 1	21 37	....	3 S.	S. 62 0 W......	S. 64 30 W......	2 30 E.	3 30 E.	1 0 W.	3 30 W.	4 30 E.	8 0	13 30 E.	4 30 E.	9 0
19	26 50	23 1	....	....	S. 11 0 E......	S. 25 30 E......	14 30 W.	18 30 W.	4 0 E.	2 30 E.	4 45 W.	7 15	1 30 E.*	3 0 W.	4 30
21	30 41	20 25	....	....	S. 17 0 E......	S. 35 0 E......	18 0	20 30	2 30	1 0 W.	6 0	5 0	1 0 W.	3 30	4 30
22	32 47	18 11	....	2 P.	S. 17 0 E......	S. 36 0 E......	19 0	20 30	1 30	....	6 0	6 0	0 0	3 30	3 30
24	35 13	12 27	....	....	S. 25 0 E......	S. 45 0 E......	20 0	21 0	1 0	1 0 W.	7 0	6 0	1 0	3 30	2 30 E.
28	39 12	0 22	....	....	S. 34 0 E......	S. 54 0 E......	20 0	21 30	1 30 E.	2 0 E.	7 0	9 0	4 0	3 0	1 0 W.
		East.													
29	39 5	2 40	....	....	S. 45 0 E......	S. 65 0 E......	21 0	20 45	0 15 W.	1 0	7 45	8 45	8 0	2 30	5 30
30	39 11	5 18	....	....	S. 45 0 E......	S. 67 0 E......	22 0	20 30	1 30	2 0	7 45	9 45	7 0	2 30	4 30
Oct. 1	39 12	7 6	....	....	S. 45 0 E......	S. 66 0 E......	21 0	20 30	0 30 W.	1 0 E.	7 45 W.	8 45 E.	9 0 W.	2 30 W.	6 30
4	38 51	12 25	....	....	S. 45 0 W......	S. 44 45 W......	0 15	1 0	0 45 E.	11 15 W.	0 E.	14 15 W.	2 45 E.	3 30 E.	0 45
					S. 45 0 E......	S. 66 15 E......	21 30	20 30	1 0 W.	4 45 E.	7 45 W.	12 30 E.	3 15 W.	2 30 W.	0 45 W.
5	39 40	15 29	....	4 S.	S. 22 0 W......	S. 17 30 W......	4 30	8 30	4 0 E.	1 45	0 15 E.	1 30	5 45 E.	0 45 E.	5 0 E.
6	41 19	16 21	....	2 S.	S. 17 0 E......	S. 35 0 E......	18 0	20 30	2 30 E.	3 0	5 45 W.	8 45	2 0 W.	3 30 W.	1 30
8	42 12	20 40	....	....	S. 39 30 E......	S. 61 30 E......	22 0	20 45	1 15 W.	5 0	7 45	12 45	3 0 W.	3 0 W.	....
12	41 25	33 18	....	....	S. 39 30 E......	S. 59 30 E......	20 0	11 0	1 0 E.	12 0	7 45	19 45	1 0 E.	3 0	4 0
16	40 38	46 54	....	....	S. 62 0 E......	S. 83 0 E......	21 0	17 0	4 0 W.	8 0	7 30	15 30	1 0 W.	1 15	0 15 E.
17	39 41	50 36	....	....	S. 67 30 E......	S. 86 30 E......	19 0	16 0	3 0	11 0	7 30	18 30	2 0	1 0	1 0 W.

18	38 25	53 30	....	1 P.	S. 79 0 E.	N. 84 30 E.	16 30	11 30	5 0	7 30	6 0	13 30	3 30	0 15	3 15
19	37 34	55 46	....	....	S. 79 0 E.	N. 86 30 E.	14 30	13 0	1 30	7 30	6 15	13 45	4 30	0 15 W.	4 30
20	36 34	57 50	....	....	S. 87 0 E.	N. 82 0 E.	11 0	10 0	1 0 W.	10 0	6 0	16 0	4 0	....	4 0
22	35 49	62 41	....	7 S.	S. 67 30 E.	S. 83 15 E.	15 45	17 15	1 30 E.	4 15	6 0	10 15	6 45	....	6 45
24	34 32	69 23	....	6 S.	N. 84 30 E.	N. 75 30 E.	9 0 W.	6 0 W.	3 0 W.	7 0	5 30	12 30	2 0	0 45 E.	2 45
26	32 6	73 46	....	....	N. 34 0 E.	N. 40 0 E.	6 0 E.	14 0 E.	8 0 W.	3 0	2 30	15 30	2 0 W.	1 15	3 15 W.
28	28 46	75 16	....	4 P.	N. 34 0 E.	N. 46 0 E.	12 0	11 30	0 30 E.	10 0	2 30	12 30	4 0 E.	1 30	2 30 E.
29	26 37	76 12	....	5 P.	N. 17 0 E.	N. 27 45 E.	10 45	16 30	5 45 W.	5 45	2 0	7 45	0 45 E.	1 0	0 15 W.
30	24 21	76 40	....	5 P.	N. 5 30 E.	N. 16 30 E.	11 0	18 30	7 30	4 0	1 45	5 45	....	0 45	0 45
Nov. 1	19 46	77 1	....	6 P.	North	N. 9 0 E.	9 0	17 45	8 45	3 0	1 15	4 15	....	0 15	0 15
3	14 46	78 0	....	6 P.	N. 17 0 E.	N. 25 0 E.	8 0	16 30	8 30	2 0	2 0	4 0	1 0 W.	0 45	1 45 W.
4	11 59	78 30	....	4 P.	N. 17 0 E.	N. 25 15 E.	8 15	16 30	8 30	5 15	2 0	7 15	1 15 E.	0 45	0 30 E.
5	9 10	79 21	....	4 P.	N. 17 0 E.	N. 24 0 E.	7 0	16 30	9 30	4 0	2 0	6 0	1 0 E.	0 45	0 15 E.
10	3 24	82 10	....	1 P.	N. 17 0 E.	N. 23 0 E.	6 0	16 30	10 30	3 0	2 0	5 0	2 0 W.	0 45	2 45 W.
11	2 48	82 54	....	....	N. 17 0 E.	N. 23 0 E.	6 0	17 0	11 0	3 0	2 0	5 0	2 0	0 45	2 45
14	0 33	85 24	....	....	N. 5 30 W.	N. 1 0 E.	6 30	17 30	11 0	1 30	0 45	2 45	2 30 W.	....	2 30 W.
	North.														
20	6 53	87 14	....	2 P.	N. 50 30 E.	N. 53 30 E.	3 0	8 30	5 30	6 0	3 0	9 0	2 0 E.	1 45	0 15 E.
21	7 43	88 32	....	1 P.	N. 56 0 E.	N. 58 30 E.	2 30	6 0	3 30	3 30	3 0	6 30	0 30 W.	1 45	2 15 W.
22	8 5	88 53	....	....	N. 39 30 E.	N. 43 0 E.	3 30	13 0	9 30	1 30	2 30	4 0	0 30	1 30 E.	1 0
26	14 11	87 55	....	3 P.	N. 5 30 W.	N. 1 15 E.	6 45 E.	17 30 E.	10 45 W.	2 45 E.	0 45	3 30	0 15 W.	....	0 15 W.
29	16 44	87 44	....	2 S.	S. 67 30 E.	S. 77 45 E.	10 15 W.	16 45 W.	8 30 E.	0 15 W.	7 45 W.	6 30 E.	0 15	2 0 W.	1 45 E.
Dec. 5	20 50	88 32	....	3 P.	West	W. 5 0 N.	5 0 E.	8 30 E.	3 30 W.	1 0 E.	4 0 E.	3 0 W.	1 0	4 0 E.	5 0 W.
6	21 8	88 9	....	....	North	N. 8 0 E.	8 0 E.	17 30 E.	9 30 W.	2 0 W.	1 0 W.	1 0 W.	2 0 W.	0 15 E.	2 15 W.

CALCUTTA TO LIVERPOOL, FIRST VOYAGE.

1859.															
Feb. 18	20 24	88 32	....	7 P.	S. 8 30 E.	S. 14 30 E.	6 0 W.	16 30 W.	10 30 E.	0 30 W.	3 15 W.	2 45 E.	0 30 W.	2 0 W.	1 30 E.
21	18 7	89 48	....	5 P.	S. 17 0 E.	S. 23 0 E.	6 0	18 30	12 30	4 0 E.	4 20	8 20	4 0 E.	2 50	6 50
23	16 52	89 51	....	7 S.	South	S. 3 0 E.	3 0	13 40	10 40	5 0	1 45	6 45	5 0	1 0	6 0
25	13 56	89 52	....	3 S.	S. 3 0 E.	S. 4 45 E.	1 45	14 0	12 15	5 15	1 45	7 0	5 15	1 0	6 15
27	11 39	89 43	....	4 S.	S. 3 0 E.	S. 4 40 E.	1 40	14 0	12 20	5 20	1 45	7 5	5 20	1 0	6 20
28	9 41	89 37	....	10 S.	S. 3 0 E.	S. 4 30 E.	1 30	14 0	12 30	4 30	1 45	6 15	4 30	1 0	5 30
Mar. 1	8 1	89 37	....	2 S.	S. 3 0 W.	S. 1 30 W.	1 30	12 45	11 15	4 30	1 0	5 30	5 30	0 40	6 10
2	6 56	89 18	....	1 S.	S. 8 30 W.	S. 8 15 W.	0 15	11 0	10 45	4 45	0 30	5 15	5 45	0 0	5 45
4	4 29	88 23	....	3 S.	S. 8 30 W.	S. 6 30 W.	2 0	11 40	9 40	3 0	0 30	3 30	3 0	0 10	3 10
7	1 4	87 21	....	....	S. 17 0 E.	S. 21 45 E.	4 45	18 15	13 30	5 15	4 10	9 25	5 15	2 40	7 55
	South.														
13	3 41	89 5	....	16 P.	S. 11 15 E.	*S. 13 35 E.	2 20	16 0	13 40	7 40	3 10 W.	10 50	7 40	2 9 W.	9 40
15	6 54	89 4	....	10 P.	S. 22 30 W.	S. 21 30 W.	1 0	7 30	6 30	4 0	0 15 E.	3 45	4 0	1 15 E.	2 45
16	8 36	88 53	....	10 P.	South	S. 1 20 E.	1 20 W.	13 20	12 0	6 20	1 30 W.	7 50	6 20	1 0 W.	7 20
18	11 15	88 57	....	8 P.	S. 22 30 W.	S. 22 30 W.	....	7 10	7 10	4 0	0 30 E.	3 30	4 0	1 15 E.	2 45
20	14 2	87 30	....	6 P.	S. 22 30 W.	S. 25 30 W.	3 0 E.	6 20	9 20 E.	8 0 E.	0 45	7 15 E.	9 0 E.	1 40	7 20
21	14 58	86 20	....	8 S.	S. 45 0 W.	S. 42 30 W.	2 30 W.	1 30 W.	1 0 W.	2 30 W.	2 30	5 0 W.	2 30 W.	3 15	5 45
22	16 30	84 16	....	8 S.	S. 56 15 W.	S. 62 0 W.	5 45 E.	3 0 E.	2 45 E.	5 15	4 0	9 15	0 45 E.	4 30	3 45 E.
23	18 13	81 0	....	8 S.	S. 61 45 W.	S. 67 30 W.	5 45 E.	4 0 E.	1 45 E.	6 15 W.	4 30 E.	10 45 W.	0 15 W.	4 50 E.	5 5 W.

* A new card put in this compass to-day.

"*Aphrodita*"—*Liverpool to Calcutta, first voyage*—Continued.

Date.	Lat.	Long.	Dip.	Heel.—P, port, and S, starboard.	Admiralty compass. Ship's head. By compass.	Admiralty compass. Ship's head. Correct magnetic.	Admiralty compass. Observed deviation.	Admiralty compass. Deviation at Liverpool.	Admiralty compass. Difference.	Compass over companion. Observed deviation.	Compass over companion. Deviation at Liverpool.	Compass over companion. Difference.	Compass under companion. Observed deviation.	Compass under companion. Deviation at Liverpool.	Compass under companion. Difference.
1859.	*South.* ° ′	*East.* ° ′		°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Mar. 24	19 37	78 10	....	8 S.	S. 61 45 W......	S. 65 30 W......	3 45 E.	3 45 E.	0 0	9 15 W.	4 15 E.	13 30 W.	3 45 E.	4 45 E.	1 0 W.
27	22 15	71 2	....	10 S.	S. 61 45 W......	S. 67 15 W......	5 30	4 0	1 30 E.	12 30	4 20	16 50	1 30 W.	4 50	6 20 W.
29	24 13	65 53	....	11 S.	S. 61 45 W......	S. 66 45 W......	5 0	3 50	1 10	11 0	4 20	15 20	5 0 E.	4 50	0 10 E.
30	25 14	63 34	....	10 S.	S. 64 45 W......	S. 71 5 W......	6 20	4 45	0 35 E.	9 40 W.	4 15	13 55	6 20	4 50	6 30
31	26 38	60 56	....	8 S.	S. 73 0 W......	S. 79 0 W......	6 0	6 15	0 15 W.	11 0	4 20	15 20	6 0	4 45	1 15
April 1	27 54	58 11	....	2 S.	S. 67 30 W......	S. 75 0 W......	7 30	5 35	1 55 E.	9 30	4 20	13 50	5 30 E.	4 45	0 45 E.
2	29 0	56 8	....	....	S. 78 45 W......	S. 85 30 W......	6 45	7 30	0 45 W.	11 15	4 0	15 15	1 15 W.	4 40	5 55 W.
3	29 27	54 45	....	2 S.	S. 78 45 W......	S. 84 30 W......	5 45	7 10	1 25	15 15	4 0	19 15	1 15	4 45	6 0
5	30 8	49 27	....	2 S.	N. 78 45 W......	N. 71 15 W......	7 30	10 15	2 45	15 30	2 45	18 15	1 30	3 0	4 30
6	30 30	46 33	....	2 S.	N. 78 45 W......	N. 72 25 W......	6 20	10 15	3 55	14 40	2 45	17 25	2 40	3 0	5 40
7	30 36	45 35	....	....	West..............	N. 83 0 W......	7 0	9 0	2 0	15 0	3 45	18 45	2 0	3 50	5 50
8	31 11	43 41	....	14 S.	West..............	N. 83 30 W......	6 30	9 0	2 30	16 30	3 45	20 15	1 30 W.	3 50	5 20
11	32 35	34 0	....	2 S.	N. 87 45 W......	N. 70 15 W......	8 30	10 15	1 45	10 30	2 40	13 10	1 30 E.	2 50	1 20
12	32 56	33 13	....	14 S.	N. 67 30 W......	N. 59 50 W......	7 40	12 30	4 50 W.	11 20	1 45	13 5	0 20 W.	1 45	2 5
13	32 36	31 21	....	15 S.	S. 73 0 W......	S. 80 15 W......	7·15	6 30	0 45 E.	14 45	4 15	19 ·0	0 45 W.	4 40	5 25 W.
15	34 50	25 32	....	14 P.	S. 45 0 W......	S. 54 45 W......	9 45	1 0	8 45 E.	2 45	4 0 E.	1 15	16 45 E.	4 0	12 45 E.
16	34 36	24 22	....	12 S.	N. 17 0 E......	N. 21 45 E......	4 45	17 15	12 30 W.	8 15	2 0 W.	6 15	12 15 W.	0 45	13 0 W.
20	35 27	21 10	....	....	N. 78 45 W......	N. 73 45 W......	5 0	10 0	5 0	17 0	2 45 E.	17 45	6 0	3 0	9 0
21	35 12	20 2	....	2 P.	N. 56 15 W......	N. 51 25 W......	4 50	12 30	7 40	15 10	1 30	16 40	7 10	1 15 E.	8 25
22	35 19	19 6	....	5 S.	N. 33 45 W......	N. 28 0 W......	5 45	15 0	9 15	12 15	0 30 E.	12 45	7 15	....	7 15
23	33 40	16 42	....	4 S.	N. 22 30 W......	N. 19 15 W......	3 15	16 0	12 45	10 45	....	10 45	12 45	0 15 W.	13 0
26	27 25	8 46	....	....	N. 22 30 W......	N. 19 0 W......	3 30	16 0	12 30	10 30	....	10 30	10 30	0 15	10 15
27	25 50	6 34	....	....	N. 22 30 W......	N. 19 30 W......	3 0	16 0	13 0	10 0	....	10 0	10 0	0 15	9 45
30	21 50	1 46	....	....	N. 22 30 W......	N. 19 15 W......	3 15	16 0	12 48	9 45	....	9 45	9 45	0 15	9 30
May 1	21 3	0 43	....	....	N. 11 15 W......	N. 8 15 W......	3 0	17 0	14 0	7 0	0 20 W.	7 20	7 0	0 20	6 40
		West.													
4	18 22	0 57	....	4 S.	N. 33 45 W......	N. 29 15 W......	4 30	14 45	10 15	10 30	0 30 E.	11 0	8 30	....	8 30
9	13 4	8 38	....	....	N. 28 0 W......	N. 27 0 W......	1 0	15 0	14 0	9 0	0 30	9 30	9 0	0 10	8 50
10	11 35	9 57	....	....	N. 17 0 W......	N. 45 30 W......	1 30	16 0	14 30	5 30	....	5 30	5 30	0 15	5 15
12	8 24	12 38	....	....	N. 22 30 W......	N. 20 40 W......	1 40	15 45	14 15	7 20	0 10 E.	7 30	7 20	0 15	7 5
15	2 58	18 1	....	....	N. 17 0 W......	N. 16 15 W......	0 45	16 10	15 25	6 15	....	6 15	6 15	0 15	6 0
	North.														
22	3 49	22 47	....	5 P.	N. 17 0 W......	N. 15 30 W......	1 30 E.	16 0	14 30	1 30	....	1 30	1 30	0 15 W	1 15
25	5 9	23 10	....	....	N. 56 15 W......	N. 57 0 W......	0 45 W.	12 0	12 45	7 45	1 45 E.	9 30	7 45	1 45 E.	9 30

	29	7 40	22 27	....	2 S.	N. 11 15 E......	N. 11 45 E......	0 30 E.	18 0	17 30	7 30	1 30 W.	6 0	1 30	0 40 E.	2 10
June	1	8 52	22 53	....	15 P.	N. 22 30 W......	N. 20 30 W......	2 0	15 45	13 45	2 0 W.	0 10 E.	2 10 W.	2 0 W.	0 15 W.	1 45 W.
	5	11 53	27 34	....	15 P.	N. 33 45 W......	N. 29 15 W......	4 30	14 45	10 15	2 30 E.	0 30 E.	2 0 E.	5 30 E.	....	5 30 E.
	7	14 13	29 32	....	18 P.	N. 11 0 W......	N. 4 5 W......	7 10	17 0	9 50	10 10	0 30 W.	10 40	9 10	0 10	9 20
	8	15 30	30 39	....	18 P.	N. 17 0 W......	N. 10 0 W......	7 0	16 45	9 45	9 0	0 15	9 15	11 0	0 15	11 15 E.
	10	18 17	32 38	....	18 P.	N. 11 15 W......	N. 4 45 W......	9 30	17 25	7 55	10 30 E.	0 30	12 0	12 30	0 20	12 50
	11	19 44	33 20	....	16 P.	N. 11 15 W......	N. 1 55 W......	9 20	17 25	8 5	8 20	0 30	8 50	8 20	0 20	8 40
	12	21 12	34 8	....	14 P.	N. 22 30 W......	N. 16 0 W......	6 30	16 20	9 50	9 30	....	9 30	10 30	0 30 W.	11 0
	15	25 50	35 56	....	12 P.	N. 11 15 W......	N. 0 15 E......	11 30	17 25	5 55	11 30	0 30	12 0	13 30	....	13 30
	16	27 11	36 34	....	14 P.	N. 11 15 W......	N. 4 45 E......	16 0	17 40	1 40	15 0 E.	1 0	16 0	14 0 E.	0 20 E.	13 40 E.
	18	29 23	37 20	....	....	N. 11 15 E......	N. 20 0 E......	8 45	18 0	9 15	0 15 W.	2 0	1 45	3 15 W.	0 50	4 5 W.
	19	30 29	37 55	....	12 P.	N. 33 34 E......	N. 45 15 E......	11 30	12 35	1 5 W.	11 30 E.	2 40	14 10	16 30 E.	1 15	15 15 E.
	21	33 49	37 45	....	14 P.	N. 3 0 W......	N. 15 15 E......	18 15	18 0	0 15 E.	18 15	1 50	20 5	20 15	0 45 E.	19 30
	23	35 27	38 22	....	10 P.	N. 33 45 W......	N. 20 0 W......	13 45 E.	16 10	2 25 W.	10 45 E.	....	10 45	13 45	0 20 W.	14 5 E.
	25	37 8	36 20	....	8 S.	N. 61 45 E......	N. 61 30 E......	0 15 W.	5 20 E.	5 35 W.	1 15 W.	4 0	2 45	2 45	1 40 E.	1 5
	27	38 10	35 41	....	7 P.	N. 73 0 E......	N. 74 15 E......	1 15 E.	4 30	5 45 E.	6 15 E.	5 15	11 30 E.	6 15	0 50	5 25
	28	39 14	34 2	....	14 S.	N. 73 0 E......	N. 65 30 E......	7 30 W.	3 0 E.	10 30 W.	6 30 W.	4 20	2 10 W.	1 30	1 30	0 0
	30	40 33	30 24	....	15 S.	N. 78 45 E......	N. 73 15 E......	5 30	3 15 W.	2 15	3 30	5 15	1 45 E.	2 30 E.	0 50	1 40 E.
July	2	41 39	27 28	....	15 S.	N. 78 45 E......	N. 72 15 E......	6 30 W.	3 0 W.	3 30	6 30	5 0	1 30 W.	1 30 W.	0 50	2 20 W.
	3	42 9	26 19	....	....	N. 50 30 E......	N. 51 30 E......	1 ·0 E.	9 45 E.	8 45 W.	2 0 W.	2 45	0 45 E.	....	1 30	1 30 W.
	4	43 10	26 28	....	17 P.	N. 3 0 W......	N. 19 30 E......	22 30	18 0	4 30 E.	25 30 E.	2 0	27 30	14 30 E.	0 45	13 45 E.
	6	44 14	28 30	....	15 P.	N. 25 30 W......	N. 8 0 W......	22 30 E.	17 35	4 55 E.	20 20	0 30 W.	21 0 E.	24 30 E.	0 20 W.	24 50 E.
	7	44 27	28 54	....	2 S.	S. 45 0 E......	S. 57 30 E......	12 30 W.	2 10 E.	14 40 W.	3 30 E.	4 0 E.	0 30 W.	3 30 W.	4 30 E.	8 0 W.
	10	45 31	24 16	....	8 S.	S. 78 45 E......	N. 89 45 E......	11 30	15 0 W.	3 30 E.	6 30 W.	7 0 W.	0 30 E.	10 30 W.	0 20 W.	10 10 W.
	13	46 23	19 17	....	17 S.	S. 39 15 E......	S. 45 15 E......	6 0 W.	20 30 W.	14 30	11 0 E.	6 45	17 45	9 0 E.	3 30 W.	12 30 E.
	15	46 6	18 56	....	18 P.	N. 11 15 E......	N. 35 30 E......	24 15 E.	15 35 E.	8 40 E.	23 15 E.	2 10	25 25	25 15	1 20 E.	23 55
	18	47 22	17 20	....	13 S.	N. 84 15 E......	N. 77 35 E......	6 40 W.	5 30 W.	1 10 W.	1 40 W.	5 40	4 0	2 20	0 35	1 45 E.
	22	48 51	12 46	....	20 S.	N. 70 30 E......	N. 65 30 E......	5 0 W.	3 30 E.	8 30 W.	3 0 W.	4 20	1 20	1 0	1 40	0 40 W.
	25	50 31	9 35	....	5 S.	N. 67 30 E......	N. 68 30 E......	1 0 E.	0 0	1 0 E.	0 0	4 45	4 45	5 0 E.	1 15 E.	3 45 E.
	26	51 22	8 29	....	....	S. 78 45 E......	S. 87 15 E......	8 30 W.	16 0 W.	7 30 E.	1 30 E.	7 0 W.	8 30 E.	0 30 W.	0 45 W.	0 15 E.

NOTE.—As the Admiralty standard compass belonging to this ship is a very perfect instrument, and Captain Stewart states that he has only recorded those observations which he considered good, it is believed that great dependence may be placed on the deviations given above. The log for this ship is remarkable for the extreme degrees of heel which it records, and as being the first placed before the committee in which the angle of heeling has been regularly inserted.

On the outward voyage there is an evident reduction in the ship's magnetism, though not so great as appears before an allowance is made for the increase in the directive power of the earth. On the homeward voyage, after her head has been for some time to the westward, the attraction of the north end of the needle to the starboard side nearly disappears altogether; thus, May 29, after she has been for some time with her head northerly, the deviation to starboard is only half a degree. When the ship arrived in Liverpool, and while in graving-dock, with head W. 7° N., the attraction to the stern was 8°, or only half of what it was at first; but after being loaded, with her head a little to the east of north, it again increased to nearly its original quantity.

In the southern hemisphere the deviation from heeling appears small, and indication is afforded of an attraction of the needle to the low side; but when she turns her head to the northward, in the Atlantic Ocean, the deviation from heeling is towards the high side of the ship, and rapidly increases. Thus—

June 1. Head N. 22° 30′ W., heel 15° to port, the deviation is 2° 0′ E.
12. Head N. 22 30 W., heel 14 to port, the deviation is 6 30 E.
23. Head N. 33 45 W., heel 10 to port, the deviation is 13 45 E.
July 6. Head N. 25 30 W., heel 15 to port, the deviation is 22 30 E.

Again, on the 27th and 28th June, although the ship is not in a position to show much effect from heeling, her head on both days being N. 73° E., it will be seen that a change from 7° heel to port to 14° heel to starboard makes a difference in the deviation of 8° 45′.

It should be noted that, in this as in the preceding logs, the compass errors given in the originals include variation as well as deviation. In the printed record the variation, as indicated by Mr. Evans's chart, has been carefully applied, so as to show only the deviation due to the ship's magnetism.

W. W. RUNDELL.

"SLIEVE DONARD"—CAPTAIN THOMPSON.

Liverpool to Aden, first voyage.

Date.	Lat.	Long.	Dip.	Steering compass. Ship's head.	Steering compass. Total error.	Steering compass. Variation.	Steering compass. Deviation.	Ship's head, correct magnetic.	Gowland's compass. Ship's head.	Gowland's compass. Deviation.	Tell-tale compass. Ship's head.	Tell-tale compass. Deviation.	Mast compass. Ship's head.	Mast compass. Deviation.	Remarks, wind, &c.
1859.	*North* ° ′	*West.* ° ′	*North* ° ′	° ′	° ′	*West.* ° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
Mar. 31	39 55	13 46	....	S. 65 0 W.	....	23 35	....	....	S. 56 0 W.	....	S. 65 0 W.	....	S. 73 0 W.	....	Light and variable.
April 1	37 52	17 54	....	S. 65 0 W.	....	24 10	....	....	S. 53 0 W.	....	S. 62 0 W.	....	S. 73 0 W.	....	Wind S. W.; fresh.
2	36 12	18 49	....	S. 76 0 W.	24 30 W.	23 50	0 40 W.	S. 75 20 W.	S. 70 0 W.	5 20 E.	S. 70 0 W.	5 20 E.	S. 83 0 W.	7 40 W.	S. S. E., strong.
3	35 49	19 56	....	N. 77 0 W.	23 0	23 50	0 50 E.	N. 76 10 W.	N. 73 0 W.	3 10 W.	N. 79 0 W.	2 50	N. 62 0 W.	14 10	South, light.
4	35 13	23 12	....	N. 81 0 W.	....	24 10	....	....	S. 81 0 W.	....	S. 79 0 W.	....	N. 82 0 W.	....	S. W. gale.
6	32 45	23 0	....	S. 11 0 E.	21 30	23 10	1 40	S. 9 20 E.	S. 17 0 E.	7 40 E.	S. 11 15 E.	1 55 E.	South	9 20	S. S. W gale; latter part W. N. W.
7	32 6	22 46	....	S. 17 0 E.?	20 30	23 0	2 30	....	S. 70 0 E.	....	S. 67 0 E.	....	S. 64 0 E.	....	Light and calm.
8	31 40	23 26	....	S. 28 0 W.	19 30	22 35	3 5	S. 31 5 W.	S. 25 0 W.	6 5	S. 34 0 W.	2 55 W.	S. 45 0 W.	13 55	Light and calm, wind W.
9	30 41	24 9	....	S. 68 0 W.	19 30	22 0	2 30 E.	S. 70 30 W.	S. 62 0 W.	8 30	S. 65 0 W.	5 30 E.	S. 78 0 W.	7 30	Do.
10	27 48	24 4	....	S. 62 0 W.	....	21 0	....	....	S. 47 0 W.	....	S. 53 0 W.	....	S. 67 0 W.	....	E. S. E., strong.
11	24 17	25 13	....	S. 53 0 W.	....	20 0	....	....	S. 39 0 W.	....	S. 51 0 W.	....	S. 62 0 W.	....	East, strong.
12	20 44	26 29	....	S. 28 0 W.	19 0	18 10	0 50 W.	S. 27 10 W.	S. 22 0 W.	5 10	S. 25 0 W.	2 10	S. 39 0 W.	11 50	Do.
13	17 34	27 10	....	S. 45 0 W.	18 20	17 0	1 20 W.	S. 43 40 W.	S. 37 0 W.	6 40	S. 39 0 W.	4 40	S. 51 0 W.	7 20 W.	Do.
14	15 35	27 30	....	S. 47 0 W.	15 0	16 10	1 10 E.	S. 48 10 W.	S. 28 0 W.	20 10	S. 36 15 W.	11 55 E.	S. 36 30 W.	11 40 E.	East, light.
15	13 21	27 47	....	S. 5 30 E.	13 52	15 40	1 48	S. 3 42 E.	S. 6 0 E.	2 18	South	3 42 W.	S. 47 0W.?	....	N. E., light.
16	11 7	27 41	....	S. 9 0 W.	13 0	15 20	2 20	S. 11 20 W.	S. 6 0 W.	5 20	S. 5 30 W.	5 50 E.	S. 13 0 W.	1 40 W.	Do.
17	9 27	27 24	....	S. 5 30 E.	12 42	15 0	2 18	S. 3 12 E.	S. 9 0 E.	5 48	S. 5 30 E.	0 18	S. 5 30 W.	8 42	E. N. E., light.
19	5 53	27 10	34 0	S. 11 15 E.	12 0	14 45	2 45	S. 8 30 E.	S. 11 30 E.	3 0	S. 9 0 E.	0 30 E.	S. 2 45 W.	11 15	North, light.
21	3 17	26 40	30 0	S. 11 30 E.	10 56	14 45	3 49 E.	S. 7 41 E.	S. 11 15 E.	3 34 E.	S. 5 30 E.	2 11 W.	S. 4 45 W.	12 26	Do.
22	2 12	26 46	28 0	S. 14 0 W.	....	14 25	....	....	S. 5 30 W.	....	S. 11 15 W.	....	S. 14 0 W.	....	Light airs.
25	0 44	26 31	25 0	S. 22 0 W.	....	14 45	....	....	S. 17 0 W.	....	S. 14 0 W.	....	S. 25 0 W.	....	Do.
26	0 8	27 10	24 0	S. 42 0 W.	....	14 20	....	....	S. 37 0 W.	....	S. 39 0 W.	....	S. 47 0 W.	....	Calm.
	South.														
27	1 13	28 0	22 0	S. 36 0 W.	16 0	13 45	2 15 W.	S. 33 45 W.	S. 34 0 W.	0 15 W.	S. 39 0 W.	5 15 W.	S. 51 0 W.	17 15	Light airs.
28	2 49	28 7	21 0	S. 56 0 W.	18 45	13 35	5 10	S. 50 50 W.	S. 39 0 W.	11 50 E.	S. 45 0 W.	5 50 E.	S. 51 0 W.	0 10	S. E., light.
29	4 50	29 25	17 0	S. 33 30 W.	19 18	12 15	7 3	S. 26 27 W.	S. 22 0 W.	4 27	S. 28 0 W.	1 33 W.	S. 33 30 W.	6 3	S. S. E. to E., light.
30	5 30	30 15	16 0	S. 39 0 W.	19 35	11 50	7 45	S. 31 15 W.	S. 22 0 W.	9 15	S. 31 0 W.	0 15 E.	S. 37 0 W.	5 45	S. E., light.
May 1	7 8	31 10	15 0	West	19 58	11 15	8 43	S. 81 17 W.	S. 78 0 W.	3 17	S. 73 0 W.	8 17	S. 84 0 W.	2 43	Do.
2	9 22	32 36	10 0	S. 51 0 W.	20 0	10 15	9 45	S. 41 15 W.	S. 33 0 W.	8 15	S. 39 0 W.	2 15 E.	S. 45 0 W.	3 45	Do.
3	12 6	34 38	5 0	S. 39 0 W.	20 0	8 14	11 20	S. 27 40 W.	S. 22 0 W.	5 40	S. 28 0 W.	0 20 W.	S. 31 0 W.	3 20	S. S. E., strong.
4	14 57	36 23	0 0	S. 22 0 W.	14 0	7 0	7 0 W.	S. 15 0 W.	S. 7 30 W.	7 30	S. 14 0 W.	1 0 E.	S. 17 0 W.	2 0	S. by E., strong.
			South.												
5	16 8	37 0	1 0	S. 3 0 W.	4 30	6 40	2 10 E.	S. 5 10 W.	S. 5 30 E.	10 40	South	5 10	S. 5 30 W.	0 20	S. S. E., strong; latter part variable.
6	17 19	37 0	2 30	S. 22 0 W.	15 30	6 10	9 20 W.	S. 12 30 W.	S. 11 30 W.	1 0	S. 11 30 W.	1 0	S. 28 0 W.	15 30 W.	Light and variable.

7*	17 27	36 10	3 0	N. 82 0 W.	15 55 W?	6 20	....	N. 72 25 E.	S. 78 0 E.	....	S. 78 0 E.	....	S. 84 30 E.	....	Do.
					?15 55 E.		?22 15 E.	(S. 70 45 E.)		(7 15 E.)		(7 15 E.)		(13 45 E.)	
8	18 9	36 23	4 0	N. 79 0 E.	16 20	6 30	22 50	S. 78 10 E.	S. 79 0 E.	0 50 E.	S. 81 0 E.	2 50 E.	S. 78 0 E.	0 10 W.	Do.
9*	18 53	36 22	5 30	N. 48 0 E.	12 14	6 15	18 29	N. 66 20 E.	S. 28 0 E.	....	S. 28 0 E.	....	S. 28 0 E.	....	Do.
				?S. 48 0 E.				?S. 29 31 E.		(1 31 W.)		(1 31 W.)		(1 31 W.)	
10*	19 0	36 18	5 30	N. 45 0 E.	14 8 E.	6 15	20 23 E.	N. 65 23 E.	S. 28 0 E.	....	S. 25 0 E.	....	S. 25 0 E.	....	Light and variable, and calms.
				?S. 45 0 E.				?S. 24 37 E.		(3 23 E.)		(0 23 E.)		(0 23 E.)	
11	20 9	37 40	8 0	S. 62 0 W.	28 0 W.	5 0	23 0 W.	S. 39 0 W.	S. 39 0 W.	0 0	S. 45 0 W	6 0 W.	S. 45 0 W.	6 0 W.	Light and v'ble, and latter part S. by E., fresh.
12	22 34	37 30	12 0	S. 31 0 E.	3 5 E.	4 40	7 45 E.	S. 23 15 E.	S. 28 0 E.	4 45 E.	S. 28 0 E.	4 45 E.	S. 25 0 E.	1 45 E.	E. S. E., fresh.
14	27 43	33 21	21 30	S. 52 0 E.	21 0	5 50	26 50	S. 25 10 E.	S. 33 30 E.	8 20	S. 31 0 E.	5 50	S. 31 0 E.	5 50	Light and v'ble; latter part W. S. W., strong.
15	29 55	29 51	25 0	S. 61 0 E.	20 48	7 40	28 28	S. 32 32 E.	S. 42 0 E.	9 28	S. 39 0 E.	6 28	?S. 53 30 E.	20 58	West, strong.
16	31 31	26 57	27 0	S. 73 0 E.	20 0	9 10	29 10	S. 43 50 E.	S. 48 0 E.	4 10 E.	S. 48 0 E.	4 10	S. 67 30 E.	23 40	S. W., strong.
17*	31 34	23 44	27 30	S. 72 0 E.	18 24	11 20	29 44	S. 42 16 E.	S. 78 0 E.	....	S. 81 30 E.	....	S. 74 0 E.?	....	South, strong.
				?N. 72 0 E.				?S. 78 16 E.		(0 16 W.)		(3 14 E.)			
18	31 26	22 55	27 30	S. 73 0 E.	12 38	11 30	24 8	S. 48 52 E.	S. 51 0 E.	2 8 E.	S. 53 30 E.	4 38 E.	S. 78 0 E.?	29 8 E.	S. E., light airs and calm.
19	32 3	21 34	29 0	S. 78 0 E.	12 38	12 20	24 58	S. 53 2 E.	S. 53 0 E.	0 2 W.	S. 56 0 E.	2 58 E.	S. 12 0 E.	11 58 W.	N. E., light airs.
20*	33 17	18 21	31 30	S. 70 30 E.	20 23	13 50	34 13	S. 36 17 E.?	S. 70 0 E.	....	S. 67 30 E.	....	S. 67 0 E.	....	N. W.; light and latter part strong.
				?N. 70 30 E.				?S. 75 17 E.		(5 17 W.)		(7 47 W.)		(8 17 W.)	
21*	34 11	14 38	34 0	S. 79 0 E.	19 42	16 10	33 52	S. 45 8 E.	S. 67 30 E.	....	S. 64 30 E.	....	S. 64 30 E.	....	N. N. W.; light and latter part strong.
				?N. 79 0 E.				?S. 67 8 E.		(0 22 E.)		(2 38 W.)		(2 38 W.)	
22*	35 32	10 12	37 30	S. 79 0 E.	24 10	18 20	42 30	S. 36 30 E.	S. 59 0 E.	....	S. 59 0 E.	....	S. 56 30 E.	....	N. N. W.; light and latter part strong.
				?N. 79 0 E.				?S. 58 30 E.		(0 30 E.)		(0 30 E.)		(2 0 W.)	
23*	36 35	5 5	41 0	S. 87 30 E.	22 44	21 0	43 44	S. 43 46 E.	S. 47 30 E.	....	S. 51 0 E.	....	S. 53 30 E.	....	N. W.; light and latter part strong.
				?N. 87 30 E.				?S. 48 46 E.		(1 16 W.)		(2 14 E.)		(4 14 E.)	
24*	37 2	1 59	43 0	S. 82 0 E.	20 10	22 10	42 20	S. 39 40 E.	S. 57 0 E.	....	S. 52 30 E.	....	S. 52 30 E.	....	N. W.; light and latter part strong.
				?N. 82 0 E.				?S. 55 40 E.		(1 20 E.)		(3 10 E.)		(3 10 W.)	
		East.													
25*	36 57	1 45	46 0	S. 88 30 E.	18 21	24 15	42 36	S. 45 54 E.	S. 47 0 E.	....	S. 56 30 E.	....	S. 47 30 E.	....	Southerly, light, and passing squalls.
				?N. 88 30 E.				?S. 48 54 E.		(1 24 W.)		(7 36 E.)		(1 24 W.)	
26	37 58	6 3	49 0	S. 78 0 E.	15 55	26 0	41 55	S. 36 5 E.	S. 39 0 E.	2 55 E.	S. 51 0 E.	14 55	S. 39 0 E.	2 55 E.	N. W., strong; latter part S. W.
27	38 57	10 23	52 0	S. 73 0 E.	14 38	27 20	41 58	S. 31 2 E.	S. 42 0 E.	10 58	S. 39 0 E.	7 58	S. 28 30 E.	2 32 W.	S. S. W., strong.
28	39 40	15 6	54 0	N. 68 0 E.	23 52	28 50	52 42	S. 59 18 E.	S. 62 0 E.	2 42	S. 73 30 E.	14 12	S. 62 0 E.	2 42 E.	S. W., strong.
30	40 45	22 40	57 30	N. 37 0 E.	31 58	30 50	62 48	S. 80 12 E.	S. 87 0 E.	6 48 E.	N. 76 30 E.	22 18 E.	N. 82 0 E.	17 48 E.	S. W., strong gale.
June 1	41 9	26 10	58 30	N. 42 0 E.	32 16	31 30	63 46	S. 74 14 E.	?S. 62 0 E.	12 14 W.	S. 70 30 E.	3 44 W.	†	†	Hard gale: cross.
2	40 48	31 8	60 0	N. 36 30 E.	36 16	31 20	67 36	S. 75 54 E.	S. 76 30 E:	0 36 E.	S. 73 0 E.	2 54 W.	....	....	N. W., fresh.
6	35 36	34 45	58 30	N. 31 30 E.	22 56	29 0	51 56	N. 83 36 E.	N. 87 15 E.	3 39 W.	N. 65 0 E.	18 36 E.	....	....	W. N. W., moderate breeze.
7	34 2	36 34	58 0	N. 16 30 E.	6 32	27 50	34 22	N. 50 52 E.	N. 57 0 E.	5 8	N. 39 0 E.	11 52	....	....	North, moderate.
8	31 31	38 40	58 0	N. 33 0 E.	19 4	25 50	44 54	N. 77 54 E.	N. 82 0 E.	4 6 W.	N. 62 0 E.	15 54	....	....	West, moderate.
9	29 25	41 0	57 30	N. 11 15 E.	5 22	23 10	28 32	N. 39 47 E.	N. 39 0 E.	0 47 E.	N. 22 30 E.	17 17	....	....	S. W., squally.
10	28 11	41 12	57 0	N. 13 0 E.	3 2 E.	22 0	25 2 E.	N. 38 2 E.	N. 51 0 E.	12 58 W.	N. 28 0 E.	10 2	....	....	S. W.; latter part N. W.
11	26 6	40 50	56 0	N. 4 0 W.	22 34 W.	20 10	2 24 W.	N. 1 36 W.	N. 11 15 E.	12 51	N. 4 0 W.	2 24 E.	....	....	N. W.; latter part S. W.
12	23 5	40 13	53 30	N. 3 0 E.	15 26	19 20	3 54 E.	N. 6 54 E.	N. 22 30 E.	15 36	N. 7 0 E.	0 6 W.	....	....	South, fresh breeze.
13	20 43	40 35	51 30	N. 16 30 E.	3 6	17 50	14 44	N. 31 14 E.	N. 45 0 E.	13 46	N. 28 0 E.	3 14 E.	....	....	S. E., light.
14	17 48	41 28	49 0	N. 22 30 E.	3 36	15 30	11 54	N. 34 24 E.	N. 50 0 E.	15 36	N. 42 0 E.	7 36 W.	....	....	Do.
15	14 44	43 5	46 0	N. 20 0 E.	3 4	13 0	9 56 E.	N. 29 56 E.	N. 45 0 E.	15 4	N. 34 0 E.	4 4	....	....	S. W., fresh breeze.
16	12 7	43 42	43 0	N. 2 30 E.	12 42 W.	11 0	1 42 W.	N. 0 48 E.	N. 14 0 E.	13 12 W.	N. 5 30 E.	4 42 W.	....	....	S. E., fresh breeze.

* Supposed clerical errors in the copy of the log which was presented to the Compass Committee.

† Top and card blown off this compass.

"*Slieve Donard*"—*Liverpool to Aden*—Continued.

Date.	Lat.	Long.	Dip.	Steering compass. Ship's head.	Steering compass. Total error.	Steering compass. Variation.	Steering compass. Deviation.	Ship's head, correct magnetic.	Gowland's compass. Ship's head.	Gowland's compass. Deviation.	Tell-tale compass. Ship's head.	Tell-tale compass. Deviation.	Mast compass. Ship's head.	Mast compass. Deviation.	Remarks, wind, &c.
	South. ° ′	*East.* ° ′	*South.* ° ′	° ′	° ′	*West.* ° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
1859. June 17	9 5	44 24	39 0	N. 23 30 E.	5 16 W.	9 30	4 14 E.	N. 27 44 E.	N. 50 0 E.	22 16 W.	N. 39 0 E.	11 16 W.			S. E.; latter part squally, S. W.
18	6 22	44 48	32 30	N. 22 0 E.	7 0 E.	8 0	15 0	N. 35 0 E.	N. 48 0 E.	13 0	N. 34 0 E.	1 0 E.			S. E., squally.
20	1 5	47 25	25 0	N. 22 30 E.	4 0	5 30	9 30	N. 32 0 E.	N. 43 0 E.	11 0	N. 37 0 E.	5 0 W.			S. E., strong.
	North														
21	0 34	48 42	23 0	N. 11 15 E.	4 6	5 0	9 6	N. 20 21 E.	N. 28 0 E.	7 39	N. 20 30 E.	0 9			S. E.
22	2 30	49 39	20 0	N. 9 0 E.	4 36	4 30	9 6	N. 18 6 E.	N. 22 30 E.	4 24	N. 20 0 E.	1 54 W.			S. S. E.
23	4 20	51 25	15 0	N. 16 30 E.	7 56 E.	3 40	11 36 E.	N. 28 6 E.	N. 34 0 E.	5 54	N. 25 0 E.	8 6 E.			S. S. E.; latter part S. W.
24	6 24	52 11	12 30	N. 11 15 W.	7 28 W.	3 38	3 58 W.	N. 15 13 W.	N. 5 30 W.	9 43	N. 14 0 W.	1 13 W.			S. W., squally.
25	10 21	52 0	4 0	N. 11 15 W.	8 4	3 0	5 4	N. 16 19 W.	N. 5 45 W.	10 34	N. 13 0 W.	3 19			S. W., strong.
26	11 47	51 20	2 0	N. 26 0 W.	16 54	3 0	13 54	N. 39 54 W.	N. 26 0 W.	13 54 W.	N. 32 0 W.	7 54 W.			Do.
27	12 10	50 40	1 0	N. 52 0 W.	15 58	3 10	12 48	N. 64 48 W.	N. 65 0 W.	0 12 E.	N. 70 45 W.	5 57 E.			S. E. to N. E., light.
28	12 14	50 15													
July 1	11 47	48 23	2 0	N. 65 0 W.	17 24 W.	3 40	13 44 W.	N. 78 44 W.	N. 81 30 W.	2 46	N. 84 0 W.	5 16			Faint airs and calms.
2	12 27	46 53	1 6	N. 65 0 W.	17 20 W.	3 50	13 30 W.	N. 78 30 W.	N. 82 0 W.	3 30	N. 84 0 W.	5 30			Faint airs and calms; latter part S. W.
4	12 50	46 25		S. 43 0 E.	13 44 E.	4 0	17 44 E.	S. 25 16 E.	S. 30 0 E.	4 44 E.	S. 29 0 E.	3 44 E.			Variable from westw'd.

ADEN TO BOMBAY, FIRST VOYAGE.

Date.	Lat.	Long.	Dip.	Steering compass. Ship's head.	Steering compass. Total error.	Steering compass. Variation.	Steering compass. Deviation.	Ship's head, correct magnetic.	Gowland's compass. Ship's head.	Gowland's compass. Deviation.	Tell-tale compass. Ship's head.	Tell-tale compass. Deviation.	Mast compass. Ship's head.	Mast compass. Deviation.	Remarks, wind, &c.
			North												
Aug. 28	12 20	45 14		N. 85 0 E.	13 44 E.	4 15	17 59 E.	S. 77 1 E.	S. 72 30 E.	4 31 W.	S. 70 0 E.	7 1 W.			S. W., light airs.
29	12 40	47 49		N. 54 0 E.	14 18	3 40	17 58	N. 71 58 E.	N. 79 0 E.	7 2	N. 70 0 E.	1 58 E.			Do., and N. N. W.
30	12 58	49 36		N. 22 0 E.	11 24	3 20	14 44	N. 36 44 E.	N. 45 0 E.	8 16	N. 56 0 E.	19 16 W.			S. W., light.
31	13 46	51 25	1 0	N. 51 0 E.	19 56	2 45	22 41	N. 73 41 E.	N. 70 0 E.	5 19	N. 73 0 E.	0 41 E.			Do.
Sept. 1	15 8	55 20	5 0	N. 62 0 E.	18 6	2 0	20 6	N. 82 6 E.	S. 87 30 E.	10 24 W.	N. 84 30 E.	2 24 W.			S. W., strong breeze.
3	16 22	62 37	7 30	N. 38 0 E.	25 0	1 0	26 0	N. 64 0 E.	N. 51 0 E.	13 0 E.	N. 54 0 E.	10 0 E.			S. W., squally.
4	16 34	66 0	9 0	N. 34 0 E.	14 0	0 40	14 40	N. 48 40 E.	N. 56 0 E.	7 20 W.	N. 48 0 E.	0 40			Do.
5	17 19	68 45	12 0	N. 39 0 E.	19 18	0 15	19 33	N. 58 33 E.	N. 59 0 E.	0 27	N. 56 0 E.	2 33 E.			S. W.
						East.									
6	18 8	71 6	15 0	N. 37 0 E.	18 20 E.	0 15	18 5 E.	N. 55 5 E.	N. 59 0 E.	3 55 W.	N. 56 0 E.	0 55 W.			S. W.

BOMBAY TO LIVERPOOL, FIRST VOYAGE.

				Mast compass.									Steering compass.		
Dec. 13	16 13	70 3	10 0	S. 65 0 W.	2 42 W.	....	2 42 W.	S. 62 18 W.	S. 59 0 W.	3 18 E.	S. 59 0 W.	3 18 E.	S. 80 0 W.	17 42 W.	Northerly, light.
14	15 32	68 51	9 30	S. 62 0 W.	2 56	West. 0 20	2 36	S. 59 24 W.	S. 58 0 W.	1 24	S. 58 0 W.	1 24	S. 84 0 W.	24 36	N. N. W., light.
15	15 6	67 34	8 0	S. 63 0 W.	2 24	0 30	1 54	S. 61 6 W.	S. 59 0 W.	2 6 E.	S. 59 0 W.	2 6 E.	S. 82 0 W.	20 54	Do.; latter part N.
16	14 11	66 28	6 0	S. 64 30 W.	3 54	0 40	3 14	S. 61 16 W.	S. 61 45 W.	0 29 W.	S. 61 45 W.	0 29 W.	S. 78 0 W.	16 44	N.N.W.; latter part N.E.
17	13 1	64 34	3 0	S. 64 30 W.	3 34	1 0	2 34	S. 61 56 W.	S. 61 30 W.	0 26 E.	S. 61 30 W.	0 26 E.	S. 79 0 W.	17 4	N. E.
18	11 55	62 34	....	S. 69 0 W.	3 10	1 15	1 55	S. 67 5 W.	S. 67 30 W.	0 25 W.	S. 64 30 W.	2 34	S. 87 30 W.	20 25	E. N. E.
19	11 2	60 0	South. 4 0	S. 70 30 W.	3 36	1 40	1 56	S. 68 34 W.	S. 69 30 W.	0 56 W.	S. 68 30 W.	0 4	West.........	21 26	Do.
20	10 4	58 9	5 0	S. 70 30 W.	4 38	1 50	2 48	S. 68 42 W.	S. 67 30 W.	0 12 E.	S. 64 30 W.	3 12	S. 89 0 W.	21 18	Do.
21	9 18	56 7	6 0	S. 64 30 W.	3 25	2 20	1 05	S. 63 25 W.	S. 62 30 W.	0 55	S. 63 0 W.	0 25	S. 84 30 W.	21 5	Do.
22	8 27	54 35	8 30	S. 61 30 W.	3 54	2 40	1 14	S. 60 16 W.	S. 59 0 W.	1 16	S. 59 30 W.	0 46	S. 81 0 W.	20 44	N. E.; latter part E.
23	7 13	55 55	10 0	S. 62 0 W.	3 30	2 40	0 50	S. 61 10 W.	S. 62 0 W.	0 50 W.	S. 59 0 W.	2 10	S. 81 30 W.	20 20	East.
24	6 3	50 48	13 0	S. 64 30 W.	7 2	3 45	3 17	S. 61 13 W.	S. 60 0 W.	1 13 E.	S. 59 0 W.	2 13	S. 84 30 W.	23 17	N. E.
25	3 58	48 35	16 0	S. 62 0 W.	6 58	4 30	2 28	S. 59 32 W.	S. 59 0 W.	0 32	S. 59 30 W.	0 2	S. 84 30 W.	24 58	N. E.
26	0 58	45 54	23 0	S. 34 30 W.	8 20	5 40	2 40	S. 32 50 W.	S. 29 30 W.	3 20	S. 31 30 W.	1 20	S. 57 0 W.	24 10	East.
27	South 1 35	44 42	26 0	S. 25 30 W.	6 48	6 30	0 18	S. 25 12 W.	S. 23 30 W.	1 42	S. 25 0 W.	0 12 E.	S. 52 30 W.	26 18	East.
28	4 6	44 5	29 0	S. 28 30 W.	10 26	7 15	3 11	S. 25 19 W.	S. 19 30 W.	5 49	S. 25 30 W.	0 11 W.	S. 52 0 W.	26 41	East.
29	5 47	43 6	32 0	S. 32 30 W.	10 10	8 15	1 55	S. 30 35 W.	S. 22 0 W.	8 35	S. 25 30 W.	5 5 E.	S. 56 0 W.	25 25	N. E.
30	7 13	43 11	35 0	S. 31 30 W.	10 14	8 50	1 24	S. 30 6 W.	S. 22 0 W.	8 6	S. 25 30 W.	4 36	S. 59 0 W.	28 54	E. N. E.; latter part E.
31	8 44	42 32	37 30	S. 31 0 W.	13 22	10 0	3 22	S. 27 38 W.	S. 19 0 W.	8 34	S. 23 30 W.	4 8 E.	S. 58 0 W.	30 22	N. E.
1860. Jan. 1	11 26	42 5	41 0	S. 42 30 W.	14 44	10 50	3 54	S. 38 36 W.	S. 31 0 W.	7 36	S. 39 30 W.	0 54 W.	S. 84 0 W.	45 24	East.
2	13 26	41 7	Sun	obscure; c	ompasses	slug	gish......	....	....	....	....	....	....	....	Variable and squally.
3	15 50	41 30	46 30	S. 56 30 W.	16 28	14 0	2 28	S. 54 2 W.	S. 50 0 W.	4 2	S. 53 38 W.	0 32 E.	N. 75 0 W.	50 58	Do.
5	17 48	40 45	48 30	S. 56 0 W.	16 2	15 50	0 12	S. 55 48 W.	S. 37 0 W. ?S. 53 0 W.	?18 48 ? 2 48	S. 52 30 W.	3 18	N. 68 30 W.	56 42	West, squally. *
6	19 20	39 14	50 0	S. 61 30 W.	16 38	17 40	1 2 E.	S. 62 32 W.	S. 53 0 W.	9 32 E.	S. 59 30 W.	3 2 E.	N. 72 30 W.	44 58	S. W., strong breeze; latter part S. E.
7	21 54	37 17	51 30	S. 29 30 W.	21 20	20 0	1 20 W.	S. 28 10 W.	S. 36 0 W.	7 50 W.	S. 29 30 W.	1 20 W.	N. 83 30 W.	68 20	S. E., strong breeze.
8	24 0	36 30	53 0	S. 31 0 W.	27 30	22 0	5 30	S. 25 30 W.	S. 18 0 W.	7 30 E.	S. 38 0 W.	12 30	N. 89 0 W.	65 30	S. E., light.
9	25 36	35 14	54 0	S. 73 30 W	26 24	23 0	3 24	S. 70 6 W.	S. 68 30 W.	1 36 E.	S. 70 30 W.	0 24	N. 57 30 W.	52 24	Do.
12	28 18	33 32	55 0	S. 54 30 W.	32 48	25 15	6 33	S. 47 57 W.	S. 60 30 W.	12 33 W.	S. 59 30 W.	11 33	S. 64 0 W.	68 3	S. S. W., light.
13	29 38	31 55	55 0	S. 73 0 W.	33 20	26 30	6 50	S. 66 10 W.	S. 70 0 W.	3 50 W.	S. 67 30 W.	1 20	S. 56 30 W.	57 20	S. E., light.
14	31 0	30 57	56 0	S. 57 0 W.	31 6	27 30	3 36	S. 53 24 W.	S. 48 30 W.	4 54 E.	S. 56 30 W.	3 6	S. 59 30 W.	67 6	South, light.
15	33 53	28 37	....	Mast com	pass unshipped.	....	....	....	....	....	S. 5 30 E.	....	Compasses going round fro	m N.W. to S. E.	S. E., light.
16	34 27	29 9	57 0	N. 72 30 W.	33 24	29 30	3 54	N. 76 24 W.	N. 63 0 W.	13 24 W.	N. 75 30 W.	0 54 W.	N. 39 0 W.	37 24	W. S. W., light.
17	34 54	27 41	57 0	N. 78 30 W.	33 0	29 40	2 20	N. 81 50 W.	N. 72 0 W.	9 50	N. 85 0 W.	3 10 E.	N. 40 0 W.	41 50	Do.
18	35 18	25 25	56 0	N. 62 0 W.	34 30	30 0	4 30	N. 66 30 W.	N. 49 0 W.	17 30	N. 67 30 W.	1 0	N. 36 30 W.	30 0	S. E.; latter part S.W.
19	35 37	22 35	55 0	N. 56 30 W.	34 20	30 0	4 20	N. 60 50 W.	N. 43 30 W.	17 20	N. 62 0 W.	1 10 E.	N. 23 0 W.	37 50	S. W.; latter part S. E.
20	35 14	17 50	53 0	N. 34 0 W.	34 32 W.	29 30	5 2 W.	N. 39 2 W.	N. 23 30 W.	15 32 W.	N. 39 0 W.	0 2 W.	N. 22 30 W.	16 32 W.	S. E.; latter part west'ly.

* Faint airs and calms; thermometer 104°; compasses no use; steering by the land.

"*Slieve Donard*"—*Bombay to Liverpool, first voyage*—Continued.

Date.	Lat.	Long.	Dip.	Mast compass. Ship's head.	Mast compass. Total error.	Mast compass. Variation.	Mast compass. Deviation.	Ship's head, correct magnetic.	Gowland's compass. Ship's head.	Gowland's compass. Deviation.	Tell-tale compass. Ship's head.	Tell-tale compass. Deviation.	Steering compass. Ship's head.	Steering compass. Deviation.	Remarks, wind, &c.
	South. ° ′	East. ° ′	South. ° ′	° ′	° ′	West. ° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
1860. Jan. 21	34 12	15 32	52 0	N. 30 30 W.	32 56 W.	29 15	3 41 W.	N. 34 11 W.	N. 19 30 W.	14 41 W.	N. 36 30 W.	2 19 E.	N. 19 30 W.	14 41 W.	S. E.; latter part west'ly.
22	32 53	12 24	50 0	N. 35 0 W.	33 34	28 30	5 14	N. 40 14 W.	N. 33 0 W.	17 14	N. 42 30 W.	2 16 E.	N. 25 0 W.	15 14 W.	Westerly; fresh breeze.
23	31 44	10 36	47 30	N. 28 30 E.	24 32	28 0	6 32	N. 21 58 E.	N. 45 0 E.	23 2	N. 34 0 E.	12 2 W.	N. 11 15 E.	10 43 E.	West, light.
24	30 39	9 28	45 0	N. 28 30 W.	26 52	27 48	0 56	N. 27 30 W.	N. 7 0 W.	20 34	N. 28 0 W.	0 26 E.	N. 16 30 W.	11 4 W.	Variable, light.
25	29 33	7 49	43 0	N. 31 0 W.	27 52	27 30	0 12	N. 31 12 W.	N. 12 0 W.	19 12	N. 31 0 W.	0 12 W.	N. 19 30 W.	11 42	Do.
26	28 36	5 41	41 30	N. 11 30 W.	28 30	27 0	1 30 W.	N. 13 0 W.	N. 9 30 E.	22 30	N. 8 30 W.	4 30 W.	N. 7 0 W.	6 0	S. S. E., light.
27	27 56	5 15	41 0	N. 17 0 W.	26 50	27 0	0 10 E.	N. 16 50 W.	N. 3 30 E.	20 20	N. 17 0 W.	0 10 E.	N. 11 30 W.	5 20	South, light.
38	27 6	3 29	38 0	N. 31 30 W.	27 50	26 30	1 20 W.	N. 32 50 W.	N. 12 0 W.	20 50	N. 28 30 W.	4 20 W.	N. 12 30 W.	20 20	Do.
29	26 16	1 58	35 0	N. 26 0 W.	27 42	26 15	1 27	N. 27 27 W.	N. 7 30 W.	19 57	N. 23 30 W.	3 57	N. 17 30 W.	9 57	S. S. E.
30	24 40	0 28	32 30	N. 19 0 W.	28 54	25 50	3 4	N. 22 4 W.	N. 2 30 W.	19 34	N. 18 0 W.	4 4	N. 14 0 W.	8 4	Do.
		West.													
31	23 44	1 42	29 0	N. 17 30 W.	28 18	25 10	3 8	N. 20 38 W.	N. 1 0 E.	21 38	N. 16 0 W.	4 38	N. 11 15 W.	9 23	Do.
Feb. 1	22 26	3 37	26 30	N. 19 30 W.	27 34	24 30	3 4	N. 22 34 W.	N. 0 30 W.	22 4	N. 19 30 W.	3 4	N. 13 30 W.	9 4	Light breeze.
2	20 56	5 26	23 0	N. 23 0 W.	26 4	24 0	2 4	N. 25 4 W.	N. 3 30 W.	21 34	N. 23 0 W.	2 4	N. 14 0 W.	11 4	E. S. E., fresh breeze; steering compass sluggish.
3	19 19	7 48	20 0	N. 19 30 W.	26 32	23 30	3 2	N. 22 32 W.	N. 2 0 W.	20 30	N. 17 0 W.	5 32	N. 14 0 W.	8 32	E. S. E., light.
5	16 51	10 15	13 0	N. 13 45 W.	22 26	22 20	0 6	N. 13 51 W.	N. 3 0 W.	10 51	N. 11 15 W.	2 36	N. 10 30 W.	3 21	Do.
6	15 32	11 52	9 0	N. 25 30 W.	23 36	21 50	1 46	N. 27 16 W.	N. 10 0 W.	17 16	N. 24 30 W.	2 46	N. 19 0 W.	8 16	Do.
7	13 25	14 22	4 0	N. 23 0 W.	25 46	21 0	4 46 W.	N. 27 46 W.	N. 8 0 W.	19 46	N. 25 30 W.	2 16	N. 17 15 W.	10 30	Moderate breeze.
8	12 21	15 37	2 0	N. 17 30 W.	19 42	20 40	0 58 E.	N. 16 32 W.	North........	16 32	N. 19 30 W.	2 58	N. 11 15 W.	5 17	Do.
			North												
9	10 36	17 32	2 0	N. 17 0 W.	19 28	19 40	0 12 E.	N. 16 48 W.	N. 2 0 E.	18 48	N. 13 15 W.	3 33	N. 11 15 W.	5 33	Do.
10	8 10	19 2	6 0	N. 17 0 W.	19 2	18 45	0 17 W.	N. 17 17 W.	North........	17 17	N. 15 0 W.	2 17	N. 11 15 W.	2 2	Do.
11	7 8	19 57	9 0	N. 14 30 W.	18 6	18 0	0 6	N. 14 36 W.	N. 1 5 E.	15 36	N. 11 15 W.	3 21	N. 11 15 W.	3 21	S. E., light.
12	5 55	21 3	12 30	N. 20 0 W.	18 24	17 20	1 4	N. 21 4 W.	N. 5 30 W.	15 34	N. 28 30 W.	2 34	N. 16 0 W.	5 4	Do.
13	4 44	22 4	14 0	N. 22 30 W.	17 52	16 50	1 2	N. 23 32 W.	N. 6 15 W.	17 17	N. 22 30 W.	1 2	N. 17 0 W.	6 32	Do.
14	3 39	22 57	17 0	N. 17 0 W.	17 40	16 20	1 20	N. 18 20 W.	N. 3 0 W.	15 20	N. 15 0 W.	3 20	N. 13 30 W.	4 56	S. E., light; compasses sluggish.
15	2 34	24 15	19 0	N. 17 30 W.	18 32	15 45	2 47	N. 20 17 W.	N. 2 30 W.	17 47	N. 17 30 W.	2 47	N. 14 0 W.	6 17	Light airs and variable.
16	1 43	24 50	20 30	N. 17 0 W.	14 58	15 30	0 32	N. 16 28 W.	North........	16 28	N. 12 0 W.	2 28	N. 11 15 W.	5 13	Do.
	North														
18	0 13	25 9	24 0	N. 5 30 W.	5 30	15 20	9 50 E.	N. 4 20 E.	N. 9 0 E.	4 40	N. 2 0 W.	6 20 E.	N. 5 0 W.	9 20 E.	Faint airs and calms.
19	0 40	25 15	24 30	N. 25 30 W.	25 30	15 20	10 10 W.	N. 26 40 W.	N. 11 0 W.	15 40	N. 23 30 W.	3 10 W.	N. 19 30 W.	7 10 W.	Do.
21	0 40	25 46	24 30	N. 2 45 W.	15 57	15 15	0 42 W.	N. 3 27 W.	N. 11 15 E.	14 42	North........	3 27	N. 4 0 W.	0 33 E.	Faint airs and variable.
22	0 54	26 9	25 0	N. 11 15 W.	13 32	15 0	1 28 E.	N. 9 47 W.	N. 4 30 E.	14 17	N. 5 30 W.	5 17	N. 17 0 W.	7 13 E.	S. E., light.
23	1 58	26 46	27 0	N. 5 30 W.	13 38	14 45	1 7 E.	N. 4 23 W.	N. 11 15 E.	15 38	N. 3 0 W.	1 23	N. 3 30 W.	0 53 W.	S. E., light; latter part squally.

	25	4 20	29 4	32 0	N. 26 0 W.	13 50	13 30	0 20 W.	N. 26 20 W.	N. 11 0 W.	15 20	N. 25 30 W.	0 50	N. 19 30 W.	6 50 W.	N. E. and squally.
	26	5 45	31 15	35 0	N. 14 0 W.	13 34	12 20	1 14	N. 15 14 W.	N. 1 0 E.	16 14	N. 11 15 W.	3 59	N. 30 0 W.	44 46 E.	Do.
	27	7 46	32 40	37 30	N. 8 30 W	13 4	12 0	1 4	N. 9 34 W.	N. 7 0 E.	16 34	N. 5 45 W.	3 49 W.	N. 5 30 W.	4 4 W.	Moderate and cloudy.
	29	11 53	34 53	44 0	N. 8 30 W.	0 0	11 25	11 25 E.	N. 2 55 E.	N. 7 0 E.	4 5	N. 2 45 W.	5 40 E.	N 7 0 W.	9 55 E.	Do.
Mar.	1	14 7	36 30	46 30	N. 5 30 W.	7 50	11 15	3 25	N. 2 5 W.	N. 11 0 E.	13 5	N. 2 45 E.	4 50 W.	N. 2 45 W.	0 40 E.	Do.
	2	16 13	36 50	49 0	N. 5 45 W.	10 42	11 20	0 38 E.	N. 5 7 W.	N. 9 0 E.	14 7	N. 2 45 W.	2 22	N. 2 45 W.	2 22 W.	Do.
	3	17 42	38 6	52 0	N. 19 30 W.	13 42	11 30	2 12 W.	N. 21 42 W.	N. 7 30 W.	14 12	N. 19 30 W.	2 12	N. 16 45 W.	4 57	Moderate and clear.
	4	19 16	30 56	53 0	N. 11 15 W.	9 36	11 15	1 30 E.	N. 9 36 W.	N. 6 45 E.	16 21	N. 5 45 W.	3 51 W.	N. 8 30 W.	1 6 W.	Do.
	6	21 47	42 44	56 30	North........	5 40	11 30	5 50	N. 5 50 E.	N. 21 0 E.	15 10	N. 5 45 E.	0 5 E.	N. 2 0 E.	3 50 E.	Do.
	7	23 47	43 24	58 0	N. 8 30 E.	5 30	12 0	6 30	N. 15 0 E.	N. 28 0 E.	13 0	N. 17 30 E.	2 30 E.	N. 8 0 E.	7 0	Do.
	8	25 28	43 16	60 9	N. 45 0 E.	6 4	13 0	6 56	N. 51 56 E.	N. 63 0 E.	11 4	N. 53 30 E.	1 34 W.	N. 36 30 E.	15 26	E. N. E., light.
	9	27 4	43 10	61 0	N. 16 30 E.	4 42	13 48	8 58	N. 25 25 E.	N. 40 0 E.	14 35	N. 28 0 E.	2 35 W.	N. 17 15 E.	7 10	East, light.
	10	29 0	42 47	62 30	N. 42 30 E.	6 10	15 0	8 50	N. 51 56 E.	N. 44 0 E.	7 20 E.	N. 34 0 E.	17 20 E.	N. 23 0 E.	27 20	Do.
	11	30 56	42 6	64 30	N. 25 30 E.	7 28	17 30	10 2	N. 35 32 E.	N. 47 0 E.	11 26 W.	N. 36 30 E.	0 58 W.	N. 25 30 E.	13 2	East, fresh breeze.
	12	33 6	41 16	66 33	N. 42 0 E.	11 52	20 0	8 8	N. 50 8 E.	N. 61 30 E.	11 22	N. 50 30 E.	0 22 W.	N. 34 0 E.	16 8	Do.
	13	34 55	40 2	67 30	N. 28 30 E.	11 28	22 0	10 32	N. 39 2 E.	N. 50 0 E.	10 58	N. 39 0 E.	0 2 E.	N. 25 0 E.	14 2	Do.
	14	36 24	40 1	68 0	N. 46 0 E.	10 38	22 40	12 2	N. 58 2 E.	N. 68 30 E.	10 28	N. 59 0 E.	0 58 W.	N. 49 0 E.	9 2	Do.
	15	37 46	38 42	69 0	N. 75 0 E.	14 22	24 30	10 8	N. 85 8 E.	S. 88 0 E.	6 52	N. 84 30 E.	0 38 E.	N. 60 0 E.	25 8	Do.
	16	39 6	36 46	69 0	N. 87 0 E.	17 18	25 30	8 12	S. 85 48 E.	S. 80 0 E.	5 48	S. 87 30 E.	1 42 W.	N. 68 30 E.	25 42	S.E., with pass'g squalls.
	17	40 14	34 42	69 30	N. 81 0 E.	19 4	27 0	7 56	N. 88 56 E.	S. 86 0 E.	5 4	N. 87 15 E.	1 41 E.	N. 64 0 E.	24 56	S.E., light.
	18	40 42	34 39	70 0	N. 34 0 E.	18 4	27 20	9 16	N. 43 16 E.	N. 55 0 E.	11 44	N. 45 0 E.	1 44 W.	N. 25 30 E.	17 46	Faint airs and calms.
	19	41 39	34 2	70 15	N. 56 45 E.	17 50	28 0	12 10	N. 68 58 E.	N. 77 0 E.	8 5	N. 67 30 E.	1 25 E.	N. 47 0 E.	21 55	Do.
	20	42 30	33 41	70 30	N. 56 30 E.	18 34	29 0	10 26	N. 66 56 E.	N. 76 30 E.	9 34	N. 67 30 E.	0 34 W.	N. 45 0 E.	21 56	Do.
	21	43 16	33 9	71 0	N. 56 30 E.	18 25	30 0	11 35	N. 65 5 E.	N. 77 0 E.	8 55 W.	N. 67 30 E.	0 35 E.	N. 45 0 E.	23 5	Do.
	22	43 32	32 12	71 0	S. 87 30 E.	22 42	30 15	7 33	S. 79 57 E.	S. 80 30 E.	0 33 E.	S. 80 0 E.	0 3	N. 70 30 E.	29 33	Do.
	23	43 44	31 43	71 0	N. 84 30 E.	23 30	30 20	7 0	S. 88 30 E.	S. 83 0 E.	5 30 W.	East.........	1 30	N. 67 15 E.	24 15	Faint airs, and second part light breeze.
	24	43 48	29 3	70 30	S. 45 0 E.	21 54	30 0	8 6	S. 34 54 E.	S. 42 0 E.	7 6 E.	S. 42 30 E.	7 36	S. 60 0 E.	25 6	E. N. E, light.
	25	44 2	28 42	70 30	N. 39 15 E.	17 23	30 0	2 47	N. 42 2 E.	N. 56 0 E.	13 58 W.	N. 41 45 E.	0 17 W.	N. 27 45 E.	14 17	Faint airs and variable.
	26	44 4	28 41	70 30	N. 34 45 E.	20 4	30 0	9 56	N. 44 4 E.	N. 56 30 E.	11 49	N. 47 45 E.	3 4 W.	N. 29 0 E.	15 41	Do.
	28	45 12	25 34	70 30	S. 83 0 E.	25 34	30 30	4 56	S. 78 4 E.	S. 75 0 E.	3 4	S. 79 0 E.	0 56 E.	N. 77 0 E.	24 56	Westerly, light airs.
	29	46 14	22 53	70 30	N. 84 30 E.	21 44	30 30	8 46	S. 86 44 E.	S. 82 0 E.	4 44	East.........	3 16	N. 64 30 E.	28 46	S. W., fresh breeze.
	30	47 38	19 27	70 30	N. 79 0 E.	20 58	29 30	8 30	N. 87 30 E.	S. 85 0 E.	7 30	N. 87 30 E.	0 0	N. 64 30 E.	23 0	SW. and S. S. W., strong gales.
April	2	48 12	13 24	70 0	N. 61 30 E.	14 56	27 30	12 54	N. 74 4 E.	S. 85 0 E.	15 56	N. 72 30 E.	4 2	N. 70 30 E.	3 34	March 31 and April 1, terrific gales from the westward; barometer 28.6 inches.
	3	50 0	11 57	70 0	N. 36 30 E.	12 34	37 15	14 41	N. 51 11 E.	N. 66 30 E.	15 19	N. 50 30 E.	0 41	N. 47 30 E.	3 41	Variable and squally.
	4	50 18	12 31	70 30	N. 84 0 E.	14 0	27 40	13 40	S. 82 20 E.	S. 78 0 E.	4 20	S. 87 30 E.	5 10	S. 84 0 E.	1 40	Do., from eastward.
	5	50 33	11 44	70 15	N. 17 30 E.	24 49	27 15	2 26	N. 19 56 E.	N. 36 30 E.	16 34	N. 20 0 E.	0 4	N. 13 0 E.	6 56	Light, from eastward.
	6	50 46	11 46	70 30	N. 17 15 E.	14 38	27 30	12 52	N. 83 7 E.	S. 88 0 E.	8 53	N. 78 30 E.	4 37	N. 78 30 E.	4 37	Calm.
	7	51 22	10 16	70 30	N. 84 15 E.	11 30 W.	26 45	15 15 E.	S. 80 30 E.	S. 79 0 E.	1 30 W.	S. 87 30 E.	7 0 E.	S. 87 30 E.	7 0 E.	Moderate from westward.

In the following extract from the log of the second voyage of the "Slieve Donard," only the observations made while the ship's head was within about two points of East and West have been selected; the chief object being to show the effect of moving the steering compass nearer to the vertical iron bar, which was introduced to compensate the changing attraction aft:

LIVERPOOL TO CALCUTTA, SECOND VOYAGE.

Date.	Lat.	Long.	Heel: P, port; S, starboard.	Mast compass.				Ship's head, correct magnetic.	Gowland's compass.		Tell-tale compass.		Steering compass.		Remarks, wind, &c.
				Ship's head.	Total error.	Variation.	Deviation.		Ship's head.	Deviation.	Ship's head.	Deviation.	Ship's head.	Deviation.	
1860.	*North* ° ′	*West.* ° ′		° ′	° ′	*West.* ° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
June 16*	35 45	14 6	....	S. 79 0 W.	3 32	25 0	5 22 W.	S. 73 38 W.	S. 72 0 W.	1 38 E.	S. 67 30 W.	6 8 E.	S. 68 30 W.	5 8 E.	1st part strong breeze and cloudy; 2d part light breeze and fine.
July 27	*South.* 34 52	19 10	....	S. 64 30 E.	13 56	8 0	5 56	S. 70 26 E.	S. 65 0 E.	5 11 W.	S. 67 30 E.	3 26 W.	S. 70 0 E.	0 26 W.	1st part mod'te breeze, with heavy rain; 2d part moderate and fine.
29	35 27	12 59	....	S. 70 30 E.	13 56	12 30	1 26	S. 71 56 E.	S. 68 30 E.	3 26	S. 78 30 E.	6 34 E.	S. 70 30 E.	1 26	Fresh breeze and cl'dy.
30	35 59	7 33	....	S. 72 30 E.	17 56	15 0	2 56	S. 75 26 E.	S. 76 0 E.	0 26	S. 79 30 E.	3 4 E.	S. 70 30 E.	5 56	Increasing breeze and fine, with heavy S. W. swell.
Aug. 9	40 20	*East.* 30 38	....	S. 73 0 E.	*West.* 22 42	32 0	9 18 E.	S. 63 42 E.	S. 67 0 E.	3 18 E.	S. 84 30 E.	20 48 E.	S. 70 30 E.	7 18 E.	Moderate breeze and cloudy.
13	38 36	*West.* 48 16	....	S. 73 0 E.	22 52	27 0	4 8 E.	S. 73 0 E.	S. 72 0 E.	3 8 E.	N. 84 30 E.	27 22	S. 73 0 E.	4 30	Increasing breeze; latter part strong gale with a heavy sea.
15	38 7	58 22	....	S. 64 30 E.	26 20	25 0	1 20 W.	S. 85 20 E.	S. 64 30 E.	1 20 W.	S. 88 0 E.	18 40	S. 70 30 E.	12 40	Strong breeze, with a very heavy sea.
16	37 28	61 52	....	S. 81 0 E.	31 55	23 30	8 25 W.	S. 89 25 E.	N. 87 0 E.	7 25 W.	N. 72 30 E.	22 35	N. 84 30 E.	6 5	Strong breeze; latter part strong gale.
17	35 33	67 6	....	S. 89 0 E.	14 40	20 30	5 50 E.	S. 83 10 E.	S. 89 6 E.	5 50 E.	N. 70 30 E.	26 20	N. 87 0 E.	9 20	Increasing gale, heavy sea running.
	35 33	67 6	....	N. 88 0 E.	14 16	20 30	6 14	S. 85 46 E.	S. 89 0 E.	3 44	N. 70 30 E.	23 44	N. 86 30 E.	7 44	
18	35 7	68 51	....	S. 78 30 E.	13 56	19 30	5 34 E.	S. 72 56 E.	S. 77 0 E.	4 4 E.	N. 81 30 E.	25 34 E.	S. 79 0 E.	5 30	

HOMEWARD VOYAGE.

Date.	Lat.	Long.	Heel	Mast: Ship's head.	Total error.	Variation.	Deviation.	Correct magnetic.	Gowland's: Ship's head.	Deviation.	Tell-tale: Ship's head.	Deviation.	Steering: Ship's head.	Deviation.	Remarks, wind, &c.
Nov. 10	3 36	88 23	2 S.	S. 79 0 W.	1 0	....	1 0 W.	S. 78 0 W.	S. 83 0 W.	5 0 W.	S. 79 0 W.	1 0 W.	S. 75 30 W.	2 30	S. E., light airs and cloudy.
			2 S.	S. 79 0 W.	1 26	....	1 26	S. 77 34 W.	S. 83 0 W.	5 26	S. 79 0 W.	1 26	S. 75 30 W.	2 4	
23	22 40	64 0	....	S. 75 30 W.	13 32	11 0	2 32	S. 74 58 W.	S. 81 0 W.	8 2	S. 79 0 W.	6 2	S. 69 0 W.	4 2	S. E., light winds with heavy head sea.
				S. 77 30 W.	12 16	....	1 16	S. 74 14 W.	S. 84 0 W.	7 40	S. 81 0 W.	4 16	S. 74 0 W.	2 44	

24	22 50	62 19	....	N. 87 30 W.	13 4	13 0	0 4	N. 87 26 W.	N. 80 0 W.	7 34	N. 83 30 W.	4 4	N. 90 0 W.	3 26	E. S. E., light winds; clear weather.
				N. 87 0 W.	13 52	....	0 52 W.	N. 86 8 W.	N. 81 30 W.	5 52	N. 86 0 W.	3 52	S. 88 0 W.	4 38	
25	23 22	60 43	3 S.	N. 76 30 W.	12 40	14 0	1 20 E.	N. 75 10 W.	N. 72 0 W.	6 10	N. 75 30 W.	0 10 W.	S. 81 0 W.	5 21	Easterly, light airs and clear weather.
				N. 76 30 W.	12 14	....	1 46 E.	N. 74 44 W.	N. 72 30 W.	2 14	N. 76 30 W.	0 46 E.	N. 80 0 W.	5 16	
27	23 58	57 57	....	N. 78 30 W.	18 22	17 0	1 22 W.	N. 79 52 W.	N. 74 30 W.	4 22	N. 78 30 W.	1 22 W.	N. 82 30 W.	4 38	Easterly, light breeze and fine.
				N. 78 12 W.	18 12	17 0	1 12	N. 77 0 W.	N. 72 30 W.	4 12	N. 77 0 W.	1 12	N. 81 30 W.	4 48	
28	24 17	55 38	....	N. 87 0 W.	23 28	18 0	5 28	N. 92 28 W.	N. 87 0 W.	5 28	N. 88 0 W.	4 28	S. 84 0 W.	4 32	East, light breeze and fine.
				N. 90 0 W.	23 30	....	5 30	N. 95 30 W.	N. 90 0 W.	5 30	S. 89 0 W.	5 0	S. 81 0 W.	3 30	
29	25 12	53 39	....	N. 89 0 W.	19 32	18 30	1 2	S. 89 58 W.	N. 84 30 W.	5 32	N. 88 0 W.	1 32	S. 86 30 W.	3 58	Light and variable between N. and E.
				N. 90 0 W.	20 38	....	2 8	S. 87 52 W.	N. 85 0 W.	7 8	N. 89 0 W.	3 8	S. 85 0 W.	2 52	
30	25 38	52 0	2 P.	N. 78 30 W.	21 20	18 45	2 35	N. 81 5 W.	N. 75 0 W.	6 5	N. 78 30 W.	2 35	N. 84 30 W.	1 55	Faint airs and variable from N. E. to N.
				N. 84 0 W.	19 48	....	1 3 W.	N. 85 3 W.	N. 76 0 W.	9 3	N. 81 30 W.	3 33	N. 88 0 W.	2 57	
Dec. 1	26 40	50 39	....	N. 83 30 W.	21 14	21 0	0 14	N. 83 44 W.	N. 78 0 W.	5 44	N. 82 30 W.	1 14	N. 90 0 W.	5 46	N. Easterly, light airs and fine; latter part moderate breeze.
				N. 83 0 W.	21 8	....	0 8	N. 83 8 W.	N. 78 30 W.	4 38	N. 81 30 W.	1 38	N. 88 30 W.	5 22	
2	27 53	47 22	4 P.	S. 88 30 W.	22 40	21 30	1 10	S. 87 20 W.	S. 83 0 W.	5 40	S. 80 0 W.	2 40	S. 73 0 W.	4 20	Steady breeze and clear; latter part varriable and squally.
3	28 2	44 21	3 P.	S. 84 0 W.	23 48	22 0	1 48	N. 84 48 W.	N. 80 0 W.	5 48	N. 80 30 W.	5 18	N. 87 0 W.	1 12	S. W.. moderate breeze and cloudy.
				S. 84 30 W.	24 38	....	2 38	N. 87 8 W.	N. 80 30 W.	7 8	N. 83 30 W.	3 38	N. 90 0 W.	2 22	
4	28 11	40 58	10 S.	West.........	27 14	23 0	4 14	S. 85 46 W.	N. 85 30 W.	7 44	N. 88 0 W.	6 44	N. 84 0 W.	1 46	S. W.. moderate breeze and squally.
				West.........	27 20	....	4 20	S. 85 40 W.	N. 87 0 W.	9 20	N. 88 0 W.	8 0	N. 83 0 W.	1 0	
5	29 10	38 30	....	N. 87 0 W.	27 50	24 0	3 50	S. 89 10 W.	N. 82 0 W.	8 50	N. 85 0 W.	6 5	N. 88 0 W.	1 10	Light airs, variable between S. and E., with clouds passing; squalls with rain.
				N. 86 30 W.	26 10	....	2 10 W.	N. 88 40 W.	N. 80 30 W.	8 40	N. 82 30 W.	6 10	N. 90 0 W.	1 20	
8	33 7	29 59	2 P.	S. 88 0 W.	29 56	31 0	1 4 E.	S. 89 41 W.	N. 88 30 W.	2 36	N. 82 30 W.	8 26	S. 83 30 W.	5 34	1st part squally with rain; 2nd part. light airs and variable.
				N. 87 0 W.	32 42	....	1 42 W.	N. 88 42 W.	N. 85 0 W.	3 42	N. 78 30 W.	10 12	S. 89 0 W.	2 18	
10	34 10	26 32	....	N. 62 30 W.	28 32	30 0	1 28 E.	....	....	....	....	....	....	....	
11	34 46	24 41	....	N. 73 30 W.	27 30	30 0	2 30	N. 71 0 W.	N. 67 30 W.	3 0	N. 62 0 W.	8 30	N. 71 30 W.	1 0 *	Light airs and variable.
				N. 72 0 W.	29 30	....	0 30 E.	N. 71 30 W.	N. 67 30 W.	4 30	N. 62 0 W.	10 0	N. 73 30 W.	1 0 E.	
1861.	*North*	*West.*													
Jan. 12	5 8	27 56	7 P.	N. 73 0 W.	16 0	12 30	3 30 W.	N. 76 30 W.	N. 70 0 W.	4 30	N. 75 0 W.	2 0	N. 76 0 W.	1 0 W.	Northerly, light winds and clear weather.
13	5 24	30 14	6 P.	N. 75 6 W.	15 58	11 20	4 38 W.	N. 79 38 W.	N. 74 0 W.	5 38	N. 73 0 W.	6 38 W.	N. 74 0 W.	5 38 W.	Do. wind and weather.
27	28 31	32 46	3 S.	N. 81 30 E.	14 30	19 30	5 0 E.	N. 86 30 E.	N. 88 30 E.	2 0 W.	N. 84 0 E.	2 30 E.	N. 82 0 E.	4 30 E.	Heavy gusts of wind split and carried away sails.
Feb. 10	43 40	16 0	9 S.	East.	17 42	27 0	9 18	S. 80 42 E.	S. 87 30 E.	6 48 E.	East..........	9 18	S. 86 0 E.	East......	Strong breeze and squally with rain.
15	51 11	11 2	....	N. 70 30 E.	14 5	28 0	13 4	N. 83 34 E.	N. 83 30 E.	0 4 W.	N. 76 0 E.	7 34	N. 82 0 E.	1 34	
				N. 79 0 E.	15 30	....	12 30 E.	N. 91 30 E.	N. 88 0 E.	3 30 W.	N. 84 30 E.	7 0 E.	East..........	1 30 E.	

* In reference to several apparent discrepancies in the deviations in the above extract, Captain Thompson stated that frequently separate azimuths were taken for each compass instead of simultaneous readings; and thus ship's head correct magnetic by mast compass is not always comparable with ship's head as shown by the other compasses.

W. W. R.

APPENDIX N.

STEAMER "GREAT EASTERN."

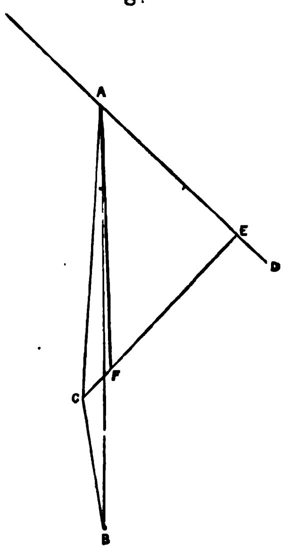
The magnetic experiments on board the "Great Eastern" were commenced in July, 1857. At this time the decks were not completed, so that there was little choice of position for the compass except near to the bulkheads. The stations selected for experiments were generally as nearly as possible over a bulkhead. The observations which are tabulated below, with the results of subsequent experiments, show the great difference which two or three feet before or two or three feet abaft a bulkhead will make in the deviations of the compass. In November of the same year some additional observations were made at stations nearer to the stern, in positions which were inaccessible in July. All the observations indicate a strong attraction of the north end of the needle towards the starboard side, and, with one exception, which is easily explained, towards the bow of the ship, these being the directions which would be indicated by the ship's position while building, which was S. 29° 50′ E.

Some further experiments were made in September, 1859, a few days before the ship left the Thames for Portland, when her head was S. 46° 20′ E, correct magnetic. It will be observed that these experiments show an increased attraction to the starboard side, and a decrease in the attraction towards the bow; both are probably due to her change of position. On each occasion observations were also made to test the ship's vertical magnetism. These, like the external experiments made almost simultaneously by Mr. Evans, showed a strong north polar attraction in the fore part of the ship, and the contrary attraction near the stern. Very near the stern the magnetism was sufficient to upset the induction due to nearly sixty feet of vertical iron, and to deflect upwards the north end of the dipping-needle with a force exceeding that of the Earth's horizontal magnetism at the station.

The vertical force experiments, which were made near the middle of the ship when she lay off Deptford, showed much less vertical magnetism than the previous experiments, which were made before the iron masts and funnels were fixed. Several experiments made on board large iron steamers at Liverpool by Mr. Towson and the writer exhibited similar results. The dipping needle in situations near a funnel in every case showed a considerable minus dip.

The experiments on the 5th of September were made in conjunction with Mr. Evans, with a view to the selection of the best position for the standard compass, so far as that could be ascertained by a single observation with a ship in a fixed position. The following diagram will illustrate the mode in which these observations were discussed, as well as how the details in the following table were obtained.

Fig. 11.



Taking station F as an example, ship's head by compass is N. 143° E., ship's head correct magnetic at the time being N. 133° 40′ E., thus showing a deviation of 9° 20′ W. The needle, which on shore vibrated about 21 times per minute, here vibrated at the rate of 11.5 times per minute. As the forces causing the vibrations will be in proportion to the squares of the numbers observed in equal times, the forces are as 132.25 to 441, or taking the latter as unity, the force observed on board, as measured in the direction of the needle when at rest, will be equal to 0.3 of the Earth's horizontal magnetic force at Deptford. Draw the line AB to represent in direction and amount the Earth's horizontal magnetism, or unity; from B draw the line BC to represent in the same way the force observed on board, making the angle ABC equal to the deviation; join AC, and the line AC will represent in amount and direction the magnetic force due to the ship alone. Through A draw the line AD, making the angle DAB equal 46° 20′, to indicate the direction of the ship's keel, D being towards the bow, then DAC will represent the starboard angle of the observed magnetism of the ship, and resolving this force into the direction of and at right angles to the line of the keel, we obtain AE for the ship's magnetism towards the bow, and EC for the ship's force to starboard. Speaking approximately, AE may be taken as co-efficient B=0.450=26° 45′, and the line EC=0.546 will represent coefficient C plus that part of the transverse induced magnetism which produces quadrantal deviation, the amount of which must be now roughly estimated. The discussion of a great number of deviation tables proves that the average quadrantal deviation in large iron ships for compasses at about the same distance as this from the deck will be very near 4°, which represents a capacity for horizontal induction equal $\frac{\text{sine } 4°}{\text{sine } 45°}=0.1$ of Earth's horizontal force; but as quadrantal deviation of more than twice this amount has been known to occur, a capacity equal to 0.15 may fairly be taken for this large ship. Considerations which affect an estimate of this kind will be discussed further on in the account of these experiments. Multiplying 0.15 by sine azimuth of ship's head, (or cosine of the angle which the transverse iron makes with the magnetic meridian,) 0.108 is obtained as approximate part of the ship's transverse magnetism due to horizontal induction, leaving 0.438=25° 59′ for approximate value of co-efficient C; it being evident from the position of the ship that the inductive magnetism of the ship is in the same direction as the transverse polar magnetism, and conspires with it to make up the observed force of 0.546. In the figure, CF being made equal 0.108, FE the remainder of CE will represent ship's starboard polar force; and A F will represent in amount and direction the ship's total polar force at this station, or 0.630, equal to a maximum polar deviation of 39° 3′ at a starboard angle DAF, equal to 44° 5′.

There is thus obtained, with very little trouble, and in less time than is taken to describe it, the approximate deviations belonging to the selected position, and a means of comparing this position with any others, so as to choose that which appears best for the compass.

The whole of the details given in the following tables for ship's horizontal, vertical, and total force were obtained in this manner by construction.

On September the 7th, when the ship commenced to steam down the Thames, it became evident that it would be useless to attempt to carry out any pre-arranged sets of experiments, and that only by mutual co-operation could any satisfactory observations be made. It was therefore agreed that primary attention should be given to the station selected for the Admiralty standard compass; that Mr. Evans should undertake to read ship's head by compass, and that the writer should simultaneously obtain ship's head correct magnetic by means of azimuth tables which he had previously arranged, and which were used in conjunction with the dumb-card or pelorus invented by Lieut. Friend, the observations at any other stations being left for such opportunities as might occur. Fortunately the sun shone out at frequent intervals, and a satisfactory number of observations were obtained between Deptford and Purfleet, when the ship anchored for the night. At Purfleet several observations were made with the vibration and dipping-needle compass, and on the following day a very complete set of observations was obtained by means of this compass near the foremost bridge, as the ship steamed down the river, and rounded to at the Nore. Here the sky became overcast, but the appearance of the sun for a few minutes gave the opportunity for ascertaining the bearings of two or three distant objects on shore, which were found very valuable for making some further observations for deviation, and also for completing the adjustment of the compensated compasses. In the same manner were obtained the correct bearings of a distant headland at Portland, and of the Rivel mountains in Carnarvonshire, when the ship was at Holyhead, as a means of ascertaining the deviations at these places.

For the deviations observed at Southampton in 1860, and at Milford in the present year, the committee is indebted entirely to Mr. Evans.

As the general result of the experiments made on board the "Great Eastern" is given in the body of the report, and most of the details will be found in the tables which are appended to this paper, it will only be necessary here to call attention to one circumstance, which had not been observed when the report was written, and which illustrates in a remarkable manner the effect on the compass of keeping an iron ship for a long time in the same position. The observations made by Mr. Evans at Milford, after the ship had been lying for more than six months on the gridiron with her head about W.N.W., or not far from the opposite direction to that in which she lay at Deptford, show that the ship's magnetism at the foremost bridge station was completely subverted, having changed from an attraction of 17° 47′ to starboard to more than 3° to port. This is equal to 0.3577, or more than one-third of the Earth's horizontal force at these places.

The position of each compass is described in the following table, and is also shown in Plate 49. This plate also shows graphically the relative amount and direction of the ship's horizontal and vertical magnetic force.

It is worthy of remark, that while the attraction towards the head at station C, at Holyhead, was only 5° 40′, at Liverpool, in June, 1861, at a position about seven feet above this station, the headward attraction is so much as 15° 35′; another example that in ships built with head to the southward the attraction to the bow becomes more evident as the compass is raised from the deck, at the after part of the ship.

Horizontal and vertical magnetic force experiments made on board the "Great Eastern."

[The details are obtained by construction only.]

Index to station, &c.	Position of the compass. (See also Plate 49.) Height of needle above the deck, 4 feet 6¼ inches.	Ship's head, correct magnetic.	Ship's head by compass.	Deviation.	Horizontal vibrations per minute, the vibrations on shore being 21 per minute.	Vibrations.*	Force in direction of needle in terms of Earth's horizontal force.	Ship's force.	Direction of ship's force.	Starboard angle of observed ship's force.	Ship's force to head. In terms of Earth's horizontal force.	Ship's force to head. Or B =
	Blackwall, July 2 and 6, 1857.	° ′	° ′	° ′					° ′	° ′		° ′
1	Station, 33 feet 6 inches from the inside of the stem.	N. 150 10 E.	N. 155 0 E.	4 50 W.	14.	196.	.444	.558	N. 183 50 E.	33 40	.465	27 43
2	Station, immediately over the second large bulkhead from the stem.	....	N. 166 0 E.	15 50	12.	144.	.326	.690	N. 187 10 E.	37 0	.549	33 18
3	Station, 4 feet before the third large bulkhead from the stem; the bulkhead rises about 2 feet 3 inches above the deck, forming the combing of a very large hatchway.	....	N. 177 0 E.	26 50 W.	23.2	538.24	1.220	.551	N. 278 50 E.	128 40	—.347	—20 18
4	Station. 1 foot before a bulkhead, and nearly abreast the fore part of the paddle-box.	....	N. 44 30 E.	105 40 E.	7.2	51.84	.117	1.034	N. 175 50 E.	23 40	.949	71 38
5	Station, 2 feet before a bulkhead, and nearly abreast the after part of the paddle-box.	....	N. 170 15 E.	20 5 W.	16.3	265.69	.602	.482	N. 181 0 E.	60 40	.274	15 54
6	Station, about 9 inches before the seventh large bulkhead from the stem, between two large hatchways, the after one open, the fore one with beams across at 2 feet 3 inches above the deck.	....	N. 116 45 E.	33 25 E.	7.9	62.41	.142	.886	N. 174 50 E.	24 40	.805	53 31
7	Station, 4 feet abaft the next bulkhead to station 6.	....	N. 29 15 E.	120 55 E.	10.2	104.04	.236	1.144	N. 169 15 E.	19 35	1.077	....
8	Station, immediately over the last large bulkhead aft.	....	N. 150 15 E.	0 5 W.	10.8	116.64	.264	.736	N. 180 3 E.	29 53	.661	41 23
	Blackwall, November 2 and 5, 1857.											
a	Station, on middle of hatchway between the first and second large bulkheads.	....	N. 176 30 E.	26 20	14.48	209.67	.475	.599	N. 199 40 E.	49 30	.388	22 50
b	Station, 2 feet from fore edge of plating over the aftermost large bulkhead.	....	N. 173 15 E.	23 5	16.08	258.57	.586	.515	N. 206 30 E.	56 20	.286	16 37

c	Station, immediately over the aftermost bulkhead.		N. 168 0 E.	17 50 W.	10.66	107.65	.254	.761	N. 185 45 E.	35 35	.611	37 40
d	Station, 2 feet from aft edge of plating over the aftermost large bulkhead.		N. 128 10 E.	22 0 E.	5.46	29.81	.068	.940	N. 178 20 E.	28 10	.823	55 23
e	Station, on planking 12 feet abaft the station d.		N. 177 45 E.	27 35 W.	12.	144.	.327	.728	N. 206 20 E.	56 10	.542	32 49
f	Station, 12 feet abaft station e		N. 173 30 E.	23 20	13.67	186.87	.424	.628	N. 195 10 E.	45 0	.443	26 18
g	Station, in the centre of the space between stations f and h.		N. 160 30 E.	10 20	12.34	152.28	.845	.660	N. 185 45 E.	35 35	.536	32 25
h	Station, between two hatchways, about 21 feet from front of rudder head.		N. 154 0 E.	3 50	13.95	194.60	.441	.561	N. 182 50 E	32 40	.471	28 6
i	Station, 10 feet 6 inches from front of rudder head.		N. 161 30 E.	11 20 W.	13.68	187.14	.424	.590	N. 188 0 E.	37 50	.467	27 50
	Off Deptford, September 5, 1859. (Height of needle, 4 feet 9¾ inches.)											
A	Station, midway between the two foremost funnels, 4 feet 9¾ inches above the platform.	N. 133 40 E.	N. 131 30 E.	2 10 E.	11.15	124.32	.282	.715	N. 179 5 E.	45 25	.504	30 16
B (1)	Station, on house in front of bridge (Needle about 13 feet above the deck.)		N. 152 45 E.	19 5 W.	15.	255.	.510	.541	N. 198 10 E.	64 30	.233	13 28
C	Station, 5 feet from after end of raised platform between the after main and the mizzenmast, and 4 feet 9¾ inches above the platform, which is 2 feet 3 inches from the deck.		N. 157 40 E.	24 0	14.43	208.22	.472	.598	N. 199 0 E.	65 20	.249	14 25
D	Station, 3 feet aft of hatch, and immediately before the mizzenmast.		N. 151 0 E.	17 20 W.	12.36	152.77	.346	.678	N. 188 55 E.	55 15	.384	22 35
E	Station, 6 feet 6 inches aft the hatchway, immediately abaft the mizzenmast.		N. 132 0 E.	1 40 E.	10.85	117.72	.267	.733	N. 179 15 E.	45 35	.518	31 12
F	Station of Mr. Gray's standard compass, 58 feet forward from rudder head.		N. 143 0 E.	9 20 W.	11.5	132.25	.300	.710	N. 184 10 E.	50 30	.450	26 45
G	Station of Admiralty standard compass, 41 feet forward from rudder head.		N. 145 20 E.	11 40	12.55	157.49	.357	.655	N. 186 20 E.	52 40	.405	23 53
H	Station of compass in front of the port side of steering wheel, about 6 feet above the deck.		N. 149 15 E.	15 35	13.33	173.33	.393	.630	N. 189 50 E.	56 10	.350	20 30
I	Station of compass in front of the starboard side of the steering wheel, about 6 feet above the deck.		N. 149 45 E.	16 5	12.4	153.76	.349	.674	N. 188 30 E.	54 50	.395	23 16
	Purfleet, September 7, 1859.											
H	Station of port steering compass	N. 45 30 W. N. 56 0 W. (about.)	N. 44 30 W. N. 54 0 W.	1 0	22.02	484.84	1.099	.101	N. 349 0 E.	34 30	.082	4 42
I	Station of starboard steering compass	N. 67 30 W. N. 48 30 W. (about.)	N. 60 30 W. N. 43 30 W.	6 0 W.	22.43	503.10	1.141	.183	N. 316 35 E.	24 5	.166	9 33

Horizontal and vertical magnetic force experiments made on board the "Great Eastern"—Continued.

[The details are obtained by construction only.]

Index to station, &c.	Position of the compass. (See also Plate 49.) Height of needle above the deck, 4 feet 6¼ inches.	Ship's head, correct magnetic.	Ship's head by compass.	Deviation.	Ship's force to starboard. As observed.	Ship's force to starboard. Correct'n for + D.	Ship's force to starboard. As corrected for + D.	C=	Ship's total polar force.	Maximum polar deviation.	Starboard angle of ship's polar force.	Vertical vibrations.	Vertical vibration.²	Vertical force in terms of Earth's horizontal force.	Ship's vertical force.	Ship's total magnetic force.	At angle from the vertical.
	Blackwall, July 2 and 6, 1857.	° ′	° ′	° ′				° ′		° ′	° ′						° ′
1	Station, 33 feet 6 inches from the inside of the stem.	N. 150 10 E.	N. 155 0 E.	4 50 W.	.308	—.075	.233	13 29	.520	31 20	26 15	....	....	....	....	....	....
2	Station, immediately over the second large bulkhead from the stem.	....	N. 166 0 E.	15 50	.415	....	.340	19 53	.647	40 19	31 50	48.	2304	5.224	2.706	2.775	13 20
3	Station, 4 feet before the third large bulkhead from the stem; the bulkhead rises about 2 feet 3 inches above the deck, forming the combing of a very large hatchway.	....	N. 177 0 E.	26 50 W.	.429	....	.354	20 44	.498	29 52	133 50	48.	2304	5.224	2.706	2.748	10 20
4	Station, 1 foot before a bulkhead, and nearly abreast the fore part of the paddle-box.	....	N. 44 30 E.	105 40 E.	.412	....	.337	19 42	1.007	*	19 40	39.8	1584.04	3.592	1.074	1.467	43 15
5	Station, 2 feet before a bulkhead, and nearly abreast the after part of the paddle-box.	....	N. 170 15 E.	20 5 W.	.395	....	.320	18 42	.419	24 46	54 35	38.6	1489.96	3.378	.860	.954	26 15
6	Station, about 9 inches before the seventh large bulkhead from the stem, between two large hatchways, the after one open, the fore one with beams across at 2 feet 4 inches above the deck.	....	N. 116 45 E.	33 25 E.	.365	....	.290	16 52	.855	58 46	20 0	41.2	1697.44	3.849	1.331	1.578	33 0
7	Station, 4 feet abaft the next bulkhead to station 6.	....	N. 29 15 E.	120 55 E.	.380	....	.305	17 46	1.120	†	15 50	35.6	1267.36	2.869	.351	1.172	72 30
8	Station, immediately over the last large bulkhead aft.	....	N. 150 15 E.	0 5 W.	.376	....	.301	17 31	.729	46 48	24 40	29.33	860.25	1.951	— .567	.923	—52 0
	Blackwall, November 2 and 5, 1857.																
a	Station on middle of hatchway, between the first and second large bulkheads.	....	N. 176 30 E.	26 20	.465	....	.390	22 58	.551	33 26	49 30	40.	1600.	3.628	1.090	1.222	27 5
b	Station, 2 ft. from fore edge of plating over the aftermost large bulkhead.	....	N. 173 15 E.	23 5	.426	....	.351	20 33	.454	27 0	51 10	35.15	1235.52	2.8016	.263	.525	60 30
c	Station, immediately over the aftermost bulkhead.	....	N. 168 0 E.	17 50 W.	.443	....	.368	21 36	.717	45 48	31 0	31.58	997.30	2.261	— .277	.767	—59 15
d	Station, 2 feet from aft edge of plating over the aftermost large bulkhead.	....	N. 128 10 E.	22 0 E.	.439	....	.364	21 21	.906	64 57	28 50	32.09	1029.77	2.335	— .204	.930	—78 0

e	Station, on planking 12 feet abaft the station d.	....	N. 177 45 E.	27 35 W.	.478	....	.403	23 46	.679	42 46	51 5	28.04	786.24	1.783	— .756	1.014	—42 20
f	Station, 12 feet abaft station e.	....	N. 178 30 E.	23 20	.444	....	.369	21 39	.577	35 14	39 5	25.12	631.01	1.431	—1.108	1.252	—27 50
g	Station, in the centre of the space between stations f and h.	....	N. 160 30 E.	10 20	.381	....	.306	17 49	.618	38 10	29 50	27.95	781.20	1.771	— .767	.983	—39 10
h	Station, between two hatchways, about 21 feet from front of rudder head.	....	N. 154 0 E.	3 50	.301	....	.226	13 4	.525	31 40	25 50	23.08	532.69	1.208	—1.331	1.431	—21 45
i	Station, 10 feet 6 inches from front of rudder head.	....	N. 161 30 E.	11 20 W.	.360	....	.285	16 34	.540	33 18	31 30	21.39	457.63	1.038	—1.501	1.595	—20 15
	Off Deptford, September 5, 1859. (Height of needle, 4 feet 9¾ inches.)											Observed dip on shore with weighted needle. ° ′	Dip on board with weg'ted needle. ° ′	Ship's vertical force.	Ship's vertical force in terms of Earth's hor. force.		
A	Station, midway between the two foremost funnels, 4 feet 9¾ inches above the platform.	N. 133 40 E.	N. 131 30 E.	2 10 E.	.509	—.108	.401	23 39	.640	39 48	38 45	44 0	48 55	.1877	— .4744	.795	53 20
B(1)	Station, on house in front of bridge... (Needle about 13 ft. above the deck.)	....	N. 152 45 E.	19 5 W.	.488	....	.380	22 20	.444	26 22	58 35	....	42 31	—.0660	— .1661	.473	—70 30
C	Station, 5 ft. from after end of raised platform, between the after main and the mizzenmast, and 4 feet 9¾ inches above the platform, which is 2 feet 3 inches from the deck.	....	N. 157 40 E.	24 0	.544	....	.436	25 51	.500	30 0	60 35	....	46 42	.0989	.2491	.560	64 10
D	Station, 3 feet aft of hatch, and immediately before the mizzenmast.	....	N. 151 0 E.	17 20 W.	.554	....	.446	26 29	.642	39 56	49 0	....	39 15	—.1530	— .3851	.746	—59 30
E	Station, 6 ft. 6 ins. aft the hatchway, immediately abaft the mizzenmast.	....	N. 132 0 E.	1 40 E.	.522	....	.414	24 18	.656	41 0	38 30	....	33 12	—.3227	— .8122	1.043	—39 5
F	Station of Mr. Gray's stand'd compass, 58 feet forward from rudder head.	....	N. 143 0 E.	9 20 W.	.546	....	.438	25 59	.630	39 3	44 5	....	31 45	—.3592	— .9041	1.130	—34 0
G	Station of Admiralty stand'd compass, 41 feet forward from rudder head.	....	N. 145 20 E.	11 40	.516	....	.408	24 5	.577	35 14	46 10	....	31 22	—.3687	— .9282	1.090	—32 5
H	Station of compass in front of the port side of steering wheel, about 6 feet above the deck.	....	N. 149 15 E.	15 35	.522	....	.414	24 27	.543	32 53	40 45	....	17 15	—.6785	—1.7080	1.790	—17 40
I	Station of compass in front of the starboard side of the steering wheel, about 6 feet above the deck.	....	N. 149 45 E.	16 5	.542	....	.434	25 43	.587	35 57	48 25	....	21 37	—.5097	—1.2830	1.410	—24 50
	Purfleet, September 7, 1859.																
H	Station of port steering compass.	N. 45 30 W.	N. 44 30 W.	1 0	.057	.107	.164	9 27	.186	10 43	62 40	....	....	....	....	....	....
		N. 56 0 W. (about.)	N. 54 0 W.	....	....	....	....	....	(Say .186)	....	....	....	26 0	—.4949	—1.2450	1.259	— 8 45
I	Station of starboard steering compass.	N. 67 30 W.	N. 60 30 W.	6 0 W.	.076	.139	.215	12 25	.275	15 58	52 10	....	....	....	....	....	....
		N. 48 30 W. (about.)	N. 43 30 W.	....	....	....	....	....	(Say .275)	....	....	....	26 15	—.4894	—1.2331	1.262	—12 40

* 180° 0′. Needle without directive power.   † Needle always within 60.56 of ship's neutral point.

Horizontal and vertical force magnetic experiments made on board the "Great Eastern"—Continued.

Index to station, &c.	Position of the compass.	Ship's head, correct magnetic.	Ship's head by compass.	Deviation.	Horizontal vibrations per minute, the vibrations on shore being 21 per minute.	Vibrations *.	Force in direction of needle, in terms of Earth's horizontal force.	Ship's force.	Direction of ship's force.	Starboard angle of observed ship's force.	Ship's force to head. In terms of Earth's horizontal force.	Ship's force to head. Or B =
		° ′	° ′	° ′					° ′	° ′		° ′
B (2)	Dipping-needle compass on house before the foremost bridge, about 13 feet above the deck:											
	Between Purfleet and the Nore, September 8, 1859	N. 33 0 E.	N. 8 20 E.	24 40 E.	23.6	556.96	1.263	.539	74 30	40 30	.406	23 57
	(Horizontal vibrations of needle, 21 per minute; dip, 68° 30′.)	N. 40 0 E.	N. 17 20 E.	31 40 E.								
		S. 70 40 E.	N. 69 40 E.	39 30 E.	15.	225.	.510	.688	112 40	42 0	.508	30 32
		S. 63 0 E.	N. 80 30 E.	36 30 E.	14.7	216.09	.492	.673	100 0	37 0	.532	32 9
		S. 28 0 E.	S. 22 30 E.	5 30 W.	12.52	156.75	.355	.647	183 10	31 10	.553	33 34
		S. 17 45 E.	S. 0 25 E.	17 20 W.								
		S. 88 30 W.	N. 66 0 W.	25 30 W.	22.1	488.41	1.108	.478	180 0	1 30	.477	28 39
C.	Dipping-needle compass on the platform, 2 feet 3 inches above the deck, &c.											
	Near Blackwall, September 5	S. 46 20 E.	S. 22 20 E.	24 0 W.	14.43	208.22	.472	.598	199 0	65 20	.249	14 25
	Off Purfleet, September 7	N. 46 48 W.	N. 43 15 W.	3 33 W.	24.08	579.85	1.315	.319	347 40	34 28	.268	15 33
		S. 59 0 W.	S. 74 45 W.	15 45 W.	21.24	451.14	1.023	.279	266 10	27 10	.247	14 18
		S. 22 30 W.	S. 43 30 W.	21 0 W.	20.16	406.83	.923	.360	247 0	44 30	.254	14 43
		S. 11 0 E.	S. 12 45 W.	23 45 W.	19.	361.	.819	.411	232 15	63 15	.184	10 36
		S. 15 0 E.	S. 8 40 W.	23 40 W.	18.56	344.27	.783	.424	228 0	63 0	.187	10 47
		S. 22 30 E.	S. 1 30 W.	24 0 W.								
	Means										.232	
	At the Nore, September 9	S. 22 30 W.	S. 41 40 W.	19 10 W.	20.07	428.49	.972	.328	255 20	52 50	.200	11 32
		S. 8 30 W.	S. 28 50 W.	20 20 W.	19.89	395.61	.897	.350	243 10	54 40	.203	11 43
		S. 4 0 W.	S. 24 30 W.	20 30 W.								
		S. 5 0 E.	S. 15 40 W.	20 40 W.	18.41	338.93	.769	.393	223 45	48 45	.260	15 4
		S. 10 30 E.	S. 10 15 W.	20 45 W.	18.0	324.	.735	409	219 30	50 0	.262	15 11
	At the Nore, ship under way	S. 42 30 E.	S. 24 45 E.	17 45 W.	15.71	246.80	.560	497	200 0	62 30	.234	13 32
	At the Nore, ship under way	S. 52 0 E.	S. 37 30 E.	14 30 W.	14.63	213.04	.483	.548	192 20	64 20	.240	13 53
	Means										.233	

At Portland, September 10	N. 73 0 W.	N. 66 40 W.	6 20 W.	22.60	514.84	1.167	.199	320 15	33 15	.166	9 38
	N. 76 0 W.	N. 68 10 W.	7 50 W.	22.5	506.25	1.148	.203	310 35	26 35	.181	10 26
	N. 52 0 W.	N. 53 0 W.	1 0 E.	22.86	522.58	1.187	.184	5 40	57 40	.100	5 45
	N. 45 0 W.	N. 47 45 W.	2 45 E.	23.61	557.43	1.264	.267	12 20	57 20	.144	8 17
At Portland, September 12	S. 54 30 W.	S. 67 45 W.	13 15 W.	22.91	524.87	1.190	.324	299 30	65 0	.130	7 28
	S. 6 15 E.	S. 13 15 W.	19 30 W.	18.65	347.82	.789	.367	225 15	51 30	.229	18 14
Means	....	....	....	....	....	....	....	....	....	.158	....
At Holyhead, October 23 and 24, 1859	N. 53 40 W.	N. 52 30 W.	1 10 W.	22.06	486.64	1.212	.209	353 20	47 0	.141	8 6
(Horizontal vibrations of needle, 20 per minute; dip,	N. 54 23 W.	N. 53 0 W.	1 23 W.	....	....	....	....	....	....	....	....
70° 10′.)	N. 49 52 W.	N. 40 52 W.	0 0	22.18	491.95	1.230	.230	0 0	49 52	.144	8 17
	N. 19 15 W.	N. 27 30 W.	8 15 E.	22.22	493.73	1.234	.282	39 30	58 45	.163	9 23
Means	....	....	....	....	....	....	....	....	....	.149	....

Horizontal and vertical magnetic force experiments made on board the "Great Eastern"—Continued.

Index to station, &c.	Position of the compass.	Ship's head, correct magnetic.	Ship's head by compass.	Deviation.	Ship's force to starboard. As observed.	Ship's force to starboard. Correction for + D.	Ship's force to starboard. As corrected for + D.	Ship's force to starboard. C=	Ship's total polar force.	Maximum polar deviation.	Starboard angle of ship's polar force.	Dip on shore with weighted needle.	Dip on board with weighted needle.	Ship's vertical force.	Ship's vertical force in terms of Earth's horizontal force.	Ship's total magnetic force.	At angle from the vertical.
B (2)	Dipping-needle compass on house before the foremost bridge, about 13 feet above the deck:	° ′	° ′	° ′				° ′		° ′	° ′	° ′	° ′				° ′
	Between Purfleet and the Nore, September 8, 1859	N. 33 0 E.	N. 8 20 E.	24 40 E.	.357	—.082	.275	15 58	.490	29 20	34 15	44 0					
		N. 49 0 E.	N. 17 20 E.	31 40 E.									43 40	—.0116	—.0292		
	(Horizontal vibrations of the needle, 21 per minute; dip, 68° 30′.)	S. 70 40 E.	N. 69 40 E.	39 30 E.	.460	—.142	.318	18 33	.599	36 48	32 0		44 15	.0087	.0219	.600	87 40
		S. 63 0 E.	N. 80 30 E.	36 30 E.	.403	—.134	.269	15 36	.599	36 48	26 50						
		S. 28 0 E.	S. 22 30 E.	5 30 W.	.330	—.070	.230	15 5	.610	37 36	25 30						
		S. 17 45 E.	S. 0 25 E.	17 20 W.									45 22	.0488	.1228		
		S. 88 30 W.	N. 66 0 W.	25 30 W.	.013	.150	.163	9 23	.506	30 24	18 30		43 15	—.0259	—.0651	.513	96 40
C.	Dipping-needle compass on the platform, 2 feet 3 inches above the deck, &c.:																
	Near Blackwall, September 5	S. 46 20 E.	S. 22 20 E.	24 0 W.	.144	—.144	.400	23 35	.470	28 2	58 20		46 42	.0988	.2487	.535	61 45
	Off Purfleet, September 7	N. 46 48 W.	N. 43 15 W.	3 33 W.	.173	.146	.319	18 36	.419	24 46	51 8		46 24	.0874	.2200	.474	61 40
		S. 59 0 W.	S. 74 45 W.	15 45 W.	.127	.171	.298	17 20	.390	22 57	49 50						
		S. 22 30 W.	S. 43 30 W.	21 0 W.	.250	.076	.326	19 2	.419	24 46	51 50		46 45	—.1008	.2537	.493	58 15
		S. 11 0 E.	S. 12 45 W.	23 45 W.	.367	—.038	.329	19 13	.375	22 2	60 40						
		S. 15 0 E.	S. 8 40 W.	23 40 W.	.375	—.052	.323	18 51	.377 (Say	22 9	59 35						
		S. 22 30 E.	S. 1 30 W.	24 0 W.					.377				46 55	.1072	.2698	.460	55 0
	Means						.333		.408		55 14				.2481	.491	59 10
	At the Nôre, September 9	S. 22 30 W.	S. 41 40 W.	19 10 W.	.266	.076	.342	20 0	.390	22 57	59 30		46 55	.1072	.2698	.478	55 0
		S. 8 30 W.	S. 28 50 W.	20 20 W.	.285	.030	.315	18 22	.373 (Say	21 54	57 40						
		S. 4 0 W.	S. 24 30 W.	20 30 W.					.373)				46 42	.0988	.2487	.448	55 45
		S. 5 0 E.	S. 15 40 W.	20 40 W.	.295	—.017	.278	16 9	.380	22 20	47 5		46 40	.0986	.2482	.456	56 15

	S. 10 30 E.	S. 10 15 W.	20 45 W.	.314	—.036	.278	16 9	.383	22 31	46 40		46 52	.1053	.2650	.406	54 45
At the Nore, ship under way...	S. 42 30 E.	S. 24 45 E.	17 45 W.	.438	—.135	.303	17 38	.382	22 28	52 40		46 30	.0912	.22#5	.447	58 50
At the Nore, ship under way...	S. 52 0 E.	S. 37 30 E.	14 30 W.	.494	—.158	.336	19 38	.411	24 16	55 0		6 30	.0912	.2295	.472	60 25
Means						.309		.387		53 6				.2485	.461	56 50
At Portland, September 10	N. 73 0 W.	N. 66 40 W.	6 20 W.	.113	.191	.304	17 42	.346	20 15	60 45						
	N. 76 0 W.	N. 68 10 W.	7 50 W.	.094	.194	.288	16 44	.340	19 53	56 55		46 32	.0925	.2328	.412	55 50
	N. 52 0 W.	N. 53 0 W.	1 0 E.	.157	.158	.315	18 22	.330	19 16	72 15						
	N. 45 0 W.	N. 47 45 W.	2 45 E.	.222	.140	.362	21 14	.430	25 28	69 0						
At Portland, September 12	S. 54 30 W.	S. 67 45 W.	13 15 W.	.285	.163	.448	26 37	.458	27 16	72 50		46 20	.0849	.2137	.505	64 20
	S. 6 15 E.	S. 13 15 W.	19 30 W.	.290	—.022	.268	15 33	.349	20 26	49 15		46 10	.0785	.1976	.402	60 9
Means						.331		.376		63 30				.2110	.443	60 30
At Holyhead, October 23 and	N. 53 40 W.	N. 52 30 W.	1 10 W.	.156	.163	.319	18 86	.346	20 15	65 10	45 16					
24, 1859	N. 54 23 W.	N. 53 0 W.	1 23 W.									47 52	.0679	.1872	.392	61 0
	N. 49 52 W.	N. 49 52 W.	0 0	.174	.152	.326	19 2	.358	20 59	65 27						
(Horizontal vibrations of needle, 20 per minute; dip, 70° 10′.)	N. 19 15 W.	N. 27 30 W.	8 15 E.	.240	.066	.306	17 49	.343	20 4	64 20		47 10	.0945	.2619	.433	52 0
Means						.317		.340		65 2				.2245	.413	56 30

"Great Eastern."—Deviation tables for admiralty standard compass and mast compass.

Ship's head by compass.	Admiralty standard compass.							Mast compass.		
	River Thames, Sept. 7, 1859.	Portland, September 10 to 12, 1859.			Holyhead, October 22 to 24, 1859.	Southampton, June 13, 14, and 15, 1860.	* Milford, April 28 to 29, 1861.	River Thames, Sept. 7 and 8, 1859.	Portland, Sept. 10 to 12, 1859.	Holyhead, October 22 to 24, 1859.
		When entering the Roads.	While at anchor afterwards.	At anchor, September 12.						
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	26 30 E.			i 17 0 E.	10 30 E.		5 40 E.	i 11 30 E.	i 5 15 E.	10 45 E.
N. by E	32 30			i 23 30	16 20		10 10	i 14 5	i 10 0	14 45
N. N. E.	36 50			i 28 0	21 15		13 50	i 16 0	i 13 10	17 30
N. E. by N.	38 50			i 30 30	24 20		16 10	i 17 30	i 15 45	20 0
N. E.	39 0			31 10	25 45		17 0	i 18 15	i 17 40	21 20
N. E. by E.	37 0			30 30	25 55		17 15	i 18 0	i 18 45	21 40
E. N. E.	33 15			28 30	24 35		16 0	i 17 15	18 50	21 20
E. by N.	28 0			25 5	22 15		14 0	i 15 20	18 30	20 25
East	22 20			21 20	18 50		i 11 50	i 13 45	17 10	18 30
E. by S.	15 40			16 45	14 50		i 9 28	i 9 55	15 40	16 30
E. S. E.	8 50			11 40	10 10		i 6 40	6 20	13 40	14 0
S. E. by E.	2 20 E.			5 50 E.	5 35		i 4 10	2 35	11 30	11 40
S. E.	4 20 W.			0 0	0 55 E.		i 1 40	0 50 W.	8 50	8 30
S. E. by S.	11 5			5 50 W.	3 25 W.		0 10 W.	3 50	6 15	5 20
S. S. E.	i 17 10			11 15	7 20	2 0 E.	1 30	6 25	3 30	1 50 E.
S. by E.	23 0			15 40	11 0	0 20 E.	2 30	8 40	0 40 E.	i 1 50 W.
South	27 30			19 20	i 13 55	1 40 W.	3 25	11 0	2 10 W.	i 5 35
S. by W.	30 40			22 0	i 16 0	3 40	4 10	12 50	4 50	i 8 50
S. S. W.	31 45			23 15	i 17 10	4 45	5 0	14 10	7 25	i 11 20
S. W. by S.	31 50			24 0	i 18 5	5 30	6 10	15 0	9 50	i 13 35
S. W.	30 50			24 20	i 18 35	6 30	7 30	15 5	11 40	i 14 50
S. W. by W.	28 45			24 0	i 19 0	8 25	9 30	15 0	13 10	i 15 30
W. S. W.	26 30			23 35	i 19 10	10 15	12 0	14 30	i 14 10	i 15 40
W. by S.	24 0			23 10	i 19 5	12 0	13 40	13 30	i 14 30	i 15 10
West	21 30	20 55 W.	i 21 55	22 0	i 18 40	13 0	14 50	12 50	i 14 40	i 14 10
W. by N.	18 0	18 30	i 19 45	20 30	i 17 50	14 20	14 50	11 15	13 50	i 12 40
W. N. W.	14 30	15 36	i 17 20	18 0	16 40	14 50	14 0	9 10	i 12 40	10 40
N. W. by W.	9 55	12 25	i 14 15	15 0	14 0	14 15	12 30	6 15	i 11 0	8 30
N. W.	i 4 30 W.	8 0	10 0	11 0	10 10	12 50	10 40	2 40 W.	i 8 40	5 35
N. W. by N.	i 1 40 E.	3 0 W.	5 15 W.	6 40	5 30 W.	10 10 W.	7 40	1 40 E.	i 5 25	2 40 W.
N. N. W.	9 20	2 55 E.	0 25 E.	0 45 W.	0 20 E.	W. N. W. ½ W. 8 0 W.	3 50 W.	i 5 0	2 0 W.	0 45 E.
N. by W.	18 30 E.			i 7 0 E.	4 55 E.		0 50 E.	i 8 30 E.	i 1 0 E.	5 0 E.

MAGNETIC CO-EFFICIENTS, (CALCULATED BY MR. EVANS.)

	° ′	° ′	° ′	° ′	° ′	*Approximate.* ° ′	° ′	° ′	° ′	° ′
A	−0 10	....	....	−1 3	−0 24	....	+0 2	+0 4	+1 21	+2 20
B	+23 13	....	....	+22 42	+19 18	+13 30	+13 14	+12 43	+16 12	+17 2
C	+25 38	....	....	+16 43	+12 3	+1 40	+4 28	+11 12	+4 20	+7 30
D	+4 21	....	....	+4 44	+4 8	+4 20	+4 32	+1 32	+1 30	+1 0
E	−0 37	....	....	−0 45	−0 17	....	+1 17	+0 4	−0 10	+0 7

* Through a change in the position of the capstan, this compass was placed about 12 feet forward from its old station, 14 feet 9 inches from new position of the spindle of the capstan, and 9 feet 3 inches from the nearest end of the magnets in the compensated standard compass, which had also been moved further forward. Mr. Evans states that he has since determined, experimentally, that the maximum effect of the magnets on the admiralty compass would not exceed 0° 40′.

In each table the letter (*i*) indicates interpolations.

"*Great Eastern*"—*Deviation tables for the dipping-needle compass.*

Ship's head by compass.	Station B.—On house before the foremost bridge.		Station C.						On house built above station C, and rather more than 13 feet above the deck, Liverpool, June 25 and 26, 1861.
	Between Purfleet and the Nore, Sept. 8, 1859.	Compass placed at same station at Milford, April 26 to 29, 1861.	At Purfleet, Sept. 7 and 8, 1859.	At the Nore, Sept. 8 and 9.	Observations made at Portland. Sept. 10.	Sept. 11.	Sept. 12.	At Holyhead, Oct. 22 to 24, 1859.	
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	i 17 20 E.	4 40 W.	i 21 30 E.				i 20 20 E.	17 40 E.	9 30 E.
N. by E.	26 40	3 0 E.	i 27 40				i 25 0		14 15
N. N. E.	34 35	11 0	i 31 20				i 28 45		18 0
N. E. by N.	39 25	20 0	i 33 0				i 30 15		20 40
N. E.	41 45	i 26 30	i 32 20				i 29 50		21 30
N. E. by E.	41 45	i 30 30	i 30 30				i 27 30		21 30
E. N. E.	40 0	i 32 30	i 25 45				i 23 30		20 30
E. by N.	36 45	i 33 0	i 19 45				i 17 45		18 30
East	32 10	i 31 30	i 13 0				11 30		15 40
E. by S.	26 20	i 30 0	i 4 45 E.				i 4 50 E.		12 20
E. S. E.	i 20 0	i 27 30	i 2 0 W.				i 1 20 W.		8 50
S. E. by E.	i 13 35	i 24 0	i 8 20				i 7 10		5 20
S. E.	i 7 15	i 20 30	i 14 0				i 11 50		2 0 E.
S. E. by S.	i 1 0 E.	i 16 30	i 18 30				i 15 40		i 1 15 W.
S. S. E.	5 20 W.	i 12 0	i 21 30				i 18 10		i 4 20
S. by E.	11 35	i 7 30	i 23 30				i 19 30		i 7 10
South	17 35	i 2 40 E.	24 0	20 45 W.			i 20 0		i 9 30
S. by W.	23 10	i 2 0 W.	23 50	21 0			20 0		i 11 15
S. S. W.	27 30	i 7 0	23 20	20 30			i 19 30		i 12 40
S. W. by S.	30 50	i 11 40	22 30	19 50			i 18 30		i 13 40
S. W.	32 45	i 16 30	20 30	18 35 W.			i 16 55		i 14 20
S. W. by W.	33 50	i 20 30	i 19 0				i 15 0		i 14 50
W. S. W.	33 45	i 24 0	i 17 30				13 20		i 15 0
W. by S.	32 50	i 27 0	15 20				i 10 50		i 15 30
West	31 20	i 29 0	i 13 40				i 8 30	5 40 W.	i 15 30
W. by N.	29 0	i 30 0	i 11 40		8 40 W.	7 10 W.	i 6 35	2 20	i 15 0
W. N. W.	25 50	i 30 0	i 9 20		6 25 W.	4 15 W.	i 2 30 W.	5 40	i 13 45
N. W. by W.	i 21 50	i 30 0	i 6 40				0 0	2 20 W.	i 11 40
N. W.	i 16 0	28 0	3 45 W.				3 30 E.	1 30 E.	9 0

N. W. by N.	*i* 9 25	25 0	0 0	....	....	....	*i* 6 50	5 55	5 0
N. N. W.	*i* 1 40 W.	19 30	5 30 E.	....	....	....	*i* 10 45	10 20	0 30 W.
N. by W.	*i* 7 15 E.	12 0 W.	12 30 E.	....	....	....	*i* 15 15 E.	14 35 E.	4 30 E.

MAGNETIC CO-EFFICIENTS.

	° ′	*Approximate.* ° ′	*Approximate.* ° ′	*Approximate.* ° ′	*Approximate.* ° ′	*Approximate.* ° ′	*Approximate.* ° ′	*Approximate.* ° ′	*Approximate.* ° ′
A.	+ 0 3	....	− 1 40	....	....	....	....	....	− 0 6
B.	+ 31 55	+ 30 15	+ 13 34	....	+ 10 30	+ 9 10	+ 10 0	+ 5 40	+ 5 53
C.	+ 17 47	− 3 40	+ 22 41	+ 20 45	....	....	+ 20 10	+ 17 40	+ 9 30
D.	+ 4 31	+ 4 23	+ 7 55	....	....	....	+ 5 5	....	+ 3 15
E.	− 0 9	....	− 0 12	....	....	....	....	....	− 0 8

In each table the italic (*i*) indicates interpolations.

An inspection of the values obtained by the vibration experiments at the foremost bridge station, for ship's force to the bow or headward, at once indicates the presence of a fore-and-aft inductive force, varying with the direction of the ship's head. Comparing the value when ship's head is S. 88° 30′ W., when this induction will nearly vanish, with the other observations, and taking a mean of the equations which they afford, a capacity for fore-and-aft induction equal to 0.104 of Earth's horizontal force is obtained, the ship's headward polar force being 0.477. Using these co-efficients, it will be seen that the calculated values correspond sufficiently close with the observed values.

	Calculated Values.	Observed Values.
0.104 cos 33° 0′ + 0.477 = — 0.087 + 0.477 =	0.390	0.406
0.104 cos 109 20 + 0.477 = 0.034 + 0.477 =	0.511	0.508
0.104 cos 117 0 + 0.477 = 0.047 + 0.477 =	0.524	0.532
0.104 cos 152 0 + 0.477 = 0.092 + 0.477 =	0.569	0.553
0.104 cos 268 0 + 0.477 = 0.003 + 0.477 =	0.480	0.477

The values for ship's force to starboard show a much larger capacity in the ship for transverse induction. By equating the second and third observations with the last, as those best adapted for the purpose, and taking a mean, the following are obtained for ship's capacity for transverse induction and polar attraction to starboard, namely, 0.218 and 0.231, respectively, of Earth's horizontal force.

The calculated and observed values of ship's force to starboard will stand thus:

	Calculated Values.	Observed Values.
0.218 sin 33° 0′ + 0.231 = 0.119 + 0.231 =	0.350	0.357
0.218 sin 109 20 + 0.231 = 0.206 + 0.231 =	0.437	0.460
0.218 sin 117 0 + 0.231 = 0.194 + 0.231 =	0.425	0.403
0.218 sin 152 0 + 0.231 = 0.102 + 0.231 =	0.333	0.330
0.218 sin 268 0 + 0.231 = — 0.218 + 0.231 =	0.013	0.013

The fore-and-aft induction represents a — D = 0.104 sin 45° = 0.104 × 0.701 = 0.0729 = 4° 11′.

The transverse induction represents a + D = 0.218 sin 45° = 218 × 0.701 = 0.1528 = 8° 47′.

The sum of these, or — D 4° 11′ + D 8° 47′ = + D 4.31, the same value exactly as was previously obtained from the table of deviations, or taking (0.218 — 0.104) × sin 45° as the more correct expression, we obtain 0.114 × 0.701 = 0.0799 = 4° 35′, a remarkably close approximation to the mean D obtained from the observed deviations.

It should be observed that both of these induced magnetisms tend to decrease the directive power of the compass needle, and that on the four point courses it amounts to so much as 0.226, or nearly one-fourth of the

Earth's horizontal force; a decided example of the necessity for correcting quadrantal deviation, and that by soft iron rather than by an adjacent compass, which would tend to still further decrease the directive power of the needles.

The observations made at the platform station of the dipping-needle compass do not afford any very satisfactory data for estimating the effect of the fore-and-aft inductive magnetism of the ship, but they are sufficient, it is thought, to show that any change in the observed magnetism from this cause must be very small. They afford better evidence of a continued decrease in the attraction towards the bow. Thus—

One observation at Deptford gives the headward force, or B, as	=0.249
The mean of five observations at Purfleet gives........................	0.228
The mean of six observations at the Nore gives........................	0.233
The mean of six observations at Portland gives........................	0.158
The mean of three observations at Holyhead gives.....................	0.149

For the transverse magnetism at this station, the Purfleet observations give the following equations:

Polar magnetism, minus (capacity for induced magnetism multiplied by sin 52° 54′) = 0.150.

Polar magnetism, minus (capacity for induced magnetism multiplied by sin 22° 30′) = 0.250.

Polar magnetism, plus (capacity for induced magnetism multiplied by sin 13° 0′) = 0.371.

The first and second, the first and third, and the second and third of these equations give 0.241, 0.216, and 0.199, respectively, as the capacity for transverse induction, or a mean value of 0.219, which, multiplied by sin 45°, gives 0.1533 = 8° 49′ as the co-efficient for quadrantal deviation; the deviation table for the same place giving + D 7° 55′.

Treating the most distant of the observations at the Nore in the same way, a mean value of 0.201 is obtained, which gives 8° 5′ for the quadrantal deviation. The two most distant of the Portland observations gives 0.173 as the capacity, and 6° 57′ for the quadrantal deviation; and the Holyhead observations in like manner give 0.164 and 6° 36′.

It can scarcely be admitted that the capacity for transverse induction has sensibly decreased, nor that the difference is due entirely to instrumental errors and errors of observation, but rather that when the ship quietly swings at anchor through a few points of the compass, the change in the horizontal induction has not the time which is required nor the incitement which is necessary for full development. These experiments on board the "Great Eastern," in conjunction with a very large number of observations made on board other ships, induce in the writer a conviction that careful experiment would show that co-efficient *D* may, in some ships, be made to vary fully 25 per cent., by adopting different methods of swinging ship.*

Using the values for transverse induction obtained above to ascertain the ship's polar transverse magnetism at each place, we obtain—

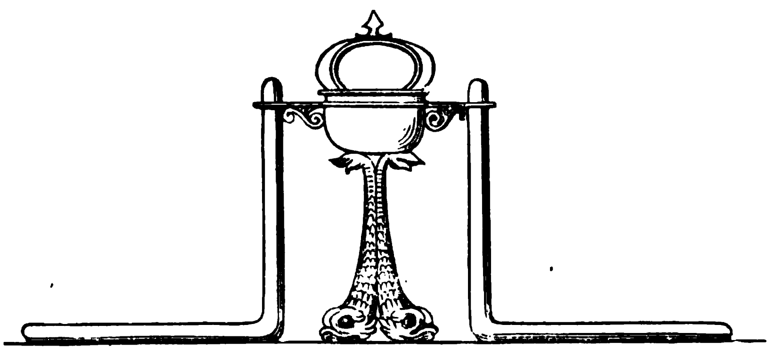
		°	′
At Deptford................................	C = 0.3849 =	22	38
At Purfleet.................................	C = 0.3271 =	19	42
At the Nore................................	C = 0.3140 =	18	18
At Portland	C = 0.2706 =	15	42
At Holyhead................................	C = 0.2940 =	17	6

In the preceding tables the dip at the first four stations has been taken as 68° 30′, and at Holyhead as 70° 10′. The larger dip at Holyhead will to some extent, account for the larger C observed at this place; in some measure it will also be due to the small value used for D.

W. W. R.

* A modification of the present mode of compensating quadrantal deviation, as described below, might, it is thought, be advantageously introduced to cure the fluctuations here referred to, as well as those in the transverse sub-permanent magnetism which are known to be constantly taking place. Some instances of change in a ship's transverse magnetism are quoted in the report. The following occurred recently: A ship was swung after lying for some time with her head to the eastward. On testing her transverse magnetism, the following day, after lying in the meantime with her head to the westward, it was found to have changed more than two degrees. In cases in which ships sail or steam for some days on opposite courses the change must be much greater; for instance, see the logs appended to this report.

Fig. 12.



On each side of the compass, at a distance to be found by trial, and depending on the size of the bars of iron employed, place a bar, bent at right angles, as shown in the sketch: the horizontal part of the bar might be let into the deck, or be placed entirely below it, and should be of a length to suit the ascertained magnetism of the ship. By care in selecting the iron, and in making use of any susceptibility it might have for retaining magnetism in one direction, nearly the whole of the transverse magnetism of the ship might be compensated in this manner.

An arrangement of bars of iron of this kind would have the following recommendations: It would compensate quadrantal deviation; it would compensate a considerable part, if

APPENDIX O.

Letters from Mr. Thomas Bennett, compass adjuster, Cork, on the magnetism of iron ships.

CORK, *April*, 1857.

GENTLEMEN: Being for the last few years engaged in the correction of compasses in iron ships at this port, and most of them having been built in a north and south direction, I have had frequent opportunities of observing the peculiarities of their magnetism, consequent (as it seems to me) on their being built in this position. I shall therefore proceed, with your permission, to give some account of my observations and views on the subject.

The river here runs nearly east and west past the building yards, which are on the northern side of it, so that all the ships that have been built here were laid down nearly in the line of the magnetic meridian, and all of them, till within the last two years, with their heads to the north, as it was thought most convenient to launch them "stern on."

I perceived about this time that all the ships which had been built here exhibited southern polarity aft and northern forward; that is to say, they had assumed a local polarity in accordance with the horizontal direction of terrestial magnetism, in reference to the position in which they had been built; and I thought it likely that the magnetism was induced in a vertical direction also, in accordance with the magnetic dip; and having tried a mast compass in one of them, I found that it was more correct on the foremast, even when placed low down, than on the mizzenmast in a very much higher position. I may remark that I always found on adjusting ships built here, that they required the correcting magnets to be much nearer to the compass, more powerful, or more numerous than was ever necessary for the correction of ships built in other places; and I thought that if they could be laid down in a position the reverse of the usual one here, (that is with the stern instead of the head to the north,) that the polar direction being then induced to follow the dip, its intensity would be below and much farther from the after compass. Accordingly, I induced Mr. Robinson (a private builder here) to lay down a steam ship, which he was about to build, with her head to the south, so that she was launched "stem on," and I was greatly pleased to find that she had northern polarity aft and southern forwards, and

---

not all, of the changes in the sub-permanent transverse magnetism; it would correct a large part of the error from heeling; and, in conjunction with the vertical bar, already introduced for compensating the ship's fore-and-aft changing magnetism, it would considerably increase the directive power of the compass.

W. W. R.

that when her head was E. and W., a compass placed aft had much less error than in any former ship, and much less than in the forward part of this ship; and consequently it required less magnets to adjust her. I found that the horizontal direction of her magnetism nearly coincided with the line of her keel, and the intensity was low in the after part of the ship, and high forward, so that it tended towards the direction of the dip, but was not nearly so vertical.

I tried the compass in several positions on board her, both before she was launched and afterwards, and found in all cases that the compass aft was much less affected by local attraction than when placed forward, and less on the bridge than at either end. In order to test the relative intensities of the ship's magnetism while on the stocks, I placed (before bringing the compass on board to experiment with) a deflecting magnet below the compass, and attached to it, which produced a deviation of 45°, so that the compass needle when brought on board should be presented at that angle to the direction of the ship's polarity. I also tried her errors a couple of days after she was launched, and two or three times at intervals of a week each afterwards, while she lay at the dock quay, (nearly E. and W.,) and I found that her after compass was less in error two days after she was launched that a week after; so that I think the line of her intensity became more horizontal; at any rate, there was a very decided change aft, during the first week or ten days, but none that I could perceive afterwards.

As regards the mode of correcting iron ships generally, I may remark that I have found the correction of the E. and W., deviation by fore-and-aft magnets placed parallel to each other, and on *each* side of the compass, is seldom very satisfactory, as I think they produce a magnetic error intermediate between the cardinal points, and being magnetic cannot be absorbed by the adjustment for non-polar or quadrantal deviation; so that I think the original directions of Professor Airy for placing the magnet or magnets on *one side* of the centre of the compass, for each correction of it, will be found more satisfactory in practice than placing them on opposite sides, as is frequently done.

I have lately been rather pleased with a correction I made by placing an auxiliary magnet directly under the centre of the compass and coincident with the direction of the ship's keel, of sufficient power to correct a good deal but not all of the error, (with her head E. and W.,) and then perfecting that correction by another magnet placed parallel to the first, but at a considerable distance at one side of it; however, I dare say this mode of making the correction would only be necessary when the ship's polarity is nearly in the line of her keel, or when the compass is placed close to a capstan, the spindle of which may happen to have sufficient vertical magnetism to affect the compass.

In correcting ships, I have found that though I had generally no difficulty in making a perfect correction of the bridge compass, I have almost always found a small error in the after compass on reversion, which I might transpose, but could not get rid of; and on thinking the matter over, I have concluded that it was due to the nearer proximity of one pole of the ship's magnetism to the after compass; and if so, that it might be compensated for by placing the neutral points of the correcting magnets a little more forward than the centre of the compass; at any rate, I hope soon to have an opportunity of testing the matter practically. I may just add, that I have not always found the neutral points of a magnetic bar to be equidistant from each end, and have therefore always thought it better to ascertain the neutral point of each magnet before applying it for correction. In conclusion, I beg to say that if I can afford any further information on the subject, I shall be most happy to do so, and am, gentlemen, your most obedient,

THOMAS BENNETT.

The LIVERPOOL COMPASS COMMITTEE.

CORK, *December* 14, 1858.

MY DEAR SIR: It seems so long a time since I last wrote to you, that I hardly know how to begin now; besides, in truth, "the Report," which you were kind enough to send me in the early part of the year, is so correct and so comprehensive on everything connected with the magnetism of iron ships, that it does not seem to leave room for much more upon the subject.

I have the Report now before me, and shall take the liberty, as I turn over the pages of it, to remark on anything that may appear to me unusual, or offer any suggestion that my own experience of the matter may dictate. And am sure that you will be more kind than critical regarding my mode of doing so.

I perceive that you speak of a "dumb card" for ascertaining the position of a ship's head at any moment; and though I have never seen one, I have no doubt it is exactly similar in principle to an instrument which I contrived for my own use some years since, and which I have been using very satisfactorily ever since; in fact, as the adjustment of ships at Cork has to be made in a tideway, and without any buoys laid down for the purpose, it would be impossible to make a correct adjustment without something of the kind. I dare say my instrument is more complete than anything that could be applied in or on an ordinary compass. I use it on a tripod near the binnacle, and it is fitted with clamp and tangent screw, divided glass reflectors for back observations, and transparent glass sights, graduated to hundredths of a point for direct view. But no matter how simply such an instrument may be constructed, it is infinitely preferable for ascertaining the errors of a ship to any mode of signalling or sighting from the shore.

I have had only two or three opportunities since I last wrote to you of ascertaining the effect of a ship's position while building on the distribution of her magnetism; but these have quite tended to confirm my former views, and quite agree with your observations in the Report. As regards the permanence of a ship's magnetism, I have from time to time had to readjust steamships after undergoing repairs, and have generally been surprised to find how little their magnetism had altered in direction, or even in amount, from the time of their former adjustment. In fact, I am inclined to think that *that* part of a ship's magnetism which causes the greatest errors of the compass is much more permanent than most people think. I doubt even if it alters much by concussion, (at least for any considerable time.) I have, in fact, found more change in ships after lying up for a long time than I ever did in ships kept constantly at work under any circumstances.

I had an opportunity, too, of testing one steamer after a severe collision, and could not perceive any change in her horizontal adjustment, though a vertical magnet in the pillar of the binnacle, with which I had originally corrected her errors for heeling, was obliged to be lower, after which her adjustment seemed again perfect; but strange to say, after she made a few short voyages, I was obliged to replace it in its original position.

I have sometimes found considerable change in the bridge compass of a ship after repairs, but have always been able to trace it to the substitution of new boilers, or to some decided change in the iron work near the binnacle. I think it right to say that the greater number of ships I have had to deal with are built in a N. and S. direction, and it may be that on that account their magnetism is more permanent than that of ships built in a different position, and I am inclined to think that it is so; but I expect, in future, to have opportunities of testing ships built in an E. and W. direction also, and shall then be able to speak more positively on the subject.

The great difficulty which I have to contend with in arriving at any conclusion as regards the magnetism of ships is caused by the great hurry in which they are got ready for sea. Every one here connected with them is anxious to oblige me as much as they possibly can, but really the urgency of sending them off at the last moment overrules all other considerations, so that they are only anxious to get the adjustment made as quickly as possible, and say and do all they can to hurry me with it. Even for a good while before the ships are ready for sea, there are generally such a number of workmen in every part of them that it is almost impossible to get an opportunity of making satisfactory experiments.

As regards tables of errors, I think they are always necessary, and should be carefully made out and supplied after adjustment. I have had some years experience in the adjustment of iron ships, and I think I never knew an instance in which all the errors were neutralized; and I have met some in which the curves exhibited sudden and singular flexures which it would be difficult to account for, and I believe quite impossible to imitate artificially on a small scale. So that I think, whether the quadrantal adjustment is applied or not, the errors ought in all cases to be carefully ascertained, and, if possible, on every point of the compass, not by symmetry or analogy of opposite errors, but by actual observation of all.

I quite agree with the remarks in the Report as to the utility of "the error curves" for exhibiting the nature and characteristics both of quadrantal and polar errors, as well as the value of accustoming the eye to their combinations; and I think the long diagrams, on Plate 27, will be more useful for that purpose, because more easily understood, than those on Plate 26; at least, I must confess the latter puzzled me a little at first.

With regard to the adjustment for quadrantal errors, I know how important a thing it would be, for many reasons, if it could be accurately and judiciously applied, but am sorry to say that my own experience is rather against it in many—I am afraid I must say in most—cases where the mass of the ship's iron is very great, or very near the compass.

The principal objection to it is, that it renders the compass more sluggish than it otherwise would be, particularly on E. and W. courses, and often to an extent materially to interfere with the integrity of the compass, even in these latitudes, where the terrestrial directive force is so considerable; besides, the accuracy of the adjustment depends on the uniformity of the errors in opposite quadrants, and I think you will find that in iron ships they are not always uniform.

I might also urge one or two other objections to the practical application of soft-iron correctors, but really this paper has alrealy extended to such a length that I must now try and finish it as briefly as possible.

I should like to mention one instance of unusual magnetic force that came under my own observation lately. It was that of a new iron screw steamer which was built for whaling purposes, and was fitted aft with a large iron trunkway or shaft, for the purpose of raising or lowering the propeller through. The upper end of this propeller shaft possessed intense southern polarity, and as the skylight on which the binnacle and compass was placed was very close to it, its effect upon the compass exceeded anything of the kind in my experience. When the ship's head was true magnetic N., the compass indicated S.W. by W.; when the ship's head was W., the compass was S.S.W. A dipping needle, which on shore dipped to 68°, when placed in the position of the compass became vertical. I then removed it on shore, and counteracted its dip by a sliding weight, so as to bring it to 0; and when again placed on the skylight it dipped, notwithstanding the weight, to 25°. A horizontal needle, too, which on shore made 14 vibrations per minute, when placed on the skylight made only at the rate of 5½. I think in such a ship you would hardly recommend chain boxes. No doubt in some iron ships they may be advantageously used, and in all wooden ships with much horizontal iron affecting the compass; but I think I am correct in saying that there are many instances of iron ships where they would do more harm than good.

Whenever quadrantal correctors are used, I think they should be carefully tested beforehand, to make sure that they do not possess polarity. In experimenting, some time since, I tested cast-iron cylinders, boxes of cast-iron borings, wrought-iron turnings, wrought-iron punchings, and chain, and found them all more or less magnetic, so that when applied in one way they corrected or tended to correct the error, but when reversed end for end they failed to do so; in fact, I believe, after all, that well-softened iron chain is as good as anything. But whatever may be used as correctors, they should be as large and as far from the compass as circumstances will permit. A small compensator near the compass does not produce the same effect as a larger one at a greater distance. Besides, the compass has sometimes to be changed at sea for another one; and, though the extreme fittings of the two compasses may be the same size, the bowls or cards may not; for instance, a heavy floating compass with comparatively a small card and short needles, is sometimes removed in fine weather to substitute a quicker compass with single bowl and larger card; in this case the nearer the compensators the greater the error produced by the change.

But my principal objection to the close proximity of the compensators is, that they do not then correct accurately at all; that they do not produce their maximum effect where the maximum error generally is, (when the ship is on the quarterly courses,) but when the ship's head is about a point nearer to E. or W., and that when the ship's head is about E. or W. the small compensators very near the compass produce a very serious obstruction to its free motion.

I shall only add, in conclusion, that I have also satisfied myself, by repeated trials, that a polar adjustment is never so uniform when made by weak magnets near the compass as it might be by stronger ones further off. I have lately read of adjustments made by small magnets, "end on" to the compass, and have, in consequence, tried a good many experiments in this way, but could not possibly produce a uniform correction; and I am quite sure that where large errors had to be compensated it would be quite impossible to do it accurately in this way.

I am afraid you will think this letter unreasonably long, and indeed it is very much longer than I at first intended it should be, but I have really found it impossible to make myself intelligible in less words, and have tried to exclude everything that had not some practical bearing on the subject. If you think anything in this letter worth the consideration of "the Compass Committee," you will be good enough to submit it to them; but, in any case, I should be glad of a few lines, at your earliest convenience, in reference to it, particularly as regards the practical application of quadrantal adjustment. I know you have given considerable attention to the subject, and are very likely to have arrived at a correct conclusion about it. If I find that your opinion coincides with mine, I shall feel fortified in the matter; but if, on the contrary, you have arrived at different results, I shall then carefully reconsider the whole subject again, and make some experiments for the purpose of satisfying myself about it.

I am, dear sir, yours, very truly,

THOS. BENNETT.

MR. W. W. RUNDELL.

While the foregoing was passing through the press, the following additional letter was received from Mr. Bennett:

124 PATRICK STREET, CORK, *August* 15, 1861.

MY DEAR SIR: In a letter I wrote to you some time since, when speaking of the quadrantal errors of iron ships, I stated that I thought the soft-iron adjustment for those errors rendered the compass more sluggish than it otherwise would be. Since then I have had repeated opportunities of testing the matter, and think it right to say that I am now much more favorably disposed towards the soft-iron correctors than at that time; in fact, I think the sluggishness of the compass referred to on that occasion was due to the proximity of a large mass of vertical iron, from the influence of which of course the quadrantal errors could not relieve it; indeed, I do not know anything connected with the errors of iron ships so difficult to deal satisfactorily with as the proximity of vertical iron to the compass; and this is peculiarly the case in ships built head to north.

I have had more opportunities of experimenting in such ships than any others, and I am satisfied that after being a short time afloat and in motion, particularly under steam, they exhibit more change in their magnetic intensity than those built in any other direction. Their errors from heeling, too, are very considerable, so that an upright centre magnet cannot well be dispensed with in such ships.

I do not think that ships built head to south would be liable to the same objections, certainly not to the same extent, though even they might not be found to answer so well in the southern hemisphere; and this matter, as to where a ship was likely to trade to, should, I think, be rather considered by any one about to determine the best direction for laying down a vessel's keel, than as to whether she was to be a sailing ship or a steamer, as I do not think the machinery in an *iron* ship exercises much influence on the after compass, compared with that of a much smaller amount of vertical iron near it, and the magnetism of which can scarcely fail to be altered by a change of hemisphere. On the whole, if I were to offer an opinion on the subject, I should be disposed to recommend an east and west direction as the best generally for laying down a ship's keel. I have myself adjusted some new ships built head to west, and found the compensation easy, and the residual errors small and uniform.

I have latterly had reason to think that some ships experience a temporary change of magnetism whenever their machinery has been a few hours in motion, and that the errors so induced disappear again after a similar period of rest; so that though the compass might exhibit little or no error on a particular course at the commencement of a voyage, it would be found considerably in error on the same course after a day's steaming. I have had a couple of reports of such cases lately, and one, at least, of them I think quite reliable; so much so, that I intend to take an early opportunity of ascertaining at sea whether it is so, and will then communicate the result, and am, my dear sir, yours, very truly,

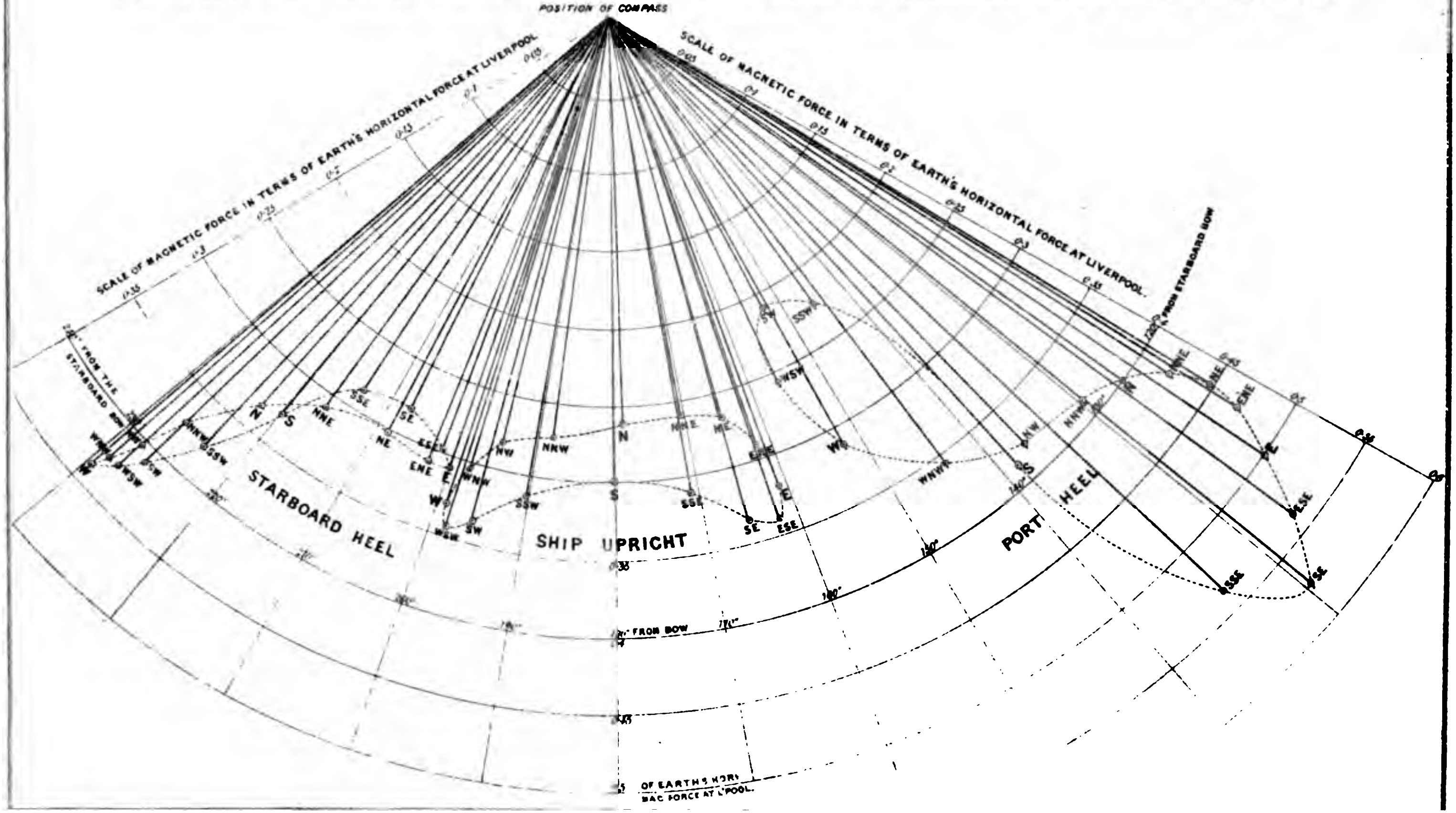
THOS. BENNETT.

Mr. W. W. RUNDELL.

Nº 31

"CITY of BALTIMORE," S.S., DIPPING NEEDLE COMPASS.

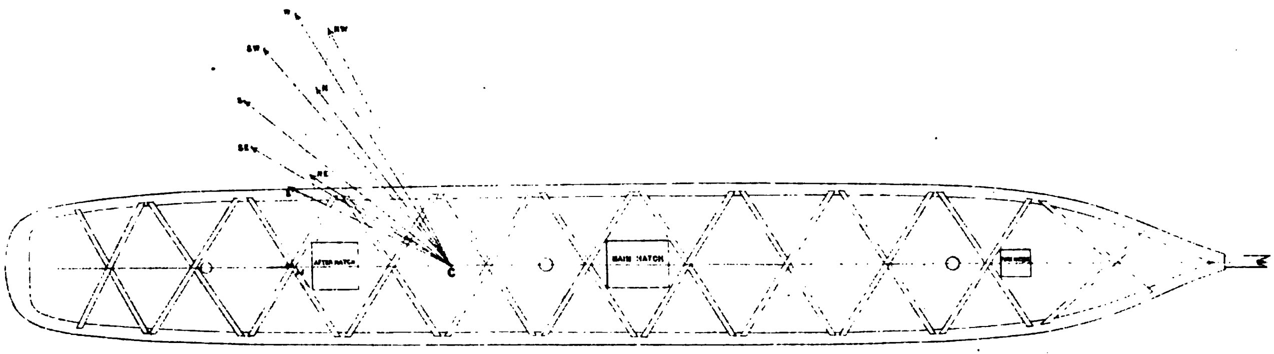
DIAGRAMS TO SHOW APPROXIMATE AMOUNT AND DIRECTION OF SHIP'S HORIZONTAL MAGNETIC FORCE, WITH SHIP'S HEAD ON EACH POINT OF THE COMPASS. (CORRECT MAGNETIC.)



CITY OF
WEST
EAST
SOUTH
WEST
NORTH

"Lexington"

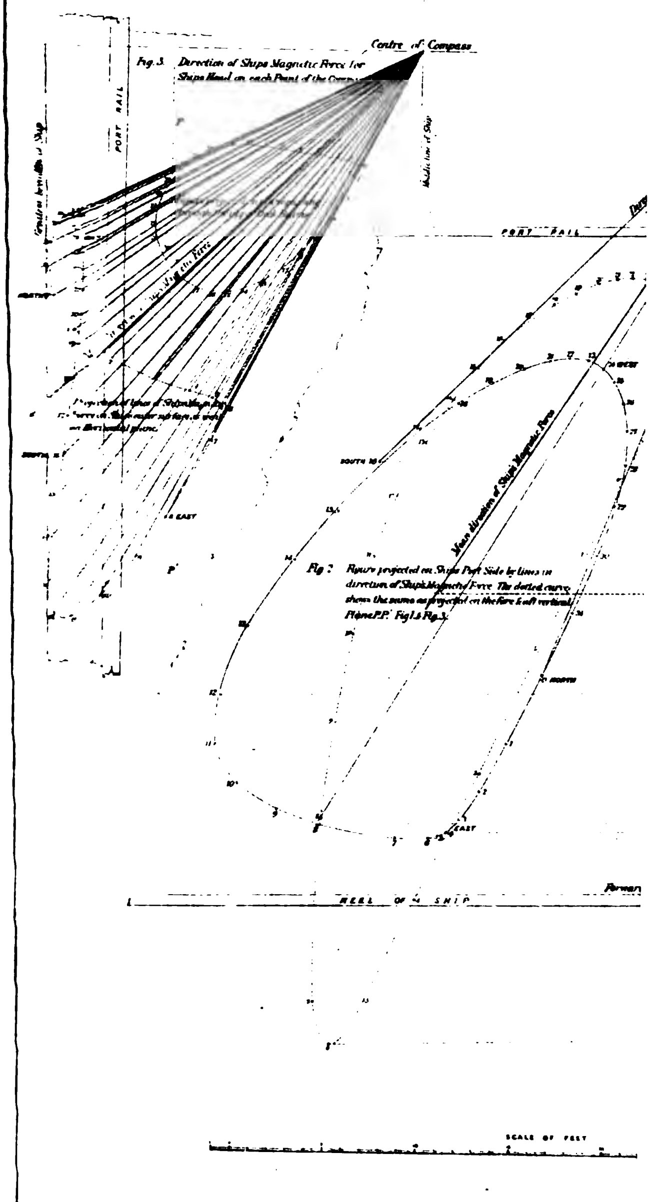
Arrangement of Diagonal Deck Ties on Spar Deck.



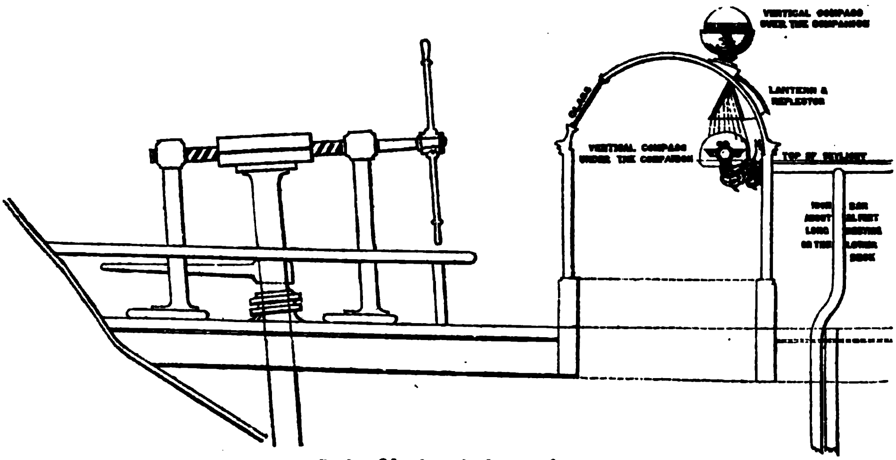
C. *Position of the Standard Compass.*
The arrows show the relative amount and direction of ships horizontal magnetic force when ships head was towards the eight principal points of the compass correct magnetic

Nº 33.

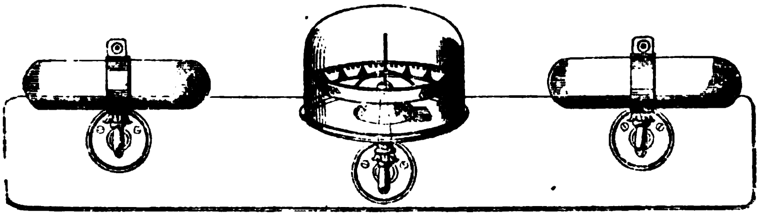
IRON SHIP "ACCRINGT



" APHRODITA."

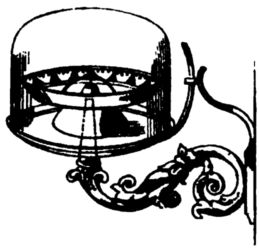


Scale ·24 of an inch to a foot.



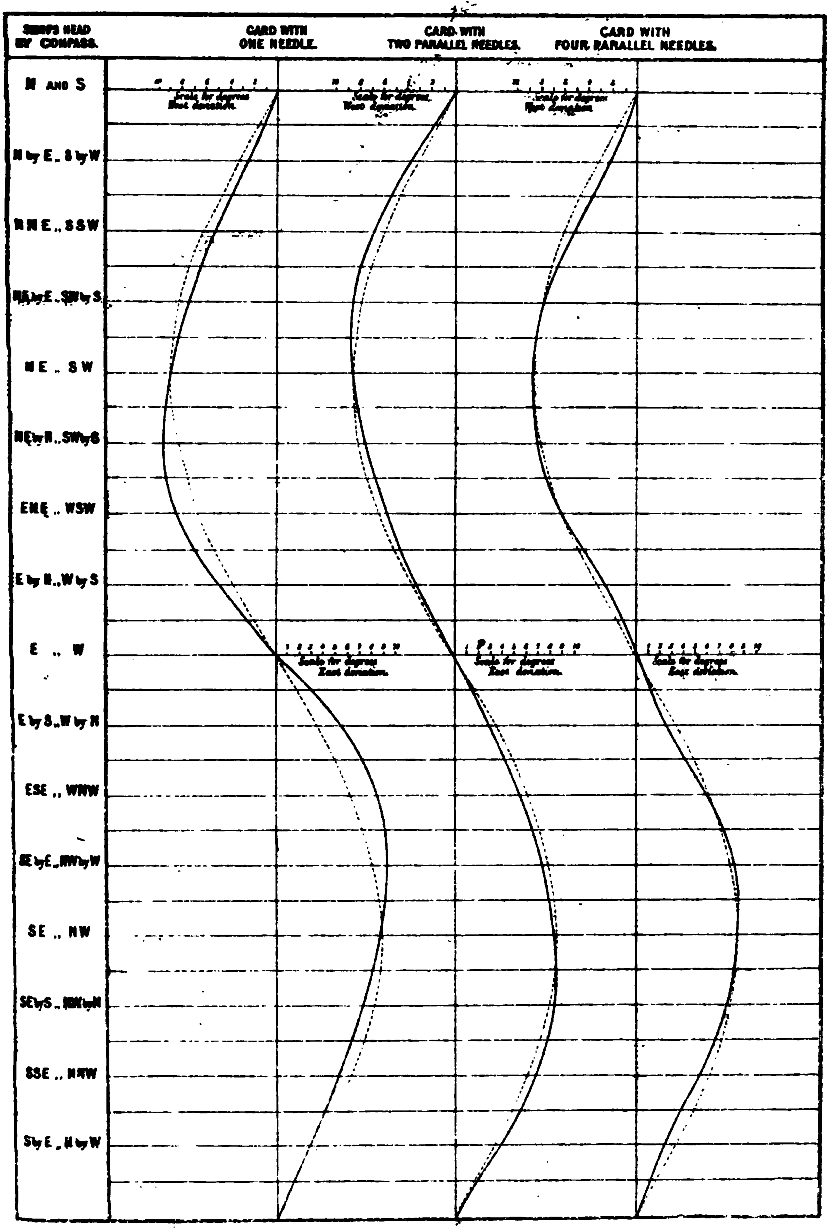
Scale
1-inch
to a foot.

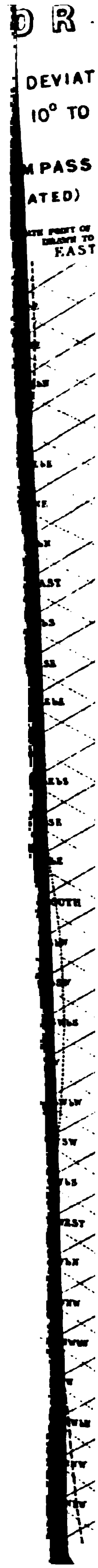
Compass under the Companion as seen from the Wheel
showing the cast-iron correctors for quadrantal deviation.



Side view of Vertical
Compass under the Companion.

No. 36.


CARD WITH ONE NEEDLE.
CARD WITH TWO PARALLEL NEEDLES.
CARD WITH FOUR PARALLEL NEEDLES.
N AND S
N by E ,, S by W
NNE ,, SSW
NE by E ,, SW by S
NE ,, SW
NE by N ,, SW by S
ENE ,, WSW
E by N ,, W by S
E ,, W
E by S ,, W by N
ESE ,, WNW
SE by E ,, NW by W
SE ,, NW
SE by S ,, NW by N
SSE ,, NNW
S by E ,, N by W
Scale for degrees East deviation.


D R
DEVIAT
10° TO
PASS
ATED)
EAST

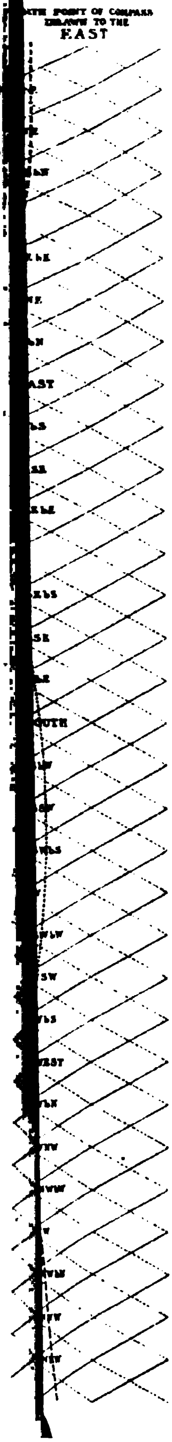
D R E.

DEVIATIONS WITH THE SHIP

10° TO STARBOARD.

MPASS

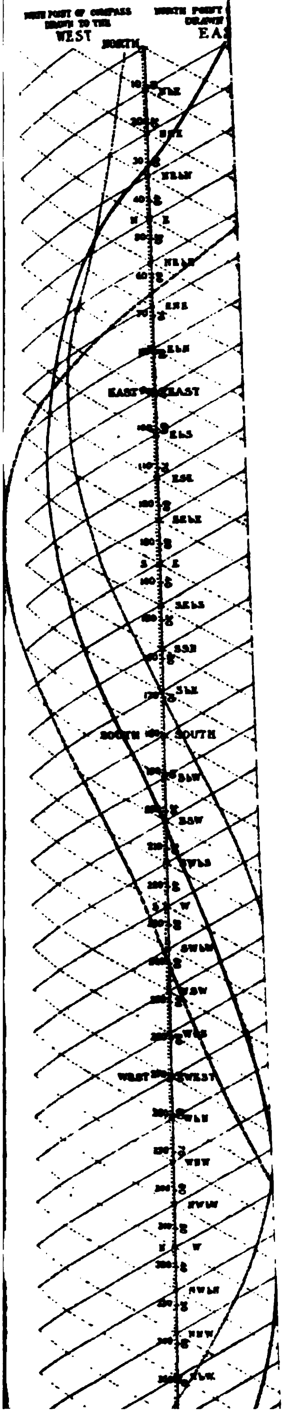
ATED)



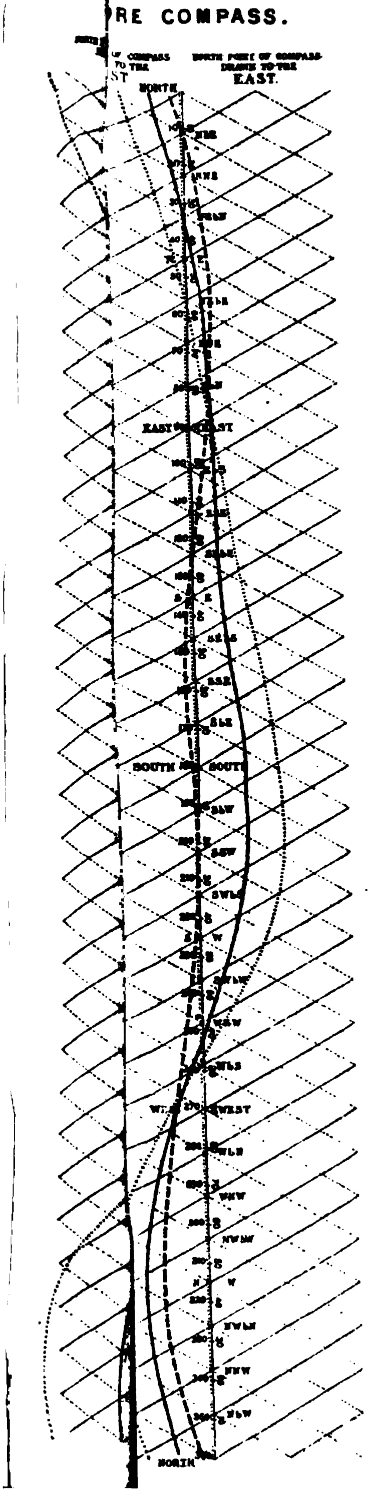
CURVES SHOW THE

COMPASS PLACED IN THE O

POSITION OF A STEERING



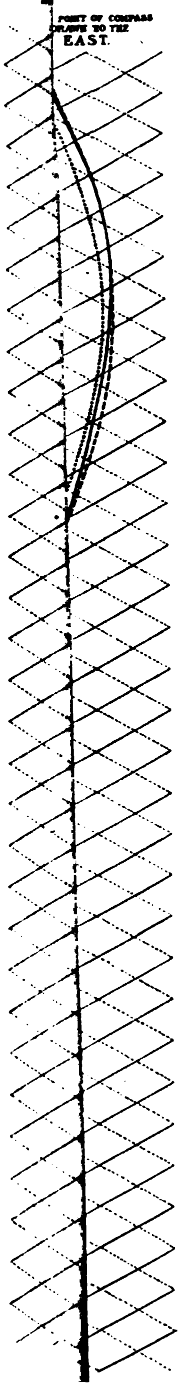
Nº 39.


RE COMPASS.
NORTH POINT OF COMPASS DRAWN TO THE
EAST.
NORTH
EAST
SOUTH
WEST
NORTH

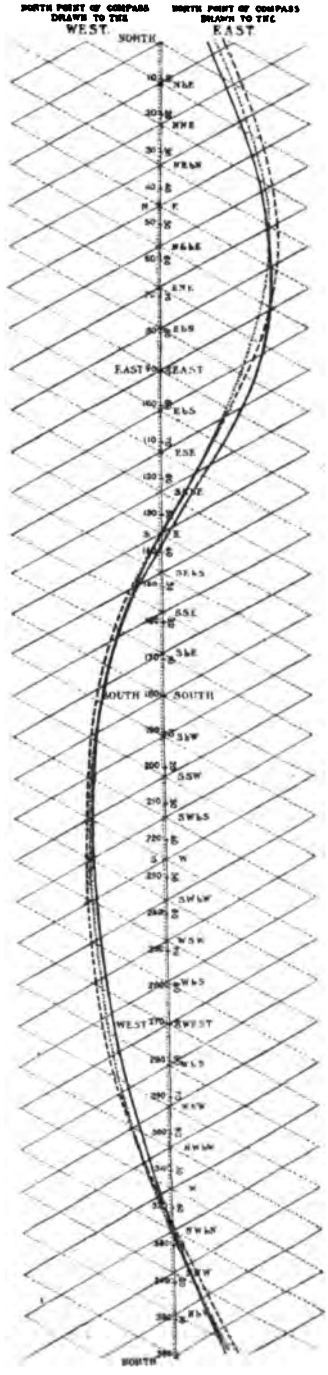
LED 10° TO PORT;

N°40.

N THE
SKYLIGHT.



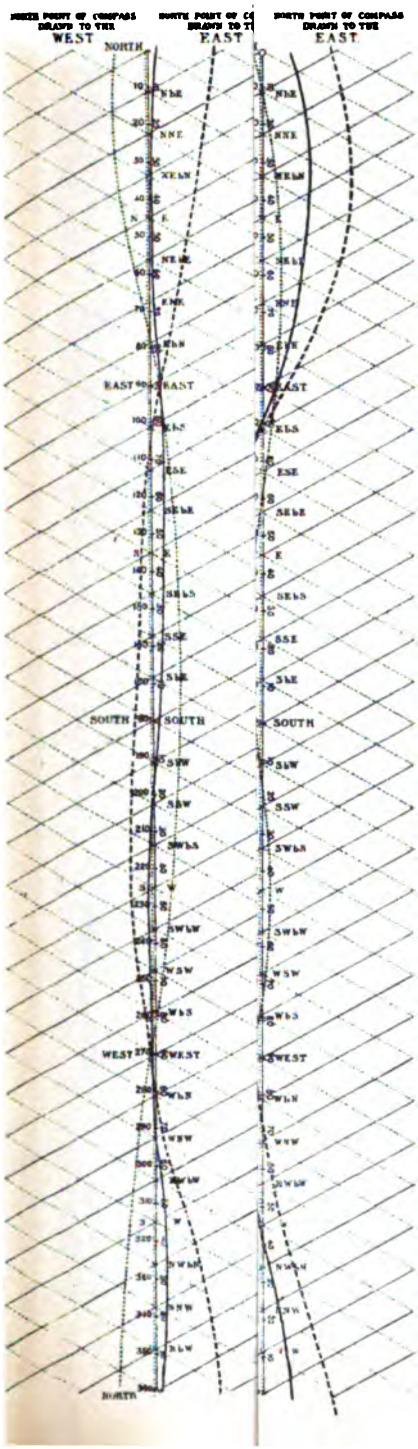
COMPASS ON THE
STARBOARD SIDE OF SKYLIGHT.



CURVO PORT;

N°41.

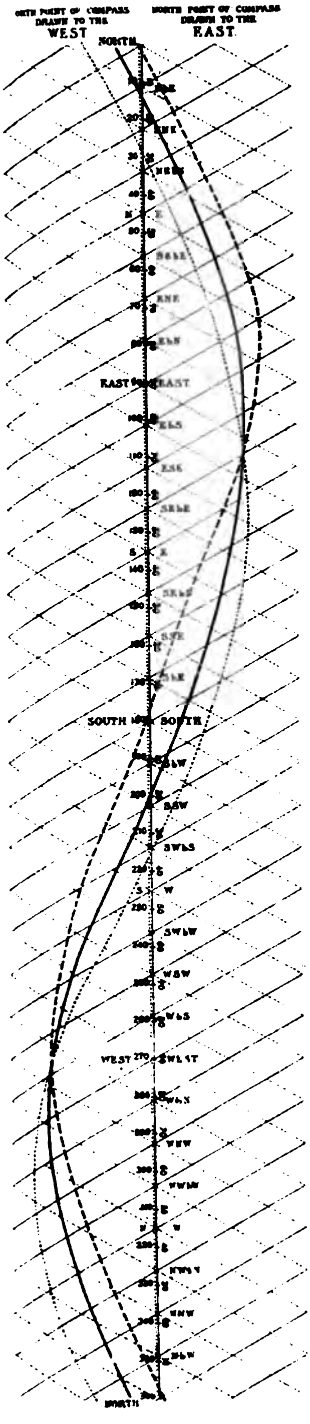
STEERING COMPASSCOMPASS.



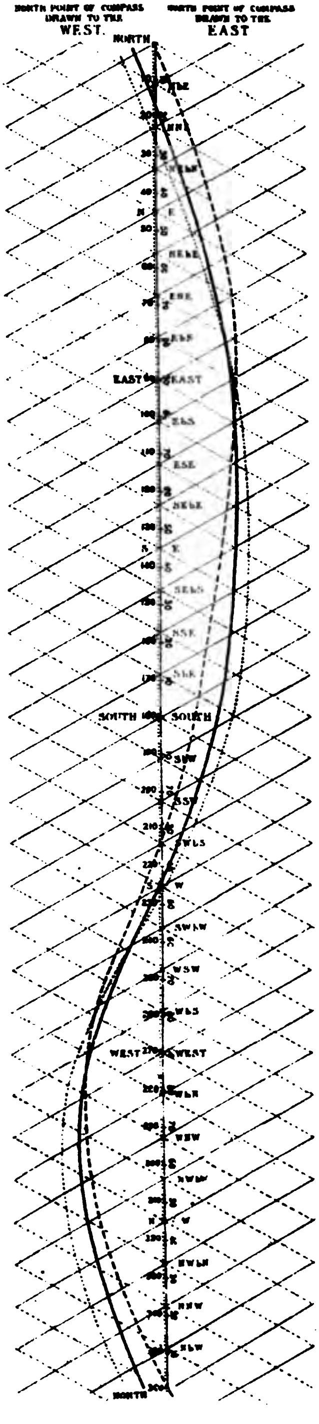
GITANA.

No. 42.

FORE COMPASS.

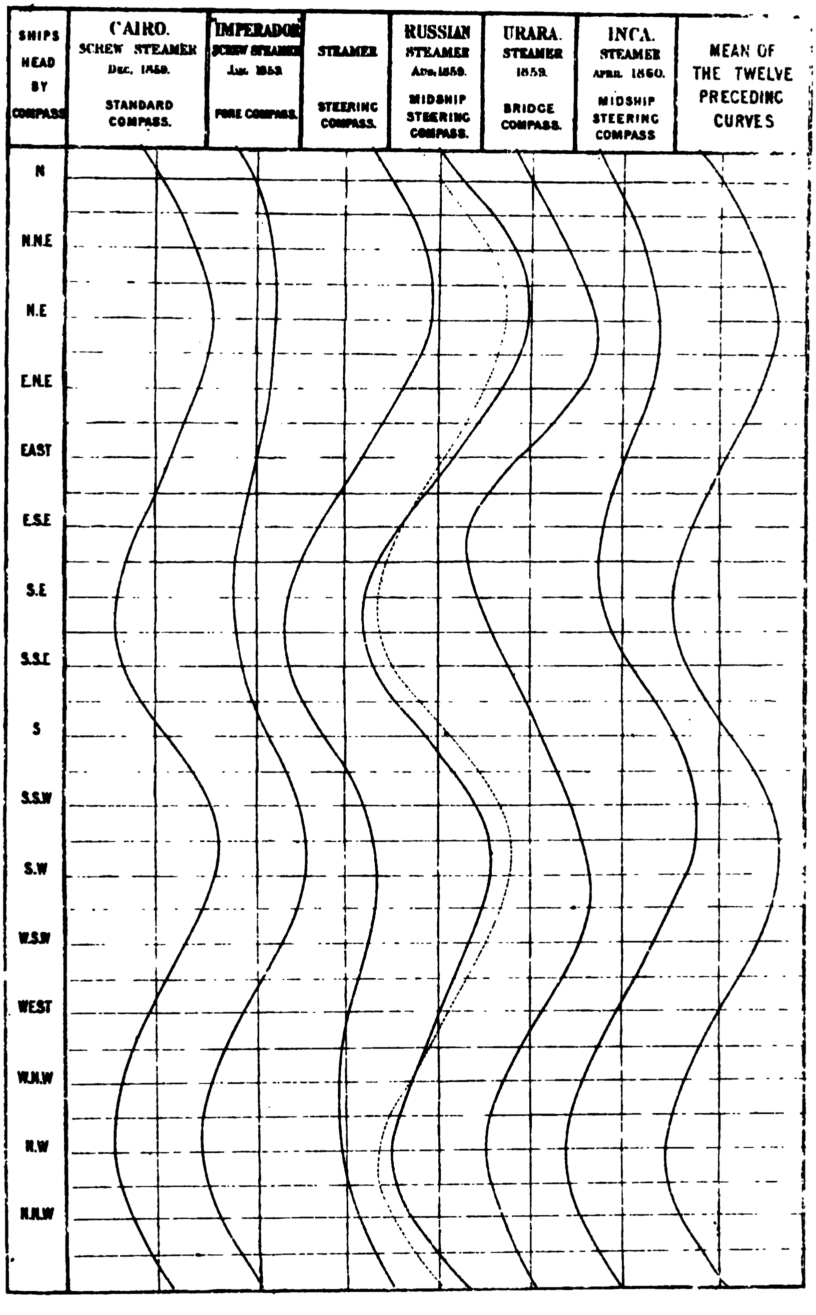


STANDARD COMPASS.

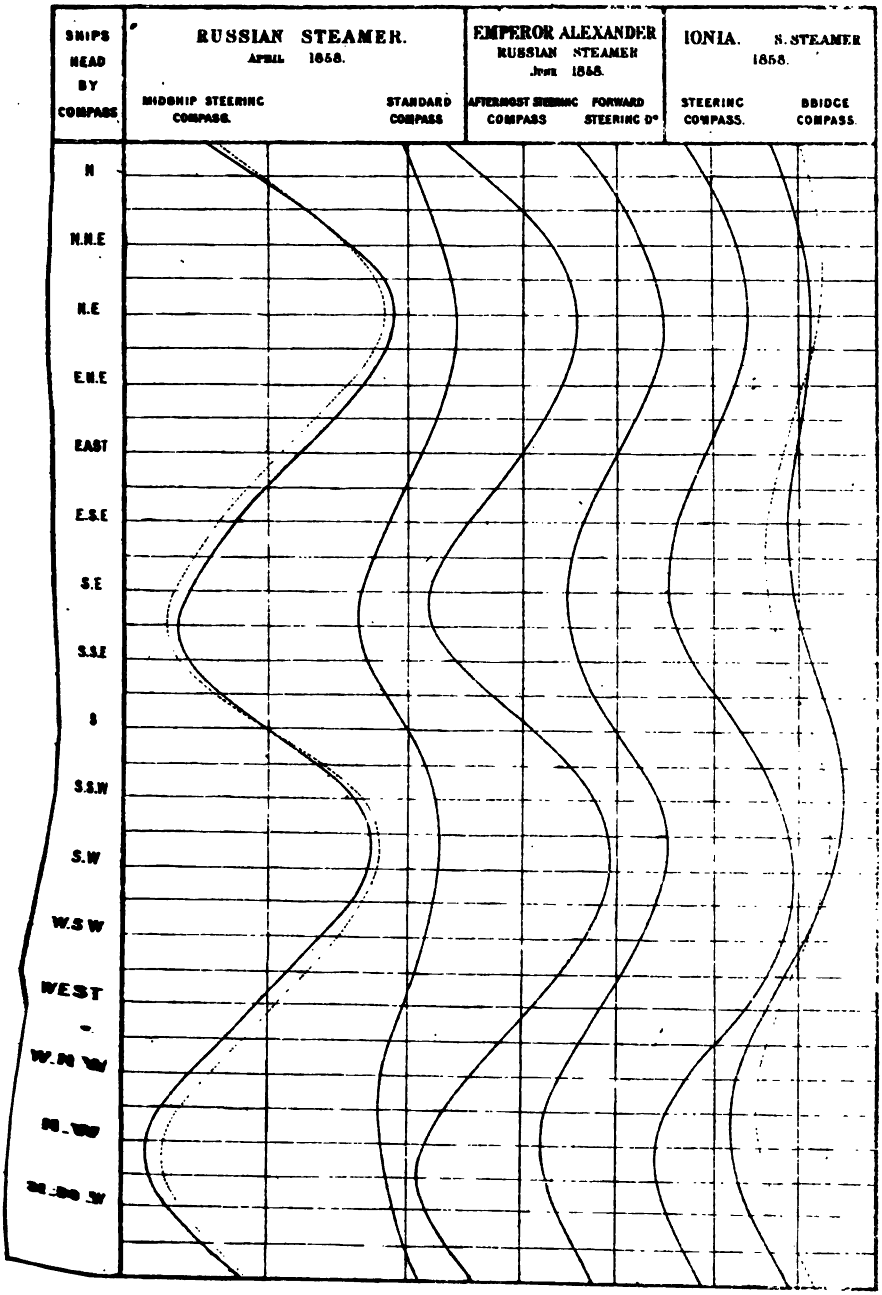


——— CURVES SHOW THE DEVIATIONS WITH SHIP UPRIGHT: - - - - - CURVES THE DEVIATIONS WITH THE SHIP HEELING 10° TO PORT; .... CURVES THE DEVIATIONS WITH THE SHIP HEELING 10° TO STARBOARD

CURVES OF COMPASS DEVIATIONS OBSERVED WHEN THE SHIPS POLAR MAGNETISM HAS BEEN MORE OR LESS COMPLETELY COMPENSATED

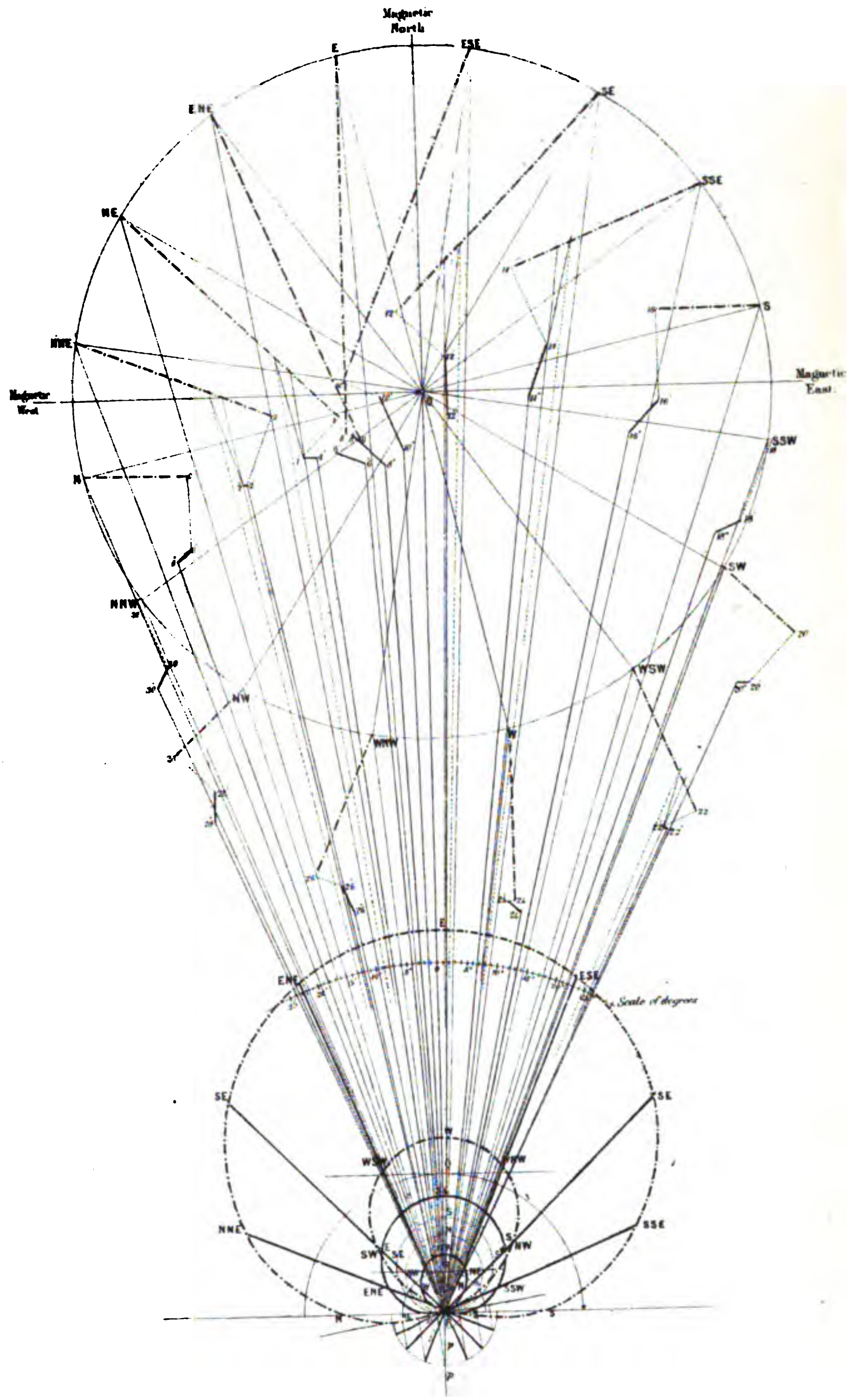


CURVES of COMPASS DEVIATIONS OBSERVED WHEN THE SHIPS POLAR MAGNETISM HAS BEEN MORE OR LESS COMPLETELY COMPENSATED.



Scale of degrees for deviation.

Nº 45



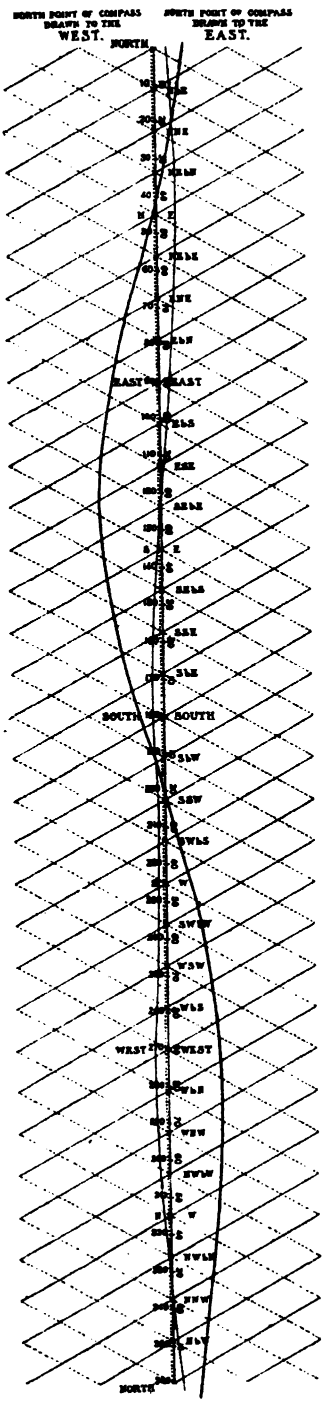
Magnetic North
Magnetic West
Magnetic East
Scale of degrees

IRON SHIP "ADVANCE"

SECOND VOYAGE.

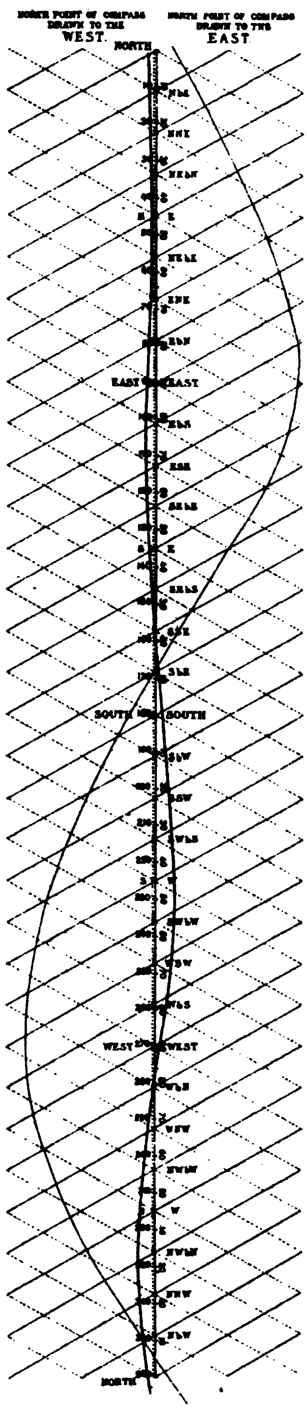
No. 47.

STANDARD COMPASS.



The Strong Curves show Approximate Deviation at Liverpool.—
The Fine Curves show Approximate Deviation South of Cape of Good Hope.—

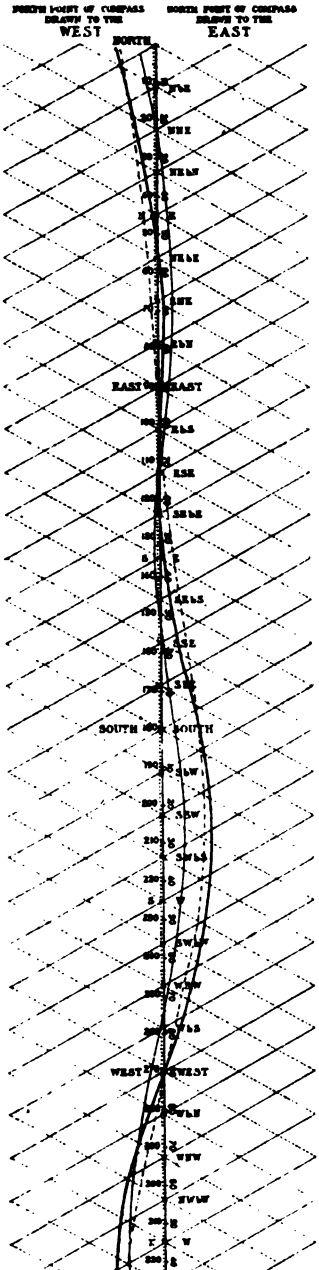
STEERING COMPASS.



IRON SHIP "SIMLA". Nº 48.

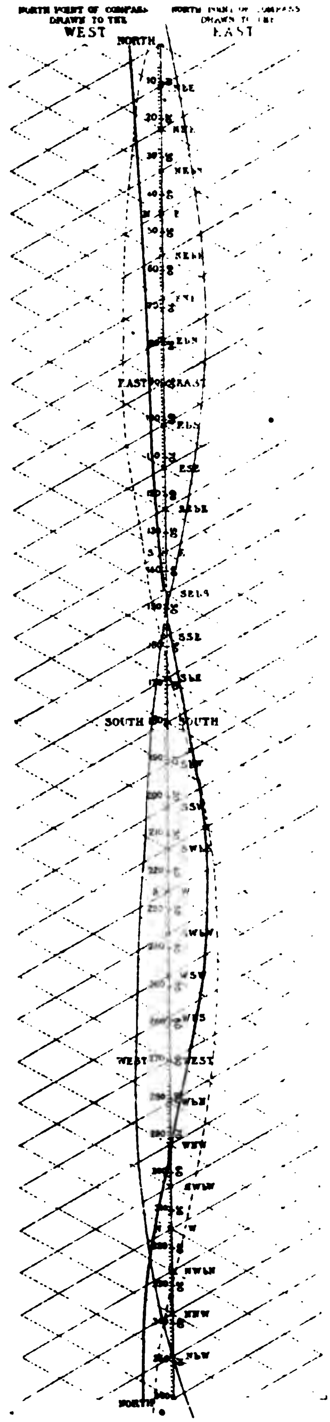
SECOND-VOYAGE.

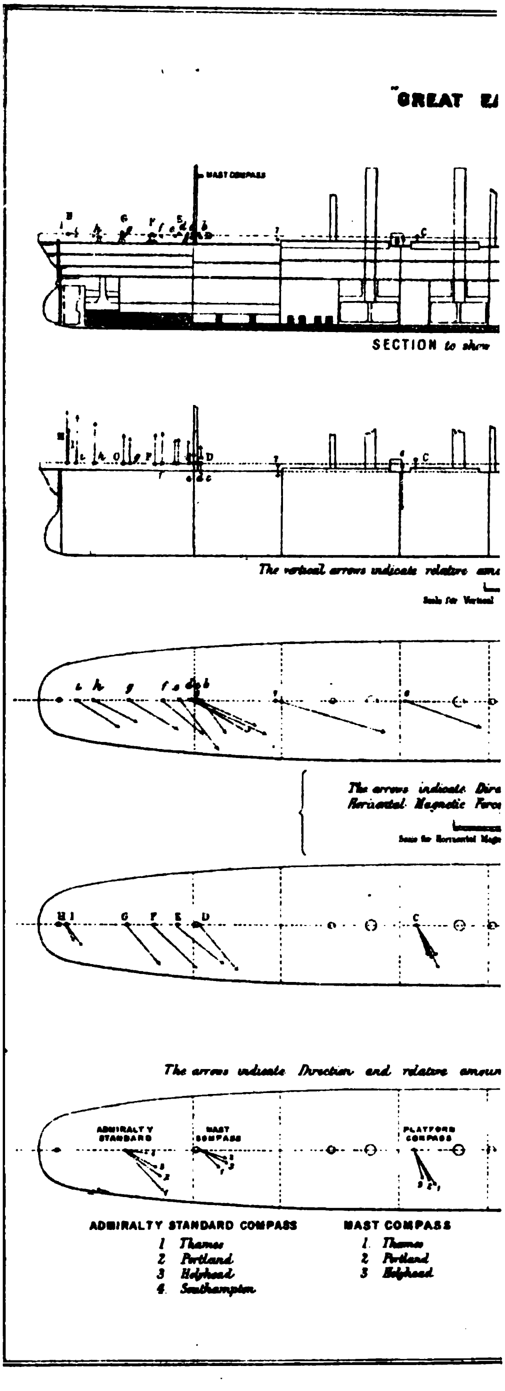
STANDARD COMPASS.



The Strong Curves show the Deviation on the Outward Voyage. Latitude 50° 0′ N Longitude 8° 30′ W
The Light Curves show the Deviation in the Southern Hemisphere. Latitude 44° 50′ S Longitude 35° 10′ E
The Dotted Curves show the Deviation on the Homeward Voyage. Latitude 45° 30′ N Longitude 11° 0′ W

STEERING COMPASS




"GREAT EA
MAST COMPASS
SECTION to show
The vertical arrows indicate relative amo
Scale for Vertical
The arrows indicate Dire
Horizontal Magnetic Forc
Scale for Horizontal Magn
The arrows indicate Direction and relative amoun
ADMIRALTY STANDARD
MAST COMPASS
PLATFORM COMPASS
ADMIRALTY STANDARD COMPASS
1 Thames
2 Portland
3 Holyhead
4 Southampton
MAST COMPASS
1 Thames
2 Portland
3 Holyhead

MR. ARCHIBALD SMITH'S INTRODUCTION

TO

DR. SCORESBY'S JOURNAL OF THE ROYAL CHARTER.

The voyage of which this volume contains the journal was undertaken by Dr. Scoresby, with the object of observing the changes which take place in the magnetic state of an iron ship in proceeding from a northern to a southern magnetic latitude, and of deciding certain questions as to the best mode of correcting the deviations of the compass in such a ship. The object was one of great importance, not only as regards science but as regards humanity. To the love of science and the devotion to the cause of humanity, which led Dr. Scoresby to undertake this voyage at an advanced period of his life, he may be said to have fallen a martyr. He did not live to prepare his journals for the press; and at the request of Major General Sabine, in whose hands his papers were placed by Mrs. Scoresby and his executors, I have undertaken the office of editor.

The materials which Dr. Scoresby left consisted, besides the record of his magnetical observations, of his journal, written from day to day, and of an introductory dissertation on magnetism, of which the MS. was nearly complete. With regard to the publication of the journal some hesitation has been felt. A detailed narrative of a voyage made on a well-known and frequented track, and diversified by no unusual incidents, may seem hardly of sufficient interest for publication; but there are considerations which lead to the conclusion that the journal may be published, and with advantage, nearly in the shape in which it was written. Dr. Scoresby had some peculiar advantages as the narrator of such a voyage. He had been a sailor by profession, and had commanded several ships in voyages to the Arctic Seas. He was afterwards a landsman for thirty years. In this interval great changes had taken place in the material, form, size, and management of vessels. A new class of vessels—the iron clipper, with an auxiliary screw—had come into existence. In making a voyage in such a vessel to the southern hemisphere, Dr. Scoresby united the fresh interest in details which a seaman can seldom have, and the nautical knowledge which enabled him, not only to observe and describe accurately what was done, but to understand and point out why it was done. The voyage, too, is one of great interest to many of our countrymen. And if it cannot be expected that the narrative will have much general interest, it cannot be doubted that there are many to whom even the most minute and trivial details will have a special interest.

The particular questions to which Dr. Scoresby's attention was directed during the voyage had been the subject of controversy between him and a mathematician and philosopher of the very first rank—the Astronomer Royal; and I cannot place my readers in a position to judge of the motives and results of Dr. Scoresby's voyage without entering in some degree into the points of difference between them. These were of great importance, both theoretical and practical. They concerned the nature of the magnetism of the rolled and hammered iron of which an iron vessel is chiefly composed, the changes which that magnetism undergoes, and the mode of correcting the deviation of the compass caused thereby, and particularly the well-known mode of correcting the deviation by the application of magnets and soft iron proposed by Mr. Airy in the year 1839, and extensively used in the mercantile navy. This mode of correction Dr. Scoresby, in common with many or most of those who have examined the question, among whom I may rank myself, considered to be not only erroneous in principle but dangerous in practice. He protested strongly against it on all occasions, and his sense of its danger was one of the motives which induced him to undertake the voyage. Under these circumstances, it will not, I trust, be considered that I am overstepping the bounds of my duty as editor, if I endeavour to ascertain what was correct or mistaken on each side of the controversy. As will be seen in the sequel, I have been led to think that Dr. Scoresby has, with others, misunderstood Mr. Airy's meaning in a most important particular, and that his own theoretical views were thereby, to some extent, diverted from considerations to which he might otherwise have attributed greater importance. If I succeed in any degree in my own object, I am confident that I shall at least be advancing what each of the parties in the controversy valued far more than the acceptance of any particular theoretical views. The points in controversy will be more easily understood, if I give a short sketch of the history of our knowledge of the "deviation of the compass."

The history of the "deviation of the compass" dates from the commencement of the present century. It had, indeed, been noticed by navigators of the last century, and its cause suggested, but no systematic attempt had been made to investigate its laws, or to discover the means of correcting it, until the voyage of Captain Flinders to Australia, in the years 1801–1803. Captain Flinders observed (Voyage, vol. II, App. II.) that when his ship's head was directed to the N. or S., (magnetic,) there was no deviation; when to the E. or W., (magnetic,) a maximum deviation; that the amount of deviation had a close connection with the dip of the needle; that in northern magnetic latitudes, the *north* end of the needle of a compass in the usual place in the ship was drawn towards the bow; that at the equator there was no deviation; that in Bass's Strait, where the southern dip is nearly as great as the northern dip in the English Channel, the *south* end of the needle was drawn towards the bow. He attributed the deviation to its true cause—the attraction of the iron in the ship magnetised by induction from the Earth. He gives a correct explanation of the mode of action, and from comparing observations made in different magnetic latitudes, he deduced the conclusion, that the deviation is proportional to the *dip* multiplied by the sine of the azimuth of the ship's head from the magnetic meridian. In this conclusion Captain Flinders was mistaken. The deviation in such vessels as Captain Flinders's, viz., wooden sailing ships, is in truth more nearly proportional, being directly proportional to the vertical force of the Earth, (its cause,) and inversely proportional to the horizontal force, (the directive force on the needle,) to the *tangent* of the dip. The difference, however, is not material, except in high magnetic latitudes. Captain Flinders further leaves out of account that part of the deviation which will hereafter be referred to under the term "quadrantal deviation." But this is of very small amount in vessels like Captain Flinders's; so that to wooden sailing ships, in low or middle magnetic latitudes, to which alone Captain Flinders refers, his formula and the mode of correction which he proposes, are still applicable. He observes that the trouble of correction may be saved, if a place can be found near the taffrail where the attraction of the iron at the stern will counteract, by its greater vicinity, the more powerful attraction of the centre and fore parts of the ship, and that, *should the attraction be too weak, it may be increased by fixing one or more upright stancheons or bars of iron in the stern.* He says: "If a neutral station can be found or made exactly amidships, and of a convenient height for taking azimuths and bearings, let a stand be there set up for the compass, and if the stand must of necessity be moveable, make permanent marks, that the exact place and elevation may always be known. Observations taken here should never undergo any change from altering the direction of the ship's head at any dip of the needle, but it will be proper to verify occasionally, and to compare the azimuths and bearings with others taken on the binnacle. The course should also be marked from this compass, though the ship be steered by one before the wheel, a quarter or half point being allowed to the right or left according as the two may be found to differ."

I have quoted these observations at length because, as regards the deviation in wooden sailing ships, little can be added to them in the present day. The mode of correction suggested, viz., by vertical iron bars, is certainly preferable to that afterwards proposed by Mr. Barlow.

The large deviations of the compass experienced in ships in the Arctic regions attracted the attention of Dr. Scoresby, in the several voyages made by him in command of whaling ships. The results of his observations and of his consideration of the subject will be found in the Philosophical Transactions for 1819, p. 96; in the "Account of the Arctic Regions," vol. II., p. 537; and in the "Journal of a Voyage to the Northern Whale Fishery," etc., p. 89.

In the second of these, p. 547, Dr. Scoresby very nearly obtained the true law connecting the deviation arising from induced magnetism with the dip; for he observed that the increased deviation is owing, not only to the increase of local attraction, but to the diminution of the directive force of the Earth on the needle.

The subject attracted the attention of the officers who accompanied Sir John Ross and Sir Edward Parry in the several voyages for the discovery of a northwest passage, between the years 1818 and 1824, and among others, of Major General (then Captain) Sabine, R. A., who accompanied these expeditions as astronomer. The results of Captain Sabine's observations are given in a paper in the Philosophical Transactions for 1819, p. 120. In this paper, Captain Sabine points out that the deviation depends as well on the diminution of the directive force on the needle, as on the increase of the force causing the deviation, but without expressly deducing the mathematical expression for the law of dependence of the principal co-efficient of the deviation on the dip.

This, so far as I am aware, was first done by Dr. Thomas Young, in a paper in Brande's Quarterly Journal for 1820, vol. IX., p. 372. In this paper Dr. Young showed that the deviation produced by the permanent magnetism of the ship varies inversely as the Earth's horizontal force, and that the deviation produced by the vertical force acting on a mass of soft iron varies as the tangent of the dip. Dr. Young went on, and he was, I believe, the first who did so, to consider the effect of the horizontal force in producing the part of the deviation which has been termed "quadrantal;" but in doing so, if I have not misunderstood his process, his results are vitiated by the accidental use of a sine for a cosine.

In the year 1820, Mr. Barlow published his "Essay on Magnetic Attractions." In this work he proposed to correct the deviations of a ship's compass by the application to it of a ball or plate of soft iron, found, by experiments made with it on a compass on shore, to produce deviations of the same amount and direction as the deviations produced on the compass on board by the iron of the ship. He appears to have at first proposed to destroy the deviations of the compass in the ship by applying the plate permanently to the compass on board, in an opposite direction to that in which it produced the same deviations as the iron of the ship; but finding that the deviations could not thus be entirely destroyed, he then proposed to apply the plate temporarily in the position in which it produced the same deviation as the iron of the ship, so as to double the deviation caused by the ship. The amount of the deviation so obtained was then to be applied in the opposite direction as a numerical correction. The cause of the failure of Mr. Barlow's plate in the first position has been pointed out by M. Poisson and Mr. Airy. The deviation consists mainly of two parts: first, that part described by Captain Flinders, which varies as the sine and cosine of the azimuth of the ship's head from the magnetic north, and which may be called the "semicircular" deviation; and, secondly, that part which varies nearly as the sine and cosine of twice the same angle, and which part has been called the "quadrantal" deviation. A plate which is found by experiment to produce the same semicircular and quadrantal deviation as the iron of a ship, will, when applied in the opposite direction, destroy the semicircular deviation, but will double the quadrantal. From this objection the vertical bar of iron proposed by Captain Flinders is free. It corrects the semicircular deviation without affecting the quadrantal deviation. The substitution of the plate for the bar by Mr. Barlow seems, therefore, in this respect, to have been a retrogade step, nor am I aware that there are any other advantages in the plate over the bar which justify the high encomiums which have been generally bestowed upon it.

In the year 1824, Poisson's two Memoirs on the Theory of Magnetism were communicated to the Institute, and published in the fifth volume of the Memoirs of the Institute. In these memoirs, M. Poisson founded a mathematical theory of transient induced magnetism, on the physical theory of Coulomb, that by induction each particle of soft iron becomes a magnet, having an intensity proportional to that of all the forces which act on it, including the force of the magnetism developed by induction in all the other particles of the mass. In the second memoir, M. Poisson gives, to express the action of the soft iron on the compass, formulæ involving co-efficients to be determined by observation. In another memoir, communicated to the Institute in 1839, and printed in the sixteenth volume of the Memoirs, "Sur les Déviations de la boussole produites par le fer de vaisseux," M. Poisson has adapted the formulæ to observations made on shipboard, sufficient in number to determine the co-efficients in the particular case of the soft iron being symmetrically placed on each side of the principal section of the vessel. The writer of this notice afterwards modified Poisson's formulæ so as to adapt them to the form in which the data generally present themselvs, viz: a vessel having hard as well as soft iron—both unsymmetrically distributed—and observations of deviation being made in a certain number of equidistant points, as shown by the compass affected by deviation. In this case we have generally more equations than are necessary to determine the co-efficients; but the application of the method of least squares, owing to certain well-known properties of trigonometrical series, gives the values of the co-efficients explicitly, in a very simple form. These forms will be found in a pamphlet, entitled "Instructions for the Computation of a Table of the Deviations of a Ship's Compass," etc., published by order of the Lords Commissioners of the Admiralty, as a supplement to the "Practical Rules for ascertaining the Deviations of the Compass;" and also, in the Philosophical Transactions for 1848, p. 347.

The subsequent part of this sketch will be better understood, if some of the conclusions derivable from Poisson's (Coulomb's) theory are here indicated.

The problem of finding the attraction, on a magnetic particle at any given place, of a mass of soft iron of given shape magnetised by induction, or of a mass of hard iron of given shape permanently magnetised according to any given law, is one in general of insuperable difficulty.

But the problem we have to deal with is much simpler. The compass needle may be considered as infinitesimally small, compared to the distance from it of the nearest iron, the iron retains the same place relatively to the compass and to the ship; and, lastly, the data of the problem are, not the shape and position of the iron, but its effects on the needle in a certain number of the positions of the ship as shown by the disturbed compass. Taking advantage of these circumstances, the problem admits of an easy and complete solution.

In the mathematical treatment of this problem, it is necessary, (at least in the first instance,) to make the assumption that every portion of the iron in the ship is, as regards magnetism, of one or other of the two extreme qualities, called "soft" and "hard." "Soft" iron, is iron which becomes instantly magnetised to its full capacity, when exposed to the influence of any magnetised body, and which loses its magnetism instantly when the influencing body is removed. "Hard" iron is iron which does not become magnetised by ordinary induction, but which, when magnetised, retains its magnetism unaffected by the influence of other magnetic bodies. The assumption is not strictly true of any iron. All iron appears to be in an intermediate state, requiring time and the molecular disturbance produced by blows, bends, or twists, to receive or lose magnetism. This intermediate state the mathematician must deal with, by supposing the co-efficients in the expressions derived from the supposition we have mentioned, to undergo a change, or by some expedient of the same kind. The magnetism of such iron is called by Dr. Scoresby "retentive," by the Astronomer Royal "sub-permanent."

The effect of hard iron on the compass is very simple. It gives rise to a single disturbing force of constant amount, acting in a constant direction in the vessel, or, as we may consider it, to three disturbing forces of constant amount—one acting *fore-and-aft*, one acting *athwartship*, and the third acting *vertically*.

The first will produce a deviation proportional (the deviations being small) to the sine of the azimuth of the ship's head; the second will produce a deviation proportional to the cosine of the azimuth. The third will produce no deviation when, as we here suppose, the ship is on an even keel. The whole effect is, therefore, what I have called a "semicircular" deviation. The force which causes this deviation being constant, the deviation produced, for a given azimuth of the ship's head, will be inversely proportional to the horizontal force of the Earth at the place.

The magnetism induced in the soft iron of the ship by the vertical force of the Earth will produce a disturbing force of the same nature, as regards the constancy of its direction in the ship, but of which the magnitude for a given azimuth is proportional to the Earth's vertical force. It therefore produces a semicircular deviation, the amount of which is directly proportional to the Earth's vertical force, and inversely proportional to the Earth's horizontal force, *i. e.*, which is directly proportional to the tangent of the dip.

The deviation produced by the horizontal force of the Earth is less simple in its law. For the single force we may substitute its two resolved parts: one directed towards the ship's head, and equal to the horizontal force multiplied by the cosine of the azimuth of the ship's head; the other directed to the starboard side, and equal to the horizontal force multiplied by the sine of the azimuth of the ship's head. Each will produce a disturbing force proportional to the resolved part of the horizontal force, but not generally in its direction. The combination of the two resolved parts gives a disturbing force, acting fore-and-aft, proportional to the horizontal force, and varying partly as the cosine and partly as the sine of the azimuth, and to a similar disturbing force acting athwartship.

The fore-and-aft force proportional to the cosine of the azimuth, and the athwartship force proportional to the sine of the azimuth, produce no deviation when the ship's head is on any of the four cardinal points, because on each the force is either zero or acts in the direction of the needle, and they produce a maximum deviation when the ship's head is near any of the intermediate points, N.E., S.E., S.W., N.W. They therefore produce a "quadrantal" deviation proportional nearly to the sine of twice the azimuth.

The fore-and-aft force proportional to the sine of the azimuth produces no deviation when the ship's head is N. or S., and a maximum deviation when E. or W.; but this is not, as at first sight it might seem, a "semicircular" deviation, because the two maxima act in the same direction. The mean is, therefore, a constant deviation in one direction; and the variable part is a quadrantal force, of which the maxima occur when the ship's head is on the four cardinal points, proportional nearly to the cosine of twice the azimuth. The same observations apply to the deviation cause by the athwartship force proportional to the cosine of the azimuth.

The last mentioned disturbing forces and the directive force on the needle being each proportional to the horizontal force, the deviations produced by them are independent of the Earth's force, and will be the same in any part of the globe.

The following, then, are the results:

The permanent magnetism of the hard iron causes a semicircular deviation inversely proportional to the horizontal force.

The transient magnetism induced in the soft iron by the vertical force of the Earth causes a semicircular deviation proportional to the tangent of the dip.

The transient magnetism induced in the soft iron by the horizontal force of the Earth causes a constant deviation and also a quadrantal deviation, both independent of the latitude.

These results are thus expressed mathematically: If δ be the deviation, reckoned positive, when the N. point of the compass deviates to the E.; θ the dip of the needle; H the Earth's horizontal force; ζ' the azimuth (by compass) of the ship's head, reckoned from the magnetic north to east:

$$\delta = A + \left(B_1 \tan\theta + \frac{B_2}{H}\right)\sin\zeta' + \left(C_1 \tan\theta + \frac{C_2}{H}\right)\cos\zeta' + D\sin 2\zeta' + E\cos 2\zeta'$$

$A\ B_1\ B_2\ C_1\ C_2\ D\ E$ being constants, depending only on the quantity, quality, and position of the iron in the ship.

It is useful to familiarize ourselves with the consideration of masses of soft iron which may produce the several terms in this expression.

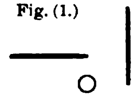
For this purpose, the most convenient shape to consider is a thin rod or bar.

Such a bar, held in the direction of the dip, receives by induction a magnetism proportional to the total force of the Earth's magnetism at the place; if held at any inclination to the dip, a magnetism proportional to the total force multiplied by the cosine of that inclination. A vertical bar, therefore, receives a magnetism proportional to the total force multiplied by the sine of the dip, *i. e.*, to the vertical force. A horizontal bar in the magnetic meridian receives a magnetism proportional to the total force multiplied by the cosine of the dip, *i. e.*, to the horizontal force. A horizontal bar in any other azimuth, receives a magnetism proportional to the horizontal force multiplied by the cosine of the azimuth.

It will easily be understood from what precedes, that a vertical bar of soft iron below the level of the compass and before it, or above and abaft, gives a positive B_1; above and before, or below and abaft, a negative B_1; below and to starboard, or above and to port, a negative C_1;

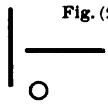
above and to starboard, or below and to port, a positive C_1. A horizontal bar of soft iron directed towards the compass, and before or abaft, gives a positive D; on the starboard or port side, a negative D; to N. E. or S.W., a negative E; to S.E. or N.W., a positive E; and two bars placed in the direction in the fig. (1,)

Fig. (1.)



a constant easterly deviation;

Fig. (2)



placed in the direction in fig. (2,)
a constant westerly deviation.

The results at which we have arrived are exact, provided the several co-efficients are so small that their squares and products may be neglected.

The exact expression, whatever be the value of the coefficients, may be obtained by mathematical operations of so great simplicity that I may, perhaps, be excused for reproducing them here.

Take the centre of the compass for the origin of the co-ordinates. Let X Y Z represent the total force of the Earth's magnetism resolved in the direction of (1) the head of the ship, (2) the starboard side, (3) vertically downwards. Each of these resolved forces will induce a force proportional to, but not generally in the direction of, the force which causes it, and therefore the resolved parts in the three directions of co-ordinates may be represented by $a\,X + b\,Y + c\,Z$ along the axis of X; $d\,X + e\,Y + f\,Z$ along the axis of Y; and $g\,X + h\,Y + k\,Z$ along the axis of Z. Let P Q R represent the resolved force of the permanent magnetism of the hard iron in the same directions. Then calling the whole forces which act on the needle in these directions X′ Y′ Z′, we have evidently

$$X' = X + a\,X + b\,Y + c\,Z + P$$
$$Y' = Y + d\,X + e\,Y + f\,Z + Q$$
$$Z' = Z + g\,X + h\,Y + k\,Z + R$$

The 12 co-efficients, $a\ b\ c\ d\ e\ f\ g\ h\ k$ P Q R, may be determined by observations made with a sufficient number of corresponding values of X′ Y′ Z′, X Y Z.

Observations with different values of X and Y are of course easily obtained by the ordinary process of swinging the ship.

Observations with different values of Z can only be obtained by heeling the ship, or by observations made in different magnetic latitudes.

The expression for the deviation is most conveniently obtained by the use of polar co-ordinates.

Let H represent the horizontal intensity of the Earth's magnetism, so that $H = \sqrt{X^2 + Y^2}$

Let θ represent the dip.

Let ζ represent the azimuth of the ship's head, reckoned to the east of the magnetic north, or the "correct magnetic course."

Let $H' = \sqrt{X'^2 + Y'^2}$ represent the horizontal intensity of the force, composed of the Earth's force and of the force of the iron in the ship, which acts on the needle.

θ' the dip of the needle acted on by the iron of the ship.

ζ' the azimuth of the ship's head, reckoned east from the N. point of the disturbed needle, or the "compass course."

Let $\delta = \zeta - \zeta'$ represent the easterly deviation of the needle.

And, for convenience, let

$$a = M + D \qquad b = E - A$$
$$e = M - D \qquad d = E + A$$
$$c \tan\theta + \frac{P}{H} = B \qquad f \tan\theta + \frac{Q}{H} = C.$$

Then we have the following expressions for the deviation and horizontal force in terms of the *compass* course:

$$(1 + M)\sin\delta = A\cos\delta + B\sin\zeta' + C\cos\zeta' + D\sin(\zeta + \zeta') + E\cos(\zeta + \zeta') \quad (1.)$$

$$\frac{H'}{H} = (1 + M)\cos\delta + A\sin\delta + B\cos\zeta' - C\sin\zeta' + D\cos(\zeta + \zeta') - E\sin(\zeta + \zeta') \quad . \ . \ . \ . \quad (2.)$$

And the following expressions for the same, in terms of the *correct magnetic* course:

$$\frac{H'}{H}\sin\delta = A + B\sin\zeta + C\cos\zeta + D\sin 2\zeta + E\cos 2\zeta \quad (3).$$

$$\frac{H'}{H}\cos\delta = (1 + M) + B\cos\zeta - C\sin\zeta + D\cos 2\zeta - E\sin 2\zeta \quad (4).$$

These expressions are quite accurate on our assumption as to the quality of the iron.

The following are the conclusions derived from them, as to the forces which act on the horizontal needle. They are—

1. The horizontal force of the Earth = H, depending on the geographical position of the ship, and acting towards the magnetic north.

The following disturbing forces, which are caused by the induction of the horizontal force on the soft iron in the ship, viz:

2. A force M.H, acting towards the magnetic north, and the effect of which is simply to increase or diminish the directive force on the needle, according as M is + or —, and thus indirectly to diminish or increase all the deviations rateably.
3. A force A H, acting towards the magnetic east, and causing the constant part of the deviation.

Forces 2 and 3 may be combined into a force $= \sqrt{M^2 + A^2}\,H$. acting towards a point whose azimuth is $\tan^{-1}\frac{A}{M}$

4. A force D H, acting towards the ship's head when the head is north, but of which the azimuth increases by twice as much as the azimuth of the ship's head.
5. A force E H, acting towards the starboard side when the ship's head is north, but of which the azimuth increases by twice as much as the azimuth of the ship's head.

Forces 4 and 5 may be combined into a force $= \sqrt{D^2 + E^2}\,H$, acting towards a point whose azimuth is $\tan^{-1}\frac{E}{D}$ when the ship's head is north, but of which the azimuth increases by twice as much as the azimuth of the ship's head, giving rise to the quadrantal deviation.

The deviations caused by forces 2, 3, 4, 5, are independent of the Earth's force and of the dip, and ought, therefore, to be the same for a compass in the same position in the same ship in all latitudes.

The following disturbing forces, which are caused by the induction of the vertical force on the soft iron in the ship, viz:

6. A force $c\,Z$, acting towards the ship's head.
7. A force $f\,Z$, acting towards the starboard side.

Forces 6 and 7 may be combined into a force $= \sqrt{c^2 + f^2}\,Z$, acting in a direction $\tan^{-1}\frac{c}{f}$ to the right of the ship's head. The deviation caused by these forces is proportional to the tangent of the dip.

The following disturbing forces, which are caused by the independent magnetism of the hard iron of the ship, viz:

8. A force P, acting towards the ship's head.
9. A force Q, acting towards the starboard side.

Forces 8 and 9 may be combined into a force $= \sqrt{P^2 + Q^2}$, acting in a direction $\tan^{-1}\frac{Q}{P}$ to the right of the ship's head. The deviation caused by these forces is inversely proportional to the horizontal force.

Forces 6 and 8 may be combined into a force $B\,H = c\,Z + P$ acting towards the ship's head, and forces 7 and 9 into a force $C\,H = f\,Z + Q$, acting towards the starboard side, and those into a force $= \sqrt{B^2 + C^2}\,H$, acting in a direction $\tan^{-1}\frac{C}{B}$ to the right of the ship's head.

B is therefore the proportion which the force directed towards the ship's head, arising from the magnetism of the hard iron and from the magnetism induced in the soft iron by the vertical part of the Earth's force, bears to the horizontal force of the Earth at the place.

C is the proportion which the force directed towards the starboard side, arising from the same causes, bears to the horizontal force of the Earth at the place.

The forces 6, 7, 8, 9, give rise to the semicircular deviation, which therefore consists of two parts—one depending on the soft iron and proportional to the tangent of the dip, and the other depending on the hard iron; and inversely proportional to the horizontal force.

The quantities M A D E depend on the soft iron, and their permanence may be relied on with some confidence.

P and Q, and therefore B and C, depend on what I have called the permanent magnetism of the hard iron, but which magnetism is, in fact, to a great extent only sub-permanent or retentive. They are, therefore liable to undergo a change not depending only or in any determinable way on the geographical position, and making any general mode of correction of the compass, either mechanical or tabular, applicable to all latitudes, impossible.

Of the equations, (1) (2) (3) (4), the first is in general the most convenient, as it does not require any observations of the horizontal force.

If the deviation be so small that the squares and products of the co-efficients may be neglected, we have

$$\delta = A + B \sin \zeta' + C \cos \zeta' + D \sin 2\zeta' + E \cos 2\zeta' \quad (5)$$

In this expression, the co-efficients are of course expressed in arc.

It must be observed, that although the co-efficient A may have a real value caused by any elongated horizontal mass of iron, as a long iron gun, the axis of which does not pass through the compass, yet it may also have an apparent value arising from an index error in the compass on board; or an index error, or an error caused by local attraction, affecting the compass on shore with which the compass on board is compared. In general, A is small and not greater than may be supposed to be caused by such errors; but I am assured by Mr. Evans, the superintendent of the Compass Department of the Admiralty, that in some vessels, particularly in iron gun-boats, the value of A is too large to be attributed to such errors. The value of E is also, in every case which I have computed, so small that it might be neglected, giving us, therefore, the following formula, which will in general express with great accuracy the apparently most irregular deviations:

$$\delta = B \sin \zeta' + C \cos \zeta' + D \sin 2\zeta' \quad . \quad . \quad (6)$$

This expression, or the expression

$$\delta = A + B \sin \zeta' + C \cos \zeta' + D \sin 2\zeta' + E \cos 2\zeta',$$

which is sufficiently accurate for all ordinary purposes, has the great advantage that from observations made on any number of equidistant parts the values of the co-efficients are obtained with the greatest ease and expedition. Forms for computing these from observations made on 8, 16, or 32 points, will be found in the supplement to the Practical Rules already referred to; and using equation (6), the coefficients B C D may be obtained with the greatest readiness from observation of the bearing of a distant object made with the ship's head on the N. E., S. E., S. W., and N. W. points, and from them a table of deviations from all other points computed or traced graphically. I now continue the sketch.

In the year 1839 a paper was presented to the Royal Society by Mr. Airy, and published in the philosophical transactions, entitled "Account of Experiments on Iron-built Ships, instituted for the purpose of discovering a correction for the deviation of the compass produced by the iron of the ships." This paper exercised so great an influence on the mode of correcting the compasses of ships practised in this country, and is of so much importance with reference to the controversy between Mr. Airy and Dr. Scoresby, to which I have referred, and to which it will be necessary to revert, that I trust I am not going out of my way in examining in some detail Mr. Airy's method and results. In this paper Mr. Airy, for what reason I do not quite understand, does not at first avail himself of those circumstances in the problem which give the solution on Poisson's theory with so much readiness, but applies himself in the first place to the solution of the problem of finding the attraction on the needle of a mass of soft iron of given shape magnetised by induction. In doing so, Mr. Airy observes that it would have been desirable to make the calculations on Poisson's theory, and that that theory possesses greater claims on our attention, as a theory representing accurately the facts of some very peculiar cases, than any other, but that the difficulties in the application of that theory to complicated cases are great, perhaps insuperable. To avoid these difficulties, Mr. Airy introduces the supposition that by the action of terrestrial magnetism every particle of soft iron is converted into a magnet, whose direction is parallel to that of the dipping-needle, and whose intensity is proportional to the intensity of terrestrial magnetism; in other words, that the particles of soft iron magnetised by induction do not induce magnetism in each other. This supposition furnishes readily expressions for the co-efficients $a\ b\ c\ d\ e\ f\ g\ h\ k$, in the form of definite integrals; and Mr. Airy observes that in ordinary cases this simple theory will give the same comparative though not the same absolute results as Poisson's.

It is to be observed, however, that the actual arrangement of the iron of an iron ship is almost entirely of that peculiar and complicated kind to which Mr. Airy here alludes, in which Poisson's theory represents accurately the facts, but in which the simpler theory used by Mr. Airy gives results differing very widely from the facts. For instance, almost the whole of the very powerful magnetism induced in bars of soft iron held in or near the direction of the dip, is caused by that mutual induction of the particles of soft iron which Mr. Airy's theory leaves out of account. According to that theory, a bar of soft iron held in the direction of the dip would exert no greater force on the needle than the same bar condensed into a disk, a result which the simplest experiment with a bar held in the line of dip will show to differ very much from the fact.

Mr. Airy does not, however, make use in actual computation of the definite integrals so obtained. He substitutes for them literal co-efficients corresponding to the $a\ b\ c\ d\ e\ f\ g\ h\ k$ of Poisson's method, which co-efficients, like Poisson's, are to be determined by observations of deviation, force, etc. Mr. Airy's results would, therefore, be free from the objections to which his theory is open, were it not that his theory gives three relations $b = d$, $c = g$, $f = h$,* which do not exist in nature, and the nine independent co-efficients of the more perfect theory are thus reduced to six, and the constant term A, which, as we have seen, has sometimes a real value, becomes equal to zero.

The last objection, for the reasons before mentioned, is rather a theoretical than a practical objection, but there is a more serious objection to some of Mr. Airy's conclusions.

It is this: It follows from the less perfect as well as from the more perfect theory, and Mr. Airy points out that we have no means of determining separately the parts of which the semicircular deviation consists, viz., that which arises from induced magnetism and that which arises from permanent magnetism, by observations made at one place, with the ship on even keel; but Mr. Airy considering that as in the first instance the correction must be effected in a British port, it was desirable to form an *à priori* conjecture as to these magnitudes, accordingly made the *conjecture* that the part of the semicircular deviation arising from induced magnetism is so small that it may be neglected.

Mr. Airy's reasons, as I collect from the paper in the Philosophical Transactions for 1839, to which I have referred, and also from a paper by the same author entitled "Results of experiments on the disturbance of the compass in iron built ships," Weale, 1840, are of this nature:—

"Although the amount of that part of the semicircular deviation which is caused by induced magnetism cannot be determined by means of observations at any one place, we know that it is a quantity of the same order as the quadrantal deviation. It may be somewhat greater or somewhat smaller, but not remarkably greater; and with some possible distributions of the soft iron, it may be zero. Of the two iron vessels examined, one, the Rainbow, with a semicircular deviation of 50°, had a quadrantal deviation of only 1°; the other, the Ironsides, with a semicircular deviation of 30°, had a quadrantal deviation of 1° 6′. There is, therefore, good reason to conclude that the part of the semicircular deviation caused by induced magnetism is, in all cases, except in very high magnetic latitudes, extremely small, and that, so far as observations with the best compasses can go, the correction of the semicircular deviation made by fixed magnets in one latitude will be perfectly correct in every other latitude."

Of these reasons, it may be observed that in many cases, of very fre-

* The mathematician will easily see that in this case these co-efficients are the second partial differential co-efficients of the potential, and that the equalities referred to are the same as

$$\frac{d^2 V}{dx\,dy} = \frac{d^2 V}{dy\,dx} \qquad \frac{d^2 V}{dx\,dz} = \frac{d^2 V}{dz\,dx} \qquad \frac{d^2 V}{dy\,dz} = \frac{d^2 V}{dz\,dy}$$

quent occurrence in iron ships, there is no relation between the two things compared. A single iron stancheon may give a large amount of semicircular deviation and no perceptible amount of quadrantal deviation. A deck-beam may give a large amount of quadrantal deviation and no perceptible semicircular deviation.

But supposing the analogy to hold, the inference to be deduced from iron ships in general differs very widely from that deduced from the Rainbow and Ironsides. Let us suppose a horizontal and a vertical bar of soft iron placed respectively at the same distance from the compass. The vertical bar, in the position in which it produces the maximum of semicircular deviation, is acted on by the whole vertical force, and acts at right angles to the needle; the horizontal bar, in the position in which it produces the maximum of quadrantal deviation, is acted on by the horizontal force multiplied by the sine of 45°, and acts at an angle of 45°. The semicircular deviation produced by the vertical bar would, therefore, *ceteris paribus*, exceed the quadrantal deviation produced by the horizontal bar in the proportion of the vertical force to ½ the horizontal force, or of 2 tan dip : 1, or (in England, where the tangent of the dip = 2.75) of 5½ : 1. Now, in general, the semicircular deviation in England does not bear a greater ratio than this to the quadrantal deviation, and, therefore, the inference to be drawn (if any) from this analogy would rather be that the whole of the semicircular deviation in iron ships arises from induced magnetism. Thus, in the case of several iron steamers swung in England, whose semicircular and quadrantal deviations are given by Mr. Airy in a paper in the Philosophical Transactions for 1853, p. 53, we have the following results:

	Quadrantal deviation.	Semicircular deviation.
	° ′	° ′
Bloodhound	3 48	15 20
Jackall	4 14	17 50
Trident	3 35	20 40
Vulcan	3 36	9 5
Simoon	4 31	22 0

In all of these the semicircular deviation is less than 5½ times the quadrantal; and unless I have misapprehended Mr. Airy's reasons, the conclusion to be drawn from these vessels would be that nearly the whole of the semicircular deviation was caused by induced magnetism. That this, however, was not the case is shown by the observations made in other latitudes in the same iron vessels, showing that a large amount (in the Trident nearly the whole) of the deviation arose from permanent magnetism.

The conclusion to which we are led, then, is the negative one, that no *à priori* conjecture, having the least probability of correctness, as to the relative proportions of the induced and permanent magnetism which give rise to the semicircular deviations, can be formed.

There are other considerations which lead to the same result. We may suppose the compass to be placed at a position in the ship in which the induced magnetism compensates itself so as to produce no semicircular deviation. In that case all the semicircular deviation will be caused by permanent or retentive magnetism; but we may in the same manner suppose a compass to be placed where all the permanent or retentive magnetism will compensate itself, in which case the whole semicircular deviation will arise from transient induced magnetism; and there was, in fact, no phenomenon observed by Mr. Airy in the Rainbow and Ironsides which might not have been caused by the transient induced magnetism of the soft iron in these ships.

This conjecture was one on the correctness of which the mode of correction originally proposed by Mr. Airy, viz., by *fixed* magnets, depended. Mr. Airy subsequently proposed to correct the semicircular part of the deviation by *adjustible* magnets, the position of which is to be altered by the captain according as the changes in dip, in the sub-permanent magnetism of the ship, or in the magnetism of the correcting magnets, introduces any serious amount of semicircular deviation. This mode of correcting the semicircular deviation would no doubt succeed in skilful hands, except in the sudden changes in the sub-permanent magnetism of newly-built iron ships, but it may be doubted how far it is prudent to trust such delicate manipulation to unskilful hands. I am not aware whether this mode of correction has been practised, or whether it has succeeded in practice.

I have stated that the conclusion of Mr. Airy as to the relative amounts of permanent and transient induced magnetism is put forward by him merely as a conjecture; but it is necessary to observe, in order to explain the mistake into which I have already alluded as one into which I cannot help thinking Dr. Scoresby fell, that some expressions used by Mr. Airy in this and subsequent papers appear to be liable to be misunderstood, and to have been misunderstood not only by Dr. Scoresby, but by other persons.

Their mistake was this: Mr. Airy having made the conjecture I have referred to, afterwards assumes the correctness of the conjecture, and uses the term "permanent magnetism" to express the force which causes semicircular deviation. In other words, he uses the term "permanent magnetism" as equivalent to "permanent magnetism" + "transient magnetism induced by the vertical part of the Earth's force." The same form of expression is used by Mr. Airy in the paper published by Mr. Weale, to which I have referred, and in a letter to the editor of the Nautical Magazine, published in the Nautical Magazine for December 2, 1843. When, therefore, Mr. Airy in those papers, speaks of his investigations and observations as showing that the deviation (other than the quadrantal) was caused by "permanent magnetism," and proposed to correct such deviation by fixed magnets, persons who looked into the paper only for the results of the mathematical investigation, without actually repeating or following the mathematical operations, easily fell into the mistake of supposing that Mr. Airy had demonstrated, or professed to have demonstrated, that the semicircular deviation did arise entirely, or almost entirely, from permanent magnetism, and that no part, or only a small and unimportant part, arose from transient induced magnetism.

Mr. Airy must himself of course be acquitted from any theoretical mistake on this point. The less perfect theory, of which he made use advisedly and with the object I have mentioned, agreed with the more perfect theory of M. Poisson, in showing that the semicircular deviation consists of two parts, which cannot be separated by observations of the horizontal needle at any one place, and this Mr. Airy points out, as well as that the effect of the impracticability of separating these parts is to render the compass incorrect in one magnetic latitude when it has been made correct in a different magnetic latitude. Mr. Airy's mistake, if I may be excused for so designating it, was in his "conjecture" that the part of the semicircular deviation which depends on the induced magnetism is so small that it may be neglected, except in the case of a ship sailing very near the magnetic pole, and in basing on this conjecture, which is certainly in many cases incorrect, a general mode of correcting the deviation by fixed magnets.

The following passage in Dr. Scoresby's Magnetical Investigations, vol. II., p. 239, seems to show that he had misunderstood Mr. Airy's results: "In his experiments on board the iron-built steamship the Rainbow, Mr. Airy found that some other quality of magnetism besides that simply due to ordinary terrestial induction was not only present but particularly influential. The proportions, too, in which the transient and partially enduring magnetism, as affecting the compass in the vessel, respectively, existed were inquired into, and found to place the latter in a highly dominant position." This, as we have seen, is a mistake. Mr. Airy's observations did not *prove* that there was any other cause operating that terrestial induction, and *à fortiori* did not establish any relation between the amounts of the transient and permanent or retentive magnetism.

I have insisted on this point, because it appears to me not improbable that Dr. Scoresby's mistake influenced, in some degree, his subsequent speculations and investigations; and that, believing Mr. Airy to have demonstrated that the semicircular deviation in iron ships was not, to any appreciable degree, due to transient induced magnetism, and yet, finding from observations made in different latitudes, that the magnetism of the ship was not permanent, he was led to attribute the semicircular deviation in iron ships almost entirely to magnetism of the kind which he denominated "retentive," *i. e.*, magnetism which may be considered permanent in the ordinary process of swinging a ship, but which changes under a change in the inducing force, and with great readiness when aided by mechanical violence.

Dr. Scoresby was thus led to investigate practically and theoretically the effect on the compass of "retentive" magnetism, and to call attention to a cause which mathematicians had to a great degree overlooked; and he showed, from the changes which take place in the magnetism of iron ships without a change of latitude, that a great part of the deviation arises neither from transient nor permanent, but from "retentive" or "sub-permanent" magnetism.

Dr. Scoresby approached the question of the deviation of the compass from an entirely different side from M. Poisson and Mr. Airy. He investigated the subject experimentally, not mathematically. He was free from the temptation to which the mathematician is exposed, of adapting his theory to the powers of his analysis rather than to the phenomena observed. His experiments were made with iron of a like quality with that of which iron ships are composed, viz., plates prepared for ship building, and the result of his experiments was to show that the state of the iron was very different from either of the states which had been supposed by mathematicians. The iron was not "soft," because it had acquired, by hammering, a great degree of magnetism, which it retained while the ship was swung in different positions; but neither was it "hard," because, in a new position, and under the influence of a new inducing force and the molecular disturbance caused by blows and strains, and even time alone, it changed. On this feature in the iron, Dr. Scoresby strongly insisted, and to him is principally due what we know of iron in this state.

Retentive magnetism is the last kind to which the mathematician has recourse in order to explain phenomena. He cannot deal with it directly in his analysis. He can only treat it as permanent magnetism which undergoes a change, or as transient magnetism which requires time and molecular disturbance to enable it to take up its new estate. Poisson does not notice it. Mr. Airy, until the subject was brought forward by Dr. Scoresby, did not notice it. Its effect on the deviation of the compass and ship was first, I believe, suggested by General Sabine in the Philosophical Transactions for 1843, p. 153, in the reduction of the magnetic observations made in the ships of Sir James Ross's Antarctic expedition. He inferred, from the observations, "that when a ship changes her magnetic latitude, the corresponding change in the magnetism of the ship, or more strictly in that portion of it which is derived from induction, follows, but does not always, or altogether, take place instantaneously;" * * "that some portion of the iron might be of a quality intermediate between that of perfectly soft iron which undergoes instantaneous change, and that of iron which acquires permanent magnetism, and that such portions should be liable, in regard to their magnetic condition, to be more or less in arrear of the ship's magnetic position."

Dr. Scoresby's attention had been early directed to the effect of percussion, and twists and strains generally, in rendering iron susceptible of induction. In the Transactions of the Royal Society of Edinburgh for 1821, there is a paper by him entitled, "Description of a Magnetometer, being a new instrument for measuring magnetic attractions and finding the dip of the needle, with an account of experiments made by it." The instrument was an iron bar, moved in the plane of the magnetic meridian till it ceased to affect the needle, when its inclination measured the dip. In this paper Dr. Scoresby describes a number of experiments, and gives a number of conclusions as to the effect of percussion, filing, bending, and twisting, in rendering bars susceptible of induction.

In the Philosophical Transactions for 1822, p. 241, there is a paper by Dr. Scoresby, "Experiments and observations on the development of magnetic properties in iron and steel by percussion." This paper was an application of the principles of the last paper to the construction of artificial magnets.

A continuation of the same paper, dated "On board the ship Baffin, off Iceland, August 27, 1823," is contained in the Philosophical Transactions for 1824, p. 197.

In a paper "On the defects and dangers arising from the use of corrective magnets for local attraction in the compasses of iron-built vessels," read before the British Association in 1847, but of which I have not been able to find any account, Dr. Scoresby, I believe, called the attention of the association to this quality of the iron composing iron ships.

In the fourth part of the "Magnetical Investigations," Dr. Scoresby considered the magnetism of iron-built ships with relation to the action of the compass and the changes to which their magnetic condition is liable. This paper sets out with referring to Mr. Airy's paper of 1839, and the mode of correction proposed by it as sufficient if the iron were all of the two qualities supposed by Mr. Airy, (which we have seen is a mistake,) and he then refers to the third quality, which he denominates "retentive" magnetism, as playing an important part in the deviation of the compasses of iron ships, and as not met by Mr. Airy's proposed mode of correction.

In the second chapter, Dr. Scoresby gives the results of experiments on the rolled iron plates used in iron ship building. His experiments led him to the conclusion that the plates of which a ship is built do not, from the mere process of manufacture, independently of the hammering received in shipbuilding, receive any large amount of permanent magnetism. In one plate the transient induced magnetism, with the plate placed upright, exceeded the permanent magnetism in the proportion of about 9 to 1. The same plate, when hammered in its vertical position, had an amount of permanent magnetism developed amounting to not more than two-sevenths of the transient induced magnetism, and this was easily inverted by a few blows when the plate was reversed. From these experiments, Dr. Scoresby deduces the inference that a great part of the deviation in iron ships is caused by the retentive magnetism, which at first is very powerful from the great amount of hammering to which the iron of such a vessel is subjected in building, but which is altered as soon as the vessel is exposed to blows or strains. The experiments seem further to show that with such retentive magnetism is united a large amount of transient induced magnetism.

At the meeting of the British Association at Liverpool, in 1854, Dr. Scoresby read a paper "On the loss of the Tayleur, and the changes in the compasses in iron ships."

The Tayleur was a new iron ship, about 2,000 tons burden. Her steering compass had originally a maximum deviation of 60°; this was corrected by a magnet. She met severe weather in going down the channel; and if, as Dr. Scoresby supposes, the effect was to "shake out" the magnetism of building, and give a new magnetism, this would leave the correcting magnets to produce a deviation, which threw her on the Irish coast.

This Dr. Scoresby explained in this paper, and insisted much on the condition of iron, viz., the retentive, which causes an intensely high state of magnetism to be induced, which cannot be retained after the ship has been exposed to different inducing forces and blows.

This paper called forth remarks from Mr. Airy, published in the Athenæum, and in the Mercantile Marine Magazine for December, 1854. In this paper Mr. Airy still treats as inconsiderable the part of the semicircular deviation which arises from induced magnetism, and speaks of the paper of 1839 as having established that the greater part of the deviation depends on the permanent or polar magnetism, and urges that, although it was evident there were causes in action tending to produce effects like those produced by Dr. Scoresby's experiments, yet that it was equally evident that the action of those causes must be exceedingly slow. That the plates of iron of a ship receive no shocks from the waves, but that the direct effect of the most violent sea is that the plates of iron are, in the course of two or three seconds of time, plunged five or six feet deeper in water, and sustain a corresponding hydrostatic pressure. That the change to be expected in a ship's sub-permanent (retentive) magnetism, in sailing from England to the Cape of Good Hope, does not essentially depend on her passing into another magnetic hemisphere; but that, supposing her to have been built with her head north, she is turned with her head south and exposed to slight tremors for some months. That, as regards the loss of the Tayleur, it was not likely, or even possible, that in two days the magnetism of the ship would be so much changed that the compass would be disturbed through an angle of two points, or even one-tenth of that amount. That, in her Majesty's ship Trident, the deviations at the Thames and at Malta were nearly in the inverse proportion of horizontal intensity, and show that the disturbing force had remained unaltered. That the correction by permanent magnets should be generally adopted, but that for voyages to the southern hemisphere the captain should be furnished with the means of adjusting the magnets.

This paper was answered by Dr. Scoresby, in a paper published in the Athenæum, and in the Mercantile Marine Magazine for January, 1855. In this paper Dr. Scoresby contended strongly that Mr. Airy's mode of compass correction could not be correct, and must in some cases dangerously mislead. Dr. Scoresby, in opposition to Mr. Airy, contends that a ship is "*most* liable to undergo a change of magnetism at any time." That the shocks of the sea on the iron plates of a ship have sufficiently the quality of impact to render his (Dr. Scoresby's) experiments by percussion applicable for indicating the probable result of magnetic changes. He points out that Mr. Airy's conclusion as to the Tayleur is inconsistent with the observed facts, viz., that two corrected compasses, which agreed at starting, differed by two points two days afterwards. That this was to be expected from known facts of observation. That in ships going to southern latitudes, adjustment by magnets will generally aggravate the error, and that the errors might be corrected by a compass at the masthead.

A reply by Mr. Airy to this paper will be found in the Mercantile Marine Magazine for March, 1855. In this Mr. Airy, referring to his conjecture that the induced part of the semicircular deviation was so small that it might be neglected, states that he is inclined to think that his estimate of the possible magnitude of that term had been too low. He insists that the blow from water, however great, is still not of the nature of impact, but pressure. That there is no sufficient evidence of sudden changes of great magnitude.

In this paper there are the following important passages:

"One general law seems to apply to ships going into the southern hemisphere: that on returning to England their compasses are, with very trifling errors, as correct as when they left England. But the state of their compasses in the southern hemisphere varies greatly; some are perfectly correct, others are very erroneous. I do not imagine that in any of these cases the sub-permanent (retentive) magnetism has undergone any particular change. I think it far more probable that the error arises from transient induced magnetism. Though the original theory was correct, the application of it has been incorrect, from throwing the correction exclusively on magnets, and not introducing also the action of a mass of soft iron below the level of the compass."

To this paper there was a rejoinder by Dr. Scoresby, in the Mercantile Marine Magazine for April, 1855.

In this, Dr. Scoresby points out how much Mr. Airy had under-estimated the impact of waves striking a ship. He insists on the observations which show sudden changes in the magnetism of vessels without change of geographical position, which can only arise from changes in the retentive magnetism.

Dr. Scoresby alludes, but does not enter minutely into Mr. Airy's expression of opinion, that the changes in vessels going to the south arise from induced not retentive magnetism.

In doing so, I cannot help thinking that Dr. Scoresby was still under the influence of the mistake which I suppose him to have made, as to what Mr. Airy had accomplished in his paper of 1839, and that, believing Mr. Airy to have *demonstrated* that the part of the semicircular deviation produced by induced magnetism was insensible, he sought for the cause of the whole change actually produced in the retentive magnetism.

These differences of opinion could not be removed without actual observations in the same vessel in different latitudes; but it must be observed, that such observations, although deciding some, would not decide all the points in question. If, on the return of a ship from the southern hemisphere, her magnetic state is found to be very different from her state at her departure, the inference is inevitable that a great change has taken place in her retentive magnetism. But if a compass corrected by magnets has a large error in the southern hemisphere, there are no obvious means of determining how much of the error arises from retentive or how much from transient induced magnetism.

In order to investigate these interesting and important questions, Dr. Scoresby undertook the voyage of which the narrative follows. It remains for me to show what the result of the voyage was in furnishing an answer to the questions.

In some respects a smaller and more manageable vessel would have had advantages over the Royal Charter.

Dr. Scoresby's researches required that the ship should be carefully swung whenever an opportunity offered; but the difficulty of swinging so large a ship, and the importance of every hour that could be saved in the voyage out and home, prevented the magnetic state of the Royal Charter being observed with the accuracy which was desirable, and it was only with the greatest and most resolute exertions on the part of Dr. Scoresby that observations of any value were made.

The Royal Charter was swung at Liverpool on the 4th of January, 1856, and the results of the observations will be found at page 13 of the narrative of the voyage.

She was again swung at Hobson's Bay, Port Phillip, on the 2d of May, as described in page 182 of the narrative. The following are the results of this swinging:

Deviations of the compasses of the Royal Charter, swung at Hobson's Bay, Port Phillip, Victoria, May 2, 1856.

Course by Admiralty compass.	Correct magnetic course.	Deviations { E denoting an easterly deviation. W denoting a westerly deviation.			
		Admiralty compass.	Masthead compass.	Steering compass.	Companion compass.
	° ′	° ′	° ′	° ′	° ′
North	N. 349 E.	W. 11	W. 2 30	E. 9 45	E. 6 15
N. by E	2 15	9	W. 30	11 15	7 15
N. N. E	15	7	E. 1 0	11 45	7 45
N. E. by N	29	4 45			
N. E	42	3	W. 15	10 15	6 15
N. E. by E	55	1 15			
E. N. E	66 30	1 30	1 0	E. 5	E. 2 30
E. by N	77	1 45			
East	89	2 30	2 15	W. 5 45	W. 3 30
E. by S	98 30	2 45			
E. S. E	109	3 30	3 30	12	7 0
S. E. by E	120 15	3 30	45		
S. E	132 15	2 45	1 30	15	9 0
S. E. by S	144 45	W. 1 30		19 15	15 30
S. S. E	158 45	E. 15	W. 1 15	18 15	13 30
S. by E	174 45	4 30	E. 30	14 15	10 15
South	187 30	7 30	E. 30	11 45	8 30
S. by W	201 45	10 15	W. 45	9 30	6 15
S. S. W	215 15	12 45	1 30	10 15	5 15
S. W. by S	226	12 15	1 30	5 15	3 45
S. W	236 15	11 15		3 30	3
S. W. by W	245 30	9 15	30	2 45	2 15
W. S. W	254 30	7	30	1 45	1 15
W. by S	262 30	E. 3 45	W. 45	W. 1	W. 45
West	270 15	W. 15	E. 15	E. 30	E. 30
W. by N	277 30	3 45	W. 1 0	3 0	1 45
W. N. by W	285 45	6 45	E. 1 45	2 15	2 15
N. W. by W	293 45	10	W. 1 15	3 30	2 45
N. W	301 45	13 15	W. 2 0	2 15	1 30
N. W. by N	313	13 15		6 30	5
N. N. W	325 30	12		7 45	6
N. by W	N. 337 E.	W. 11 45		E. 9	E. 7

On the return of the Royal Charter to Liverpool, on the 13th or 14th of August, the deviations of her compasses were observed by Dr. Scoresby, with the aid of Mr. Rundell, the secretary of the Liverpool Compass Committee, in the manner described in the narrative of the voyage, and the following were the results:

Deviations of the compasses of the Royal Charter, swung at Liverpool, August 13 and 14, 1856.

Correct magnetic course.	Deviations { E denoting an easterly deviation. W denoting a westerly deviation. Admiralty compass.	Steering compass.	Companion compass.
° ′	° ′	° ′	° ′
N. 8 30 E.	E. 0 45	E. 20 30	E. 17 45
20 30	0	19 0	16
40 15	1 30	21 30	18
53 45	2	19	17
67 15	1	E. 13 30	E. 15
178 45	....	W. 22 15	....
180	1	22 7	W. 17
183	1 30	22 30	17
199	6	18 45	14 15
203	7 45	18 15	14 30
204 45	8	17 30	14 45
208	....	16	13
217 15	9	14	12
230 45	8 45	10	9 15
247 15	6 45	8 30	3 30
259	5 30	2 30	1
266 15	E. 3	W. 1 45	W. 2 30
276 30	W. 1 30	E. 15	E. 45
288 45	6	3 15	3 15
305 30	8 45	7 45	7 45
321 15	9	12 30	12 45
341 30	4 30	17 30	17 30
N. 348 30 E.	W. 0	E. 22 30	E. 22 30

For the purpose of comparing the deviations at the different places, and freeing them as much as possible from accidental error, curves were drawn from these observations by Mr. Rundell, who obtained from them the following adjusted tables of deviations:

Deviations of the compasses of the Royal Charter, obtained by projecting the observed deviations in curves.

Course by each compass.	Admiralty compass.			Steering compass, corrected by magnets, etc.			Companion compass, corrected by magnets, etc.		
	Liverpool, Jan., 1856.	Melbourne, May, 1856.	Liverpool, Aug., 1856.	Liverpool, Jan., 1856.	Melbourne, May, 1856.	Liverpool, Aug., 1856.	Liverpool, Jan., 1856.	Melbourne, May, 1856.	Liverpool, Aug., 1856.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
North	—23 45	—11	—0 45	1 40	12 0	21 40	—3 40	+ 7 10	16 40
N. by E.	—19 45	— 9 15	— 30	3 20	11 40	21 10	—1	7 20	17 20
N. N. E.	—14	— 7 15	0 0	4 15	11	20 30	0	6 50	17 30
N. E. by N	—10 20	— 5	+1	4 50	10	19	+ 50	6 10	17 10
N. E.	— 7 40	— 3	1 45	4 50	8 20	16 30	1	5	16 40
N. E. by E.	— 5 40	— 1 15	2	4 30	6 15	13	40	3 40	14 30

Deviations of the compasses of the Royal Charter, &c.—Continued.

Course by each compass.	Admiralty compass. Liverpool, Jan., 1856.	Admiralty compass. Melbourne, May, 1856.	Admiralty compass. Liverpool, Aug., 1856.	Steering compass, corrected by magnets, etc. Liverpool, Jan., 1856.	Steering compass, corrected by magnets, etc. Melbourne, May, 1856.	Steering compass, corrected by magnets, etc. Liverpool, Aug., 1856.	Companion compass, corrected by magnets, etc. Liverpool, Jan., 1856.	Companion compass, corrected by magnets, etc. Melbourne, May, 1856.	Companion compass, corrected by magnets, etc. Liverpool, Aug., 1856.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
E. N. E.	— 4 45	— 1	1 20	3 40	3	9 10	0	1 40	11
E. by N.	— 4 40	— 1 15	— 15	3	— 40	4 20	— 40	0	7
East	— 4 30	— 1 30	—2	2	— 4 30	— 40	—1 20	— 2 30	2
E. by S	— 3	— 2 30	—3 40	1	— 7 30	— 7	—1 20	— 4 50	— 2
E. S. E.	— 30	— 3 30	—4 40	30	—10	—11 40	—1 5	— 6 50	— 6
S. E. by E.	+ 1 30	— 3 30	—4 50	0	—12 50	—16	—1	— 8 50	—11
S. E.	3 30	— 2 45	—4 20	—1	—15	—19 30	— 50	—10 40	—13 40
S. E. by S	6 45	— 1 30	—3 10	—1 40	—16 40	—21	— 40	—12	—15 15
S. S. E.	11	+ 1 15	—1 20	—2 40	—17 30	—22	— 30	—12 30	—15 40
S. by E.	15	5	+1 20	—3	—18 10	—22 10	— 20	—12 20	—15 50
South	19	8	+3 45	—3	—17	—22	— 10	—11 15	—15 40
S. by W.	21 45	10 35	5 40	—2	—15	—21 20	0	— 9 30	—15
S. S. W.	23 40	12 45	7 30	— 30	—12	—20 10	+1	— 7 10	—14 40
S. W. by S	23 50	12 15	8 40	+ 20	— 9	—18 30	2 30	— 5 30	—13 50
S. W.	22 40	11 15	9	1 30	— 6 40	—15 40	3 30	— 4	—12
S. W. by W.	19 30	9 30	8 45	2	— 4 20	—12	4 20	— 2 30	— 9 20
W. S. W.	15 10	7	7 10	2 40	— 2 20	— 8	4 30	— 1 30	— 6 10
W. by S.	9 50	4	5 15	2 30	— 50	— 4 20	4 10	— 45	— 3
West	4 20	2 20	2 30	2	+ 1	— 30	2 50	0	— 40
W. by N.	— 1 0	— 3 45	—1 50	1	2 30	+ 1 40	1 20	+ 1 50	+ 3
W. N. W.	— 6 40	— 7 15	—5 45	30	4	6 30	— 40	+ 2 15	5 30
N. W. by W.	—12 25	—10 20	—8 10	0	4 30	10 10	—2	2 30	9
N. W.	—17 30	—12 40	—8 30	— 40	6 15	14	—4	4 40	11 30
N. W. by N.	—22	—13 45	—8	—1	8 10	17 10	—5 30	5 20	13 30
N. N. W.	—24 30	—13 30	—6	—1	9 20	20	—5 40	6	16
N. by W.	—24 45	—12 30	—3 30	0	11 20	20 50	—5 10	6 50	17

Applying to these tables the formula (5) to which I have already referred, I obtain from them the following values of the co-efficients A B C D E:

Compasses.		A.	B.	C.	D.	E.
		° ′	° ′	° ′	° ′	° ′
Admiralty compass.	Liverpool, Jan., 1856	— 18	—3 40	—19 35	7 13	—1 18
	Melbourne, May, 1856	—1 27	—1 20	— 9 3	6	—0 25
	Liverpool, Aug., 1856	— 3	—1 30	— 3 22	5 58	+ 28
Steering compass, corrected by magnets and soft iron.	Liverpool, Jan., 1856	55	35	1 43	2 5	—1 17
	Melbourne, May, 1856	—1 54	—2 25	13 35	2 34	— 30
	Liverpool, Aug., 1856	— 50	— 15	22 25	1 35	+ 25
Companion compass, corrected by magnets and soft iron.	Liverpool, Jan., 1856	— 17	— 51	— 1 48	2 22	—1 23
	Melbourne, May, 1856	—1 25	—1 45	8 45	1 55	— 28
	Liverpool, Aug., 1856	47	1 15	17 35	1 34	— 11

The following were the values of the co-efficients for the steering and companion compasses at Liverpool in January, 1856, before compensation, obtained by Mr. Rundell:

Compasses.	A.	B.	C.	D.	E.
		° ′	° ′	°	
Steering compass, (before compensation)		—27 7	—30 7	5	....
Companion compass, (before compensation)		— 8	—25	....	....

The values of the same co-efficients obtained by Mr. Rundell, as given in the report of the Liverpool Compass Committee, p. 51,* are:

Compasses.		A.	B.	C.	D.	E.
		° ′	° ′	° ′	° ′	° ′
Admiralty compass.	Liverpool, Jan., 1856........	−0 27	−3 48	−19 42	+6 59	−0 52
	Melbourne, May, 1856......	−1 27	−1 ·11	− 8 59	+6 23	−0 16
	Liverpool, Aug., 1856.......	− 3	−1 6	− 3 22	+6 10	+0 56
Steering compass, corrected by magnets and soft iron.	Liverpool, Jan., 1856........	+0 20	+0 32	+ 1 50	+2 0	−1 20
	Melbourne. May, 1856......	−0 59	−2 30	+13 53	+2 34	−0 45
	Liverpool, Aug., 1806.......	−1 12	−0 15	+22 29	+1 37	+0 3
Companion compass, corrected by magnets and soft iron.	Liverpool, Jan., 1856........	−0 2	−0 56	− 1 49	+2 15	−0 50
	Melbourne, May, 1856......	−1 16	−1 59	+ 9 2	+1 56	−0 27
	Liverpool, Aug., 1856.......	+0 43	+1 15	+17 81	+1 38	−0 6

Mr. Rundell also obtained the following values of the co-efficients for the mast compass:

Mast compass.	A.	B.	C.	D.	E.
	° ′	° ′	° ′	° ′	° ′
Liverpool, Jan., 1856..	−0 35	+0 46	− 2 56	+2 28	+0 9
Melbourne, May, 1856..	−1	−0 15	− 0 9	+0 33	+0 11

These results are, however, subject to great uncertainty, as the compass was too sluggish and its graduation too rough for exact experiments.

In comparing these values, it will be seen that A and E are small and irregular. They probably arise almost entirely from errors of observation. D, which gives the principal part of the quadrantal deviation, in theory ought not to change with a change of latitude, and its constancy of value is very satisfactory. The differences in its value may arise partly from errors of observation, and partly from change of temperature.

B, as we have seen, represents the proportion which the disturbing force of the ship towards the head bears to the horizontal force at the place. C represents the proportion which the disturbing force towards the starboard side bears to the horizontal force.

The Royal Charter was built with her head in the direction N. 50° W., (magnetic.) When newly launched, there was, therefore, a strong tendency of the north point of the compass to the port side, giving a large negative value for C in her standard compass, and also in the steering and companion compasses before being corrected by fixed magnets. The blows and strains which the Royal Charter experienced in her voyage diminished, or, so to speak, "shook out," this inequality to such an extent that the standard compass, which had originally a deviation of nearly 20° to the port side when the ship's head was north, as shown by the value of C, had this deviation reduced to 3° 22′ on the ship's return to Liverpool; while the steering compass, which originally had been rather over corrected, having a C = 1° 43′, returned with C = 22° 25′, an increase of 20° 42′; while the companion compass, originally rather under

* See page 54 of this reprint. B. F. G.

corrected, having a C — 1° 48′, returned with a C = 17° 35′, a change of 19° 23′. This change was one which had evidently taken place in the retentive magnetism of the ship, and seems to justify Dr. Scoresby's anticipations, and to show that Mr. Airy had very much under-estimated the change in the retentive magnetism.

This change shows the complete failure in such a voyage of the correction by fixed magnets, while the standard compass, uncorrected, had its deviation reduced to a great extent during the voyage, the deviation of the corrected compasses grew up to more than two points.

With regard to B, it seems difficult to say what inference should be drawn. It appears to have been considerable in the steering compass before correction, but when corrected, to have changed very slightly. It seems to show an amount of permanency in the magnetism which attracted the north point of the compass to the stern, for which it appears to me difficult to account, and which may perhaps show that if iron ships were built with the keel in the magnetic meridian, and so as to have no considerable deviating force to either side, permanent magnets might be applied, as correctors, with less risk than when there is an original large deviation to one side.

The smallness of the value of B, and the nature of the changes in C, seem to show that in the three compasses of the Royal Charter, as in the case of the standard compass of the Trident, to which I have already referred, Mr. Airy's conjecture as to the smallness of that part of the semicircular deviation which arises from transient induced magnetism, was not far from being correct.

The following letter will show the inferences deduced by Mr. Airy from the observations in the Royal Charter:

"ROYAL OBSERVATORY, GREENWICH,
"*October*, 2, 1856.

"MY DEAR SIR: The pressure of Observatory business has prevented me for a time from examining the observations of compass deviation in the Royal Charter, but I have now taken them up, and find the following results:

"1. Quadrantal deviation:

Liverpool, January, 1856..................................	+ 6° 40′
Melbourne, May, 1856..................................	5° 50′
Liverpool, August, 1856..................................	5° 51′

"These agree well. Their magnitude shows that, in the operation of mechanical correction of the compass, the use of a mass of unmagnetized iron (to produce its correcting effect by its transient induced magnetism) must never be omitted. I fear that persons who profess to correct compasses *have* too often omitted it.

"2. Ship's magnetism towards the head, estimated in absolute measure, (whole horizontal force of terrestial magnetism at Liverpool = 3.54; at Melbourne, = 5.94).

Liverpool, January, 1856	—0. 199
Melbourne, May, 1856	—0. 147
Liverpool, August, 1856	—0. 106

"3. Ship's magnetism towards the starboard side, estimated in the same scale:

Liverpool, January, 1856	—1. 156
Melbourne, May, 1856	—0. 895
Liverpool, August, 1856	—0. 206

"At Liverpool a deviation of 1° will be produced by .062 in either of these magnetisms; at Melbourne, a deviation of 1° will be produced by .104.

"It appears, therefore, that the ship's magnetism has been steadily diminishing in both parts of the voyage. The headward magnetism (considered without reference to its sign) has diminished very uniformly; the starboard magnetism has diminished much more rapidly on the homeward voyage than on the outward voyage. I have the impression (but I know not whether correctly) that this is not the interpretation which you put on the changes; it is, however, (small unimportant inaccuracies of calculation excepted,) undoubtedly correct.

"I am, my dear sir, yours, very truly,

"G. B. AIRY.

"Rev. Dr. SCORESBY."

It may be mentioned that Dr. Scoresby's observations, made by applying a pocket compass to the iron plating at the "top sides" of the Royal Charter, showed that in the southern hemisphere their magnetism became inverted.

The observations made with the mast compass, though unfortunately their value was much diminished by the defects of that compass, seem sufficient to show that such a compass may be of the greatest possible value as a compass of reference and as a check on the standard compass.

The importance of these results may make us regret that Dr. Scoresby was not able to procure more accurate observations, and at a greater number of places, and may lead us to anticipate that still more valuable results might be derived from very careful observation of the deviation of the compasses, and of the variations of the vertical and horizontal force made on board an iron ship before leaving England, in the southern hemisphere, and after her return to England.

This sketch would be incomplete without some reference to what has been done on this subject by public bodies.

About the year 1840, a committee of scientific men and naval officers was appointed by the Admiralty to consider various questions connected with ship's compasses, and the correction of the deviation. That committee recommended the improved form of compass now used as the standard compass in the navy, and the correction of the deviation, not by mechanical corrections, but by "swinging" the ship, and obtaining a table of the deviations, to be afterwards applied to correct the observed courses and bearings. This system has been ever since followed in her Majesty's ships, under the able superintendence, first, of Captain E. J. Johnson, and afterwards of Mr. F. J. Evans, the present superintendent of the compass department, and with such success that I believe I am correct in saying that, with the single exception of the Birkenhead, there is no reason to believe that any of Her Majesty's ships have been wrecked in consequence of the deviation of their compasses. A work on the deviation of the compass, by Captain Johnson, contains a valuable collection of the deviations observed in ships having compasses not corrected by magnets. Various sets of "instructions" for the correction of the deviation have been published by the Admiralty.*

In the mercantile marine the case is different. No uniform system has there obtained. The profession of a compass-adjuster has sprung up. Each compass-adjuster corrects in his own way. The merchant captain does not understand the process. He assumes that his compasses are correct, till he finds out that they are in error, sometimes by shipwreck; and when he discovers the error at sea, he is unable to correct it himself, and is obliged to navigate disregarding the compass.

On the occasion of the meeting of the British Association, at Liverpool, in the year 1854, the attention of the shipowners and underwriters of Liverpool was strongly called to the subject by Dr. Scoresby and others. The result was the appointment of a local body under the name of the Liverpool Compass Committee, consisting of a number of influential ship owners, shipbuilders, underwriters, and men of science, who secured the services of a most competent secretary, Mr. W. W. Rundell, and who, in two reports made to the Board of Trade, in 1855 and 1856, and presented to both Houses of Parliament in the year 1857, collected, discussed, and published a most valuable series of observations on the deviation of the

* The following is a list of these instructions:

"Practical Rules for Ascertaining and Applying the Deviations of the Compass caused by the Iron in a Ship." Potter, London, 1855.

First supplement to the foregoing, being "Instructions for the Computation of a Table of the Deviations of a Ship's Compass, from Observations made on 4, 8, 16, or 32 Points, and a Graphic Method of Correcting the Deviation of a Ship's Compass." By Archibald Smith, Esq., M. A. Potter, London, 1855.

Second Supplement to the Practical Rules, being a "Graphic Method of Correcting the Deviation." By Captain Alfred Ryder, R. N.

"Directions for the Use of a Small Apparatus to be Employed with a Ship's Standard Compass, for the Purpose of Ascertaining the Changing (semicircular) Part of the Deviation." By Major General Edward Sabine, R. A. Potter, London. 1856.

compass in vessels having their compasses corrected by fixed magnets. I may refer to this report, pp. 47–55,* for a full and able discussion by Mr. Rundell of the observations made in the Royal Charter. The Liverpool Compass Committee having effected as much as could be effected by a private body, brought their labors to a close in the year 1857.

The Board of Trade has lately directed the attention of the mercantile marine to this subject in its publications,† but it has not yet taken up the subject in that systemactic and continuous way to which the report of the Liverpool Compass Committee points as desirable. That this might be done with great advantage, and with little more expense than that incurred by the Liverpool compass committee during its existence, does not seem to admit of doubt. Whatever difference of opinion may be entertained as to applying correctors to the steering compasses of iron ships, it can hardly admit of question that every iron ship should have at least one compass removed as much as possible from the influence of iron, and not corrected by magnets, and should be swung at the beginning and end of every voyage of any length, and the deviation of the uncorrected and corrected compasses (if any) observed. No man is competent to command an iron ship who is not competent to make these observations; and if these observations were transmitted to the Board of Trade, and systematically reduced, and discussed, and published, most valuable results would certainly be obtained. It may be added that the observations so made would furnish a test of the care, skill, and good faith of the captain who made the observations, as the process of reduction shows almost infallibly the genuineness and correctness of the observations.

A. S.

---

* See pp. 53–57 of this reprint.—B. F. G.

† "A Circular on Deviation," by Rear-Admiral Fitzroy, and "Instructions for Correcting the Deviations of the Compass." Edited by Archibald Smith, Esq., M. A., F. R. S.

ON THE CAUSES OF THE LOSS OF THE IRON BUILT SAILING SHIP "GLENORCHY."

By Archibald Smith Esq., *L.L.D.*, *F.R.S.*

[*Proceedings of the Royal Society*, *No.* 111, 1869.]

When the loss of an iron-built vessel has been caused by an error in the direction of her course by dead reckoning, as derived from her course by compass, it is a question of scientific interest whether the error has or has not arisen from an error in the assumed deviation of the compass. By careful consideration of all the circumstances of the case, and by piecing together the generally scanty fragments of information which can be obtained as to the magnetic state of the ship, a probable or certain answer to this question may be given more frequently than might be supposed possible, by those who do not know how perfectly definite and well-ascertained the laws of the deviations of the compass are, how small is the number of quantities involved which are peculiar to each particular ship, and from what apparently slight indications an approximate estimate of the numerical value of these quantities can be made.

The case, the circumstances of which I now propose to lay before the Royal Society, is one in which it appears to me that a positive answer to the question can be given. It will, I hope, be found to have some interest as an example of the manner in which such an answer can be elicited from the data. It may have some scientific interest as the first case in which any information as to the magnetic character of an English merchant ship has been published since the publication of the Third Report of the Liverpool Compass Committee is 1861; and I think it will be found to have much practical interest, as bringing into prominence a particular error of great importance, not as yet, I believe ascertained or corrected in the usual course of adjustment of compasses in merchant ships, even by the most experienced and skilful compass adjusters, but which, ever since the mode of ascertaining and correcting it without heeling the ship, was given in the "Admiralty Manual for the Deviation of the Compass," in 1862, has been ascertained, and when necessary, corrected in the ships of the Royal Navy, viz: the heeling error. The case to which I refer, is the loss of the ship "Glenorchy," of Glasgow, on the Kish Bank, in Dublin bay, on the 1st of January, 1869, on which a court of inquiry was held, under the direction of the Board of Trade, in pursuance of the merchant shipping act. In examining this case, I have had the advantage, by the permission of the Board of Trade, of perusing the evidence taken before the court of inquiry, and the report of the court. I have also had the advantage of discussing the nautical as well as the magnetical circumstances of the case with Captain Evans, F.R.S., the highest authority in all that relates to such an inquiry, and who permits me to state his concurrence in the conclusions at which I have arrived; and above all, I have to express my obligations to Mr. William Fleming, compass adjuster, James Watt street, Glasgow, for the full particulars with which he has kindly furnished me of the deviations and corrections of the compasses of the "Glenorchy," information without which the results of this inquiry would have been in a great measure conjectural.

The "Glenorchy" was an iron-built sailing ship of 1,200 tons, having an iron poop, with a wooden deck laid upon iron beams, with iron bulwarks, except on the poop-deck, above which there was a light rail. She was built at Dumbarton, in 1868. Her head in building was about N.N.E. After being launched, she was taken to Glasgow, where she lay for some time head N.W., taking in a cargo of 1,100 tons of iron railway chairs and sleepers.

She had two compasses on deck—a steering compass and a standard compass. The card of each had two edge-bar needles, 8¾ inches long, the ends separated 50°.

The steering compass was near the stern, about 32 or 33 inches above the poop-deck, and 2 feet in front of the steering wheel, which had an iron spindle. The standard compass was on a wooden pillar, about 5 feet high, standing on a wooden platform laid from the poop to the mainmast, about 15 feet abaft the mainmast, which was of iron.

On the 18th of December, the "Glenorchy" had her compasses adjusted in the Gareloch, by Mr. Fleming, in the usual way.

The deviation of the steering compass, as might have been expected from the combined effect of the position of the compass in the ship and of the ship in building, was *enormous*. Mr. Fleming says it was "as bad if not worse than any he ever saw." Mr. Fleming informs me that, before magnets were applied to the steering compass, when the ship's head bore N., (magnetic,) it bore S. by the steering compass; when the ship's head bore W., (magnetic,) it bore about S.W. by S. by the steering compass. In other words, at N. (magnetic) there was a deviation of 180°; at W. (magnetic) a deviation of about 56° 15′ E. The quadrantal deviation was about 10°.

These data give, using the notation of the "Admiralty Manual for the Deviation of the Compass"—

$$\mathfrak{B} = -1.250,$$
$$\mathfrak{C} = 0,$$

or a force of the ship to the stern exceeding by one-fourth the whole directive force of the Earth's magnetism acting on the compass, a disturbing force about twice as great as that found at the steering compass in any of the iron-built armour-plated ships in Her Majesty's navy.

This enormous disturbing force was corrected by three large magnets, one of 36 inches, and two of 26 and 28 inches, placed together, fore-and-aft, on the starboard side of the binnacle, and by two or three smaller magnets, placed so as to correct, as far as possible, the residual error on the other cardinal points.

The ship was then placed head N.W., (magnetic,) when a westerly deviation of three-fourths of a point 8° 26′ was observed. This was, of course, approximately the amount of the quadrantal deviation, and it was corrected by a No. 12 iron jack-chain placed in the chain-boxes on each side of the compass.

The ship was then swung on sixteen points, and the following deviations of the steering compass obtained, (+ signifying that the N. point of the needle was drawn to the E., — to the W.)

"*Glenorchy*" *steering compass, December* 18, 1868.

Magnetic course.	Deviation.	Magnetic course.	Deviation.
	°		°
North	0	South	—2
N. N. E.	+3	S. S. W.	+3
N. E.	+7	S. W.	0
E. N. E.	+2	W. S. W.	0
East	+3	West	+5
E. S. E.	—3	W. N. W.	—3
S. E.	—2	N. W.	0
S. S. E.	—1	N. N. W.	—2

From these I derive the following expression for the deviation (δ) in terms of the azimuth of the ship's head (ζ) measured eastward from the magnetic N.

$$\delta = 30' + 30' \sin \zeta + 1° \, 2' \cos \zeta + 2° \, 37' \sin 2\zeta - 38' \cos 2\zeta.$$

These values show that the semicircular deviation has been entirely corrected. Of the quadrantal deviation, a small part appears to have been uncorrected. There are practical difficulties in the way of correcting very large amounts of this deviation by soft iron, and I have no doubt Mr. Fleming acted with judgment in not attempting to carry this correction further. We may probably assume the maximum quadrantal deviation to have been about 10°.

The standard compass was not corrected by magnets, but its deviations were observed, and a table of the deviations furnished. They were:

"Glenorchy" standard compass, December 18, 1868.

Magnetic course.	Deviation. ° ′	Magnetic course.	Deviation. ° ′
North	+12	South	— 5
N. N. E	— 7 30	S. S. W	— 7 30
N. E	—21	S. W	—16
E. N. E	—37 30	W. S. W	+22 30
East	—38	West	+33
E. S. E	—31 30	W. N. W	+35 30
S. E	—24	N. W	+35
S. S. E	—11 30	N. N. W	+20 30

These values give—

$$\mathfrak{A} = 0, \quad \mathfrak{B} = -.610, \quad \mathfrak{C} = +.105, \quad \mathfrak{D} = +.100, \quad \mathfrak{E} = 0.$$

This table and these values do not bear directly on the loss of the ship, because owing, as I collect, to the unsteadiness of the pillar, the standard compass was found to be useless, and the ship was navigated by the steering compass alone; but it is interesting, from the light it throws on the general magnetic character of the ship, and its confirmation of the results obtained from the steering compass.

The proportion of $\mathfrak{C}$ to $-\mathfrak{B}$ exactly agrees with what we know of the direction in which the ship was built.

The large value of $-\mathfrak{B}$ was no doubt owing to the original magnetism of the hull, and not to the iron cargo, which, in fact, probably rather diminished than increased the $-\mathfrak{B}$.

Cards containing the deviations of both compasses were furnished to the captain.

The question of the correction of the standard compass by magnets is one which has become of so much importance, that I may be pardoned for interposing a digression on this subject, and for inserting a passage from the third edition of the "Admiralty Manual," now in the press.

"The question of the mechanical deviation of the compass has materially changed its aspect of late years. Before that time, the deviation of a properly placed standard compass was of moderate amount, its maximum seldom exceeding 20°, and the directive force which acted upon it being generally comprised within the limits of two-thirds and four-thirds of the mean force. There was then no difficulty and some advantage in dispensing altogether with mechanical correction; or, if mechanical correction was employed, it was possible, at least in vessels which did not change their magnetic latitude, to make the corrections so complete that tabular correction might be dispensed with. But, in the present day, it is frequently impossible to find a position for the standard compass at which the deviation and the variation of directive force do not greatly exceed these limits. In such cases, the application of magnets for the purpose of equalizing the directive force on different azimuths becomes a matter of necessity; while, at the same time, the danger of trusting to mechanical correction alone without ascertaining and applying the residual errors is increased.

"This change of the condition of the question has produced a corresponding change in the practice of the Royal Navy.

"The same care as before is still used in the selection of a place for the standard compass; but a magnet is frequently or generally introduced, for the purpose of equalizing the directive force on different azimuths, and at the same time diminishing the semicircular deviation. The quadrantal deviation is not often corrected mechanically, but is generally left for tabular correction.

"The heeling deviation is always ascertained, and is sometimes corrected mechanically."

After the "Glenorchy" was swung, she took in an additional quantity (about 120 tons) of iron. I do not, however, think it possible that this quantity could have altered the deviations sensibly.

The "Glenorchy" sailed from Greenock on the 25th of December. She had on board a pilot accustomed to the navigation of the Irish Channel. She was towed to Lamlash Harbor, in the Island of Arran, where she lay till 3 a. m. on the 31st of December. She then got under way, the wind blowing moderately from the N.W., and steered a course down mid-channel, sighting the Copeland, the Mull of Galloway, the North and South Rock, St. John's Point, and the Calf of Man lights.

The wind gradually heading her, she tacked about 6 15 a. m., on the 1st of January. At 7 10 a. m. her position was determined by a bearing and distance of the South Stack Light, which then bore S. by W., distant five miles.

Till the ship tacked, she had been on the starboard tack, on courses from S.W. to S., on which the deviation card gave small deviations for the steering compass. The bearing of the lights successively passed had, however, been carefully taken by the captain, and from these he found that the compass had a westerly deviation of one point not shown by the deviation card. From 7 10 a. m. till 3 p. m. the ship was on the port tack, sailing by the wind but kept good full, her course by the steering compass being about S.W. by W. During the whole of this time, a gale of wind was blowing from S.S.E., gradually increasing in intensity, with thick weather and rain, which cleared only for a little about 1 30 when land was seen in the distance bearing W.N.W. The lead was cast, and 35 fathoms found. The captain and pilot consulted the chart, and making what they considered a proper allowance for tide and leeway, came to the conclusion that the land was Wicklow Head, bearing W.N.W. twenty-two miles.

The ship then stood on the same course till 3 p. m., when soundings were again taken, and 25 fathoms found. Orders were then given to wear, but in wearing, and when nearly before the wind, the ship struck and remained fixed on the Kish Bank, about four miles south of the Kish light-ship.

The point at which the ship so unexpectedly found herself was about twenty geographical miles to leeward of that at which the captain and pilot supposed themselves to be. In other words, the ship's actual course was about 28° or 2½ points to the right of her supposed course. To what, then, was the error due?

In the first place, it seems impossible to attribute any large part of the error to an insufficient allowance for the effects of tide and leeway. It is true, that from 7 to 1 o'clock a spring flood-tide, assisted by a southerly gale, had been running, but this was known to the captain and pilot. They had watched with great care throughout the day the courses, the leeway, and the rate, and, if we may judge from their estimate of the distance run, had estimated them with great exactness.

The next cause that suggests itself is a deviation of the compass not allowed for.

The steering compass by which the ship was navigated was, we have seen, carefully adjusted in the Clyde, and was then nearly correct on a S.W. by W. course. Is it possible that any change in the magnetism of the ship had taken place, as has sometimes been found or supposed in new ships, which would account for the error? The answer to this must be in the negative. It is certain that any such change in the "Glenorchy" would have had the effect of producing an error of the opposite kind, and, had it operated, she would have been found to the south, not to the north, of her supposed course.

Is there, then, any other cause adequate to produce an easterly deviation on a S.W. by W. course, which might lurk concealed and undetected in the process of adjustment, and only emerge during the voyage? To this the answer is emphatically Yes! *The heeling error.*

From the combined effects of the position of the steering compass in the ship and of the ship in building, it is certain that there must have been a very large heeling error, drawing the north point of the compass to the weather side of the ship. This error was probably not less than 3° or 4° for each degree of heel on a N. or S. course, before the chain-correctors were applied. The chain-correctors would reduce it about 50′, leaving 2° or 3° for each degree of heel. On a S.W. by W. course, this error would be reduced to five-ninths of its maximum amount, or would be from 1° to 1½° for each degree of heel. Hence, if the "Glenorchy" was heeling 10°, she would *certainly* have an easterly deviation of a point to a point and a half, or possibly more, introduced.

But it may be asked, if the ship had this large amount of heeling deviation, how did it escape detection in the earlier part of the voyage, when the ship was on a southerly course, and the bearings of the lights were taken; and if detected, how was it not allowed for on the 1st of January?

The answer to these questions is remarkable; it is shortly this. The error *was* detected and *was* allowed for correctly when the ship was on the starboard tack. Afterwards, and when the ship was put on the port tack, it was still allowed for, *but in the same direction as before*, and therefore, in the wrong direction. It was allowed for as a *westerly* deviation, although it had become an *easterly* deviation; and, consequently, the heeling error, instead of being corrected, was doubled. And of this the cause was as follows:

Between Greenock and Lamlash, the ship being towed and on an even keel, there were no means of detecting the error. Between Lamlash and the Calf of Man, when the ship was on the starboard tack and on a southerly course, an error of a *point of westerly deviation* was, as we have seen, detected and allowed for by the captain. This error, I think, there cannot be a doubt was heeling error.

But when, on the morning of the 1st of January, the ship tacked and was put on the port tack, the heeling deviation changed from being a westerly deviation to an easterly deviation. The captain not being aware that there would be this change, and having no opportunity of verifying his course, continued to make the same allowance as before, and consequently made it, as I have said, in the wrong direction. As to the fact, I think, I cannot be mistaken.

The captain's words are: "Our observations of the different lights all the way down Channel showed the compasses were inaccurate, and during the whole course on the starboard tack we had to steer one point more to the west than the proper course."

Then speaking of the ship's supposed position at 1.30, he says: "The courses I had observed, and the rate we were going, allowing for the tide and the leeway, *and the point the compass was in error while on the starboard tack*, should have brought us to a point with Wicklow Head lying W. by N., twenty-one miles distant."

It is clear from this, that the captain made an allowance for the point of error he had discovered. Had he applied it in the opposite direction, he would undoubedly have mentioned that he did so, and why he did so.

The particular conclusions, then, which I draw from the facts of the case are these:

1. There must have been a large heeling error affecting the steering compass of the "Glenorchy," which, on the courses steered, would be a westerly deviation on the starboard tack, an easterly deviation on the port tack.

2. The westerly deviation detected on the starboard tack was this heeling error.

3. The true construction to be put on the captain's statement is, that when on the port tack he allowed for the point of deviation which he had detected on the starboard tack as a point of westerly deviation, not as a point of easterly deviation, as he would have done had he known the cause and the law of deviation which he had detected.

4. That, in consequence, his supposed course was in error one point *plus* the heeling deviation, which, on a S.W. by W. course, was probably about one point more.

The general conclusions to be drawn from the history of the shipwreck seem to me to be:

1. The great importance of selecting a position for the navigating compass where the force of the ship's magnetism is moderate and uniform.

2. The importance of extending the usual process of "adjustment" of a compass to the ascertaining and (if necessary) the correcting of the heeling error. This is a matter of no difficulty, if the compass adjuster is duly instructed and supplied with the requisite instruments.

ON THE AMOUNT AND CHANGES OF THE POLAR MAGNETISM, AT CERTAIN POSITIONS, IN HER MAJESTY'S IRON BUILT AND ARMOUR PLATED SHIP "NORTHUMBERLAND."

By Frederick John Evans, *Staff Captain R.N., F.R.S.*,
Chief Naval Assistant, Hydrographic Department, Admiralty.

[*Philosophical Transactions Royal Society for* 1868.]

In the year 1860, an official report made by me on the deviations of the compass observed in all the iron-built ships, and in a selection of wooden-built ships in Her Majesty's Navy, and in the iron steamship "Great Eastern," was communicated by Captain Washington, R. N., F.R.S., the Hydrographer of the Admiralty, to the Royal Society, and was published in the Philosophical Transactions for 1860, p. 337.

In the year 1865, with the sanction of the Lords Commissioners of the Admiralty, and in conjunction with Archibald Smith, Esq., F.R.S., I presented to the Society a paper on the magnetic character of the armor-plated ships of the Royal Navy, which was published in the Philosophical Transactions for 1865, p. 263.

These papers contained a reduction and discussion of observations of the deviations of the compass, and of the horizontal and vertical magnetic force made on board a large number of iron-built ships, at different positions in the ship, at different times, and in different geographical positions; and comprised almost all the results of any value or importance regarding the deviations of the compass which, up to the time of that publication, had been obtained in the classes of ships to which they related.

The system pursued in the Compass Department of the Royal Navy of making careful observations whenever the occasion offers, of the deviations and horizontal and vertical force in the ships of the Royal Navy, and of reducing such observations so as to obtain the magnetic co-efficients $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$, λ, μ, will, I hope, enable me hereafter to lay before the Society a continuation of the former papers, in which I trust one of the deficiencies, viz: the want of a variety of observations made in the same ship in different geographical positions, will be removed by the zeal of the navigating officers now serving in several of Her Majesty's ships on foreign stations.

In the meantime, I take the opportunity of an unusually detailed set of observations having been made in the latest and largest of the armor-plated ships, the "Northumberland*," to lay before the Society, with the sanction of the Lords Commissioners of the Admiralty, some results as to the amount and changes of the magnetic force, at several positions in that ship.

These results may be thought to have some special interest from the circumstance that the "Northumberland" was made the subject of an attempt to "depolarize" her, which created some interest and expectation, not only in the general public, but even in the naval profession†.

The "Northumberland" is an iron-built ship, of 6,621 tons, 400 feet long, 59¼ broad, 26¼ feet draught of water, 1,350 horse power, screw engines, armor-plated completely round, with plates of an average of 6 inches in thickness. She has further three complete iron decks, supported by iron beams and iron uprights, and a poop-deck of wood, but supported by iron beams and iron uprights. The five lower masts are also of iron. The weight of iron employed in the construction of the hull was about 4,250 tons, and in the armor-plating about 1,550 tons.

The ship was built at Millwall, on the river Thames, the direction of her head in building being N. 39½° E. magnetic. Contrary to the usual practice with ships built on a slip, the armor-plating was completed previous to launching; the latter operation, it may be recollected, was performed with great difficulty, and occupied several days. The launch was completed on the 17th April, 1866, when the ship was anchored in the river, and allowed to swing with the tide. On the 18th April she was towed to the Victoria Docks, where, on the recommendation of the Compass Department, she was placed in a direction as nearly opposite to that of the building as could be conveniently arranged, (viz: S. 22° W. magnetic.)

Unfortunately, two large iron-plated ships, (one iron-built,) lay close alongside, and no doubt affected considerably the magnetic phenomena

* The observations discussed in this paper were made, and the co-efficients computed, by Staff Commander William Mayes, my successor as Superintendent of Compasses of Her Majesty's Navy: and I am happy to have an opportunity of bearing testimony to the care and zeal with which he has discharged the duties of his office. I have also to acknowledge my obligations to Mr. Archibald Smith, F.R.S., for the assistance which he has given me in the discussion of the observations, especially in their mathematical and graphical treatment.

† I would refer especially to two papers, read before the Royal United Service Institution, London, and the discussions thereon, as published in the Journal of the Institution. The first paper, on "Terrestial Magnetism with reference to the Compasses of Iron Ships, their Deviation and Remedies," read January 29, 1866; the second paper, on the "Demagnetization of Iron Ships and of the Iron Beams, &c., of Wooden Vessels, to prevent the Deviation of the Compasses, experimentally shown by means of a Model," read May 6th, 1867. Both papers by Evan Hopkins, C.E., F.G.S. The latter paper was also read at the Salle des Conferences, Champ de Mars, Paris, (in connexion with the International Exhibition,) on the 22d June, 1867, by Captain F. A. B. Craufurd, R. N.

observed in the "Northumberland." This circumstance prevents the observations made during her stay in the Victoria Docks being strictly comparable with those made before and afterwards; and this must be borne in mind in looking at the tables. It has, as far as possible, been allowed for in the assumed value of λ. Some irregularities were also caused by the introduction and movement of the large masses of iron constituting the steam-boilers and engines.

At the end of December, 1866, the ship was completed in her equipment for temporary service, and steamed to Sheerness, where she remained swinging to the wind and tide till the early part of March, 1867, when she steamed to Devonport, at which place, with the exception of two days' trial at sea to test the machinery, in the middle of May, she has remained in a dry dock, with her head directed S. 84° E., magnetic, till the present time.

The positions of the compasses at which observations were made were the following:

STANDARD COMPASS.—The "Northumberland" having been built with her head nearly N.E., the magnetism principally developed was in the stern and starboard quarter, and it was therefore desirable that this compass should be as far forward as possible. It was accordingly placed 173 feet from the stern, and 8¾ above the iron deck.

STEERING COMPASSES.—The upper deck steering wheel is 52 feet from the stern, under the fore part of the poop wooden deck; two compasses were placed close in front of it, 6 feet apart, each 4 feet above the iron deck, and 3 feet 8 inches below the iron beams supporting the poop deck.

POOP COMPASS.—This compass was placed on the fore extreme of the poop deck, and 9 inches before the line joining the steering compasses, and 4 feet above the poop deck. In the selection of a place for these latter compasses there was no room for choice; the arrangements of the architect and the requirements of the seaman could be alone consulted.

The results of the observations will be found in the table appended to this paper, and will include a few made at temporary positions not necessary to describe in detail.

For a complete explanation of the meaning of the quantities tabulated, and the method of obtaining them by observation, I must refer to the last of the two papers mentioned above. Here it may suffice to say, that if

ζ represents the magnetic azimuth of the ship's head,

ζ' the azimuth by disturbed compass, $\delta = \zeta - \zeta'$ the deviation, then

$$\sin \delta = \mathfrak{A} \cos \delta + \mathfrak{B} \sin \zeta' + \mathfrak{C} \cos \zeta' + \mathfrak{D} \sin (2\zeta' + \delta)$$
$$+ \mathfrak{E} \cos (2\zeta' + \delta) \text{ exactly,}$$

or

$$\delta = A + B \sin \zeta' + C \cos \zeta' + D \sin 2\zeta' + E \cos 2\zeta' \text{ approximately.}$$

Of these co-efficients $\mathfrak{A}$, $\mathfrak{D}$, $\mathfrak{E}$, (or A, D, E,) depend solely on the transient magnetism induced in the soft iron, and therefore cannot be affected by any artificial magnetization or demagnetization.

$\mathfrak{B}$ (or B) depends partly on the magnetism induced in soft iron by the Earth's vertical force, partly on the permanent or sub-permanent magnetism of the hard iron. $\mathfrak{C}$ (or C) depends on the last. It is therefore to the changes in $\mathfrak{B}$ and $\mathfrak{C}$ only that we are to look for the effects of polarization or depolarization.

λ is a factor almost always less than unity, representing the mean force to north, as affected by the soft iron in the ship.

$\lambda\mathfrak{B}$ is the mean force, or, in other words, the polar force of the ship to head.

$\lambda\mathfrak{C}$ is the mean or polar force to starboard, $\lambda\sqrt{\mathfrak{B}^2 + \mathfrak{C}^2}$ the mean or polar horizontal force of the ship; each in terms of the Earth's horizontal force as unit.

$\frac{\mathfrak{C}}{\mathfrak{B}}$ is the tangent of the angle which the direction of the ship's polar horizontal force makes with the line drawn to the ship's head, or the "starboard angle."

μ is the mean or polar force downwards of Earth and ship, in terms of the Earth's vertical force as unit, and depends partly on the sub-permanent force of the hard iron, partly on vertical induction.

$\left(\mathfrak{D} + \frac{\mu}{\lambda} - 1\right) \tan\theta \times 1^\circ$ is the heeling co-efficient to windward, and represents the deviation to windward caused by an inclination of the ship of 1°, when her head is north or south by compass.

The value of these co-efficients, and also of a and e, the co-efficients of horizontal induction, headward and to starboard, for the several compasses, are given in the general table appended to this paper.

The character of the deviations of the standard, steering, and poop compasses, and of their changes, may be thus generally described:

In each, the $\mathfrak{B}$ has originally a large negative value, caused by the ship having been built nearly head north, (N. 39½ E.) This gradually diminishes as she lies in the Victoria Docks, with her head to the south, but, as is usually found, shows a tendency to return to its original value when the ship is allowed to swing. $\mathfrak{C}$, which has originally a large positive value, caused by the starboard side having been to the south, decreases, and even changes its sign in Victoria Docks, but returns to its original sign, and nearly to its original value, when the ship swings at Sheerness.

In the poop and steering compasses down to 1st January, 1867, and in the standard compass throughout—except for a short period while a magnet was applied to reduce the deviation—there are no changes, except what may be considered to be due to the ship's position, and to the other circumstances adverted to; but as regards the poop and steering compasses, between 1st and 26th January, the case is different; the causes of the difference, and the inferences to be drawn from it, it is proposed now to consider.

Early in 1866, Mr. Evan Hopkins,* C.E., applied for a patent for "An improved method of correcting the deviation of compasses in iron ships." In the provisional specification dated 23d January, 1866, the method is described as "destroying the polarity acquired while the ship is building, by passing electro-currents through the hull." In the final specification, dated 23d July, 1866, it is described as "moving an electro-magnet from end to end over, and in contact with, the main plates of the ship." There is some obscurity in both specifications, from the patentee not distinguishing between electric currents and lines of magnetic force; but whatever may be the method described in the provisional specification, it is certain that that method would be utterly inadequate to produce any sensible effect in a large ship.

The method described in the final specification would no doubt produce, wherever applied, some local effect; but the effect produced by the local application of magnetic force of high and rapidly varying intensity must necessarily be wholly different from that which has arisen from the general application of a force of low and uniform intensity, and the former cannot possibly produce any general destruction of the latter. The process, is, in fact, not one of general demagnetization, but of partial counter-magnetization. The result will be an irregular distribution of magnetism of very variable intensity, necessarily very unstable, and producing, wherever effective, a rapidly varying field of force. The justice of these remarks will, I think, be shown in the sequel.

In April, 1866, Mr. Hopkins applied to the Admiralty for permission to experiment on the "Northumberland," the largest and most heavily armored ship in the Royal navy. The application was, in the usual course, referred to the Magnetic department, and on a report that no injury was to be apprehended, the required permission was granted.†

The first trials were made on the 4th August, 1866, and are thus described by Mr. Hopkins, in a report dated 10th August, and received

* Mr. Evan Hopkins was the author of a work entitled "On the Connexion of Geology with Terrestrial Magnetism," 1844, 2d edition, in which many singular opinions are propounded on astronomy, magnetism, and general physics. I regret to have to speak of Mr Hopkins in the past tense. He died in the middle of 1867.

† That report, for which I am responsible, was made on the supposition that the process was one to be applied to the hull of the ship generally, according to the specification of the patent. Had I understood that the iron in the immediate vicinity of any compass was to be magnetized to a high degree of intensity, I should certainly have reported differently; and it will be seen in the sequel that from the results of Mr. Hopkins's experiments, I was obliged to submit that no such experiments for the future be permitted within 20 feet of any compass placed for the navigation of the ship.

at the Admiralty a few days afterwards. "After having ascertained the actual magnetic condition of the ship, I applied two of Grove's batteries of five cells each, with the electro-magnets to the main plates at the stern and bow, and in a few hours the polarity of the hull was destroyed."†

The results of the observations shown in the general table, I think, entitle me to say that there is no foundation whatever for the statement, that the polarity of the hull was destroyed. There is, in fact, no evidence of its having been affected in even the slightest degree. To facilitate the examination, I subjoin the values of the semicircular deviation of the two compasses which were most continuously examined in the period comprising the 4th August: the poop and starboard steering compasses; the position of the standard compass being at that time occupied by machinery.

Date.	Maximum of semicircular deviation.	
	Poop compass.	Starboard steering compass.
	°	°
May 29, 1866	48¾	39¼
July 12, 1866	64⅛	50
August 10, 1866	55¾	46⅛

In each case, it will be seen there is a slight decrease in the interval comprising the 4th August, but the decrease does not exceed half the increase in the preceding interval; and seems only the recovery from an anomalous increase in July, probably attributable to some external disturbing cause of the nature before mentioned, viz: the proximity of the two armor-plated ships in the Victoria Docks.

The next and final trial was made between the 1st and 26th of January, 1867, at Sheerness. Ten or twelve days were occupied in passing large electro-magnets along the outside of the ship, from the water-line to the top sides. Subsequently, and apparently as an after thought—as no mention is made in either specification of internal demagnetization on so large a scale—about five days more were occupied in applying the electro-magnets to the transverse iron beams of the poop and upper deck nearest the poop and steering compasses, and to two adjacent vertical iron stanchions supporting the upper deck. As no appreciable effect was produced on the standard compass, or on any compasses except those in the immediate vicinity of the beams and stanchions operated on, we may have confidence in attributing the change which took place entirely to the latter operations.

† This statement was subsequently repeated at a meeting of the British Association for the Advancement of Science, held at Nottingham, in 1866, in a paper "On the Depolarization of Iron Ships, to prevent the Deviation of the Compass," by Mr. Evan Hopkins, C.E. See Athenæum, of September 8, 1866.

The following tables, derived from the general table, furnish the means of deciding this question:

TABLE I.

At position of the undermentioned compasses.	(I.) B Part of semicircular deviation from headward force.	(II.) C Part of semicircular deviation from transverse force.	(III.) $\sin^{-1}\sqrt{\mathfrak{B}^2+\mathfrak{C}^2}$ Maximum of semicircular deviation.	(IV.) $\tan^{-1}\frac{\mathfrak{C}}{\mathfrak{B}}$ Starboard angle.	(V.) Mean vertical force of Earth and ship, in terms of Earth's horizontal force as unit.	(VI.) Heeling error to windward for 1° of heel.	(VII.)
January 1, 1867.	°	°	°	°		° ′	
Standard	—37	+ 4½	40½	173¾	1.223	+ 1 18	
Starboard steering	—39¾	+15¼	46½	161¼	1.056	+ 1 4	
Poop	—48¾	+15¼	56½	164¼	1.469	+ 2 1	
Port steering	—43	+19¾	51	157¼	....	....	

TABLE II.

January 26, 1867.							
Standard	—36¼	+ 7	40¼	170¼	1.271	+ 1 27	
Starboard steering	— 2¼	+38¼	36¾	94¼	1.250	+ 1 45	
Poop	— 3¼	+12¼	12¼	104¾	.986	+ 0 37	
Port steering	— 4¼	—11	11	246	....	....	

TABLE III.—*Amount and direction of magnetic forces on January* 1, 1867.

Compasses.	$\lambda\mathfrak{B}$ Ship's force to head.	$\lambda\mathfrak{C}$ Ship's force to starboard.	$(\mu-1)\tan\theta$ Ship's force downwards.	$\lambda\sqrt{\mathfrak{B}^2+\mathfrak{C}^2}$ Horizontal force of ship.	$\sqrt{\text{Col. III}^2+\text{IV}^2}$. Total force of ship.	$\tan^{-1}\frac{\mathfrak{C}}{\mathfrak{B}}$ Starboard angle of ship's force.	$\tan^{-1}\frac{\text{Col. III}}{\text{Col. IV.}}$ Dip of ship's force.
						°	° ′
Standard	—.562	+.062	+ .553	.566	.791	173¾	+44 24
Starboard steering	—.546	+.186	+ .139	.578	.595	161¾	+13 32
Poop	—.691	+.196	+1.163	.720	1.368	164¼	+52 46
Port steering	—.580	+.242	....	.628	....	157¼	....

TABLE IV.—*Amount and direction of magnetic forces on January* 26, 1867.

Standard	—.554	+.094	+.672	.562	.876	170¼	+50 5
Starboard steering	—.037	+.477	+.620	.478	.783	94¼	+52 25
Poop	—.051	+.175	+.035	.181	.184	104¾	—10 57
Port steering	—.062	—.141	....	.153	....	246	....

TABLE V.—*Amount and direction of additional forces introduced between January* 1 *and* 26, 1867.

Standard	+.008	+.032	+ .119	....	....	....	....
Starboard steering	+.509	+.291	+ .481	.586	.758	+30	+38 25
Poop	+.648	+.021	—1.198	.648	1.362	— 2	—61 35
Port steering	+.518	+.383	....	.644	....	—36¼	....

The values of B and C in table I show the remarkable amount of accordance in the deviations of the *four* compasses—a similarity which clearly indicates that the cause of the deviations is to be sought for, not in the iron in the immediate vicinity of those compasses, but in iron at such a distance that the distance between the compasses does not materially affect its action on them.

The values of B and C, in table II, show an important change in *three* of the compasses. The value of B for the starboard steering, poop, and port steering, are nearly reduced to zero, showing the introduction of a powerful force attracting to the bow of the ship, or repelling from the stern. With C the case is very different: in the port compass a deviation to port is produced; in the starboard compass a deviation to starboard; indicating the introduction of a repelling force between the two. The same conclusion may be drawn, and perhaps with greater facility, from a comparison of the value of the quantities in columns III and IV.

The quantities in columns V and VI show that the change produced is an upward force on the poop compass, and downward on the starboard steering compass; pointing to a repelling force emanating from a point or region at a height intermediate between the height of the two compasses. These several comparisons show, that the change was really caused by a repelling force (a north pole) being introduced in the iron of the poop deck a little abaft the poop compass.

The precise amount and direction of the force so introduced, and the changes it caused in the previously existing forces, will be seen distinctly by the mathematician from tables III, IV, V.

The action of the several forces may perhaps be more clearly apprehended, when they are represented graphically as in the first Plate. In this, Fig. 1 represents the projection of lines indicating the amount and direction of the magnetic forces which act on the three compasses on the horizontal plane. Fig. 2 represents the projection of the same lines on the fore-and-aft vertical plane. The figures are drawn to a scale in which one-fourth of an inch represents one foot, and also one-tenth of the Earth's horizontal force.* The lightly dotted parts represent iron.

P, Q, R, represent the positions of the port, the poop, and the starboard steering compasses, respectively; P*p*, Q*q*, R*r*, represent the projection of lines representing the magnetic forces of the ship at these positions on the 1st January, 1867; P*p'*, Q*q'*, R*r'*, the same projection on the 26th January, 1867; P*p''*, Q*q''*, R*r''*, the projection of the additional forces introduced in the interval.

In Fig. 1, the near approach to parallelism and equality in P*p*, Q*q*, R*r*, indicate a distinct cause of magnetic force. The lines P*p''*, Q*q''*, R*r''*, produced backwards, nearly meet in a point about 5 feet abaft the poop compass; indicating that the additional force is introduced at or near

* The figures and scale have been proportionally reduced in re-engraving.—B. F. G.

that point. A similar convergence of the line Qq'', Rr'', in Fig. 2, indicates that the point lies in or near the poop deck, and suggests that it arose from the magnetization of the central part of the iron beams of the poop deck, modified possibly by some magnetization of the beams of, or stanchions supporting, the upper deck.

On the 28th February, and preparatory to the ship being navigated to Devonport, the deviations and magnetic forces were observed. The deviation of the standard compass being too great for the safe navigation of the ship, and the deviation of the steering starboard compass being so great as to make it practically useless, it was necessary to reduce their semicircular deviations by the application of fixed magnets. The process employed, and which is that generally employed in the Royal Navy, is identical with one of the two methods described by the Astronomer Royal, in his well known paper on the magnetism of iron-built ships, (Philosophical Transactions, 1839, see page 196,) and may be described as follows:

The co-efficients $\mathfrak{B}$, $\mathfrak{C}$, λ being found by observation, or where necessary $\mathfrak{B}$ and $\mathfrak{C}$ being found by observation, and λ being estimated; we have $\lambda\sqrt{\mathfrak{B}^2 + \mathfrak{C}^2}$ the tangent of the semicircular deviation when the polar force acts to the east or west of the compass, and $\frac{\mathfrak{C}}{\mathfrak{B}}$ the tangent of the "starboard angle." If we desire to correct the semicircular deviation completely, a magnet of suitable size, adequate power, and proved permanence, is selected from those in store at the Compass Observatory at Woolwich. The distance above or below the card at which this magnet, when placed east and west, will produce a deviation of which the tangent is $\lambda\sqrt{\mathfrak{B}^2 + \mathfrak{C}^2}$, is ascertained by actual trial. The magnet is then inserted into the pedestal of the standard compass at the ascertained distance, immediately below the centre of the card and in the direction of the starboard angle, the poles being so placed as to counteract the polar magnetism of the ship.

As in newly built ships the polar force is generally undergoing a process of gradual diminution, it is generally considered best not to correct entirely the semicircular deviation, but to under correct it, leaving about 5° uncorrected. This was the object sought in the application of magnets to the "Northumberland;" and the success with which it was effected, and the certainty of the process, may be seen by the following comparison of the deviations on the 28th February and the 2d March:

Compasses.	Date.	A	B	C	D	E
		° ′	° ′	° ′	° ′	° ′
Standard compass	Feb. 28, 1867	+0 1	−36 13	+ 7 9	+7 19	+0 59
Do.	Mar. 2, 1867	−0 14	− 4 55	+ 0 14	+7 13	+1 15
Starboard steering compass	Feb. 28, 1867	+0 41	− 5 20	+40 41	+6 28	+2 40
Do.	Mar. 2, 1867	−0 18	− 4 15	− 1 4	+6 42	+1 44

In general, no attempt is made to correct the quadrantal deviation, that deviation and the residual semicircular deviation being the subject of tabular correction. I may observe, that in some cases, Mr. Airy's second or tentative mode of correcting, viz: by one or more fore-and-aft and transverse magnets, is adopted, but only when special circumstances prevent the first method being applicable. In general, by the process first described, all that is necessary or desirable in the way of mechanical correction can be effected.

In the middle of March, 1867, the "Northumberland," as before stated, was placed in a dry dock at Devonport, and the magnets were removed; her head in dock was S. 84° E., magnetic. Such a position would, from all former experience, and especially in a newly launched ship, be expected to increase considerably the force to starboard, or the value of + 𝕮, but without much alteration in the fore-and-aft force, or the value of 𝕭, in those compasses in which the 𝕭 and 𝕮 were caused by the general magnetism of the hull. We have continuous observations to the end of 1867, strictly comparable as regards the standard compass; but as regards the other three compasses allowances must be made for the introduction, between August and December, of five iron beams* to extend the light poop deck before the poop compass.

The changes in the standard compass, while the ship lay in dock with her head S. 84° E., are shown in the following table:

	Date.	𝕭	𝕮
Swinging at anchors	Jan. 26, 1867	—.637	+.108
Do	Feb. 28, 1867	—.637	+.110
Head S. 84° E. magnetic, from middle of March	June 26, 1867	—.576	+.277
Do ... do	Aug. 29, 1857	—.569	+.256
Do ... do	Dec. 10, 1867	—.593	+.329

These results are clearly attributable to the change in the general magnetism of the ship due to position. The fore-and-aft force has been little affected, but there is a decided increase in the transverse force, = + .219.

With respect to the compasses affected by Mr. Hopkins's process, the results are widely different. In seven months, (end of January to end of August,) as will be seen by the following table, at the starboard steering

*The effect of the introduction of the five new poop-deck beams when the ship's head was S. 84° E., magnetic, would be to increase 𝕮 and 𝕯 and to diminish λ. The exact value of the altered 𝕮 cannot be computed without knowing the altered values of 𝕯 and λ; and these cannot be ascertained till the ship is again swung. I think, however, it is certain that the change in 𝕯 cannot exceed .017, (or 1° in 𝕯,) and the change in λ cannot exceed .020, and I have accordingly inserted in the general table, under date 10th December, 1867, the values of 𝕭 and 𝕮 computed, as well with the original values of 𝕯 and λ, as with values allowing these amounts. It may be safely assumed that the true values lie between the two as limits.

—$\mathfrak{B}$ has increased .183, $\mathfrak{C}$ having scarcely changed in value; at the poop compass, —$\mathfrak{B}$ has increased .281, and +$\mathfrak{C}$ .162; at the port steering compass, —$\mathfrak{B}$ has increased .098, while the $\mathfrak{C}$ has increased .320; so that the increase of the $\mathfrak{C}$ in the poop compass is almost exactly the mean of the increase in the port and starboard compasses.

Date.	Port steering compass.		Poop compass.		Starboard steering compass.	
	$\mathfrak{B}$	$\mathfrak{C}$	$\mathfrak{B}$	$\mathfrak{C}$	$\mathfrak{B}$	$\mathfrak{C}$
1867.						
January 26	—.078	—.176	—.059	+.203	—.046	+.596
February 28	—.071	—.128	—.070	.230	—.078	+.625
June 26	....	....	—.153	+.360	....	....
August 29	—.176	+.150	—.340	+.365	—.229	+.637
December 10	—.212	+.508	—.215	+.541	—.136	+.641
Do	—.218	+.481	—.221	+.516	—.141	+.617

If we confine ourselves to the practical question of the amount of the semicircular deviation, and also the direction of the ship's force, [starboard angle,] or, in other words, the direction of the neutral or zero-points of the semicircular deviation, the comparison is as follows:

Year.	Standard.		Port steering.		Poop.		Starboard steering.	
	Maximum semicircular deviation.	Starboard angle.	Maximum semicircular deviation.	Starboard angle.	Maximum semicircular deviation.	Starboard angle.	Maximum semicircular deviation.	Starboard angle.
1867.	°	°	°	°	°	°	°	°
Jan. 1	37¼	173¾	47¼	157	51	164¼	42¾	161¼
Jan. 26	37	170¼	12	246	12¾	104¾	38¼	94¼
Feb. 28	37	170	8¾	241	14¼	107	41¾	97
June 26	39¾	155	....	....	23	112	....	....
Aug. 29	38¼	156	13¼	139¼	30	133	42¾	110
Dec. 10	42¼	151	33¼	112¼	35¼	111¼	40	102

From this comparison it will be seen how short lived is the apparent benefit derived from the process we have been considering.

The nature of the changes in the polar force will perhaps be more clearly apprehended if we represent them graphically, as in the second Plate, by taking the position of each compass as origin, and laying down the points, of which $\lambda\mathfrak{B}$ and $\lambda\mathfrak{C}$ are the co-ordinates, as derived from the observations on January 1 and 26, February 28, August 29, and December 10, 1867.

As regards each compass, a line drawn from the origin to one of these points represents in amount and direction the polar force acting on that compass at that epoch; and a line drawn from one point to the next succeeding in order of date represents, in amount and direction, the additional polar forces acting on that compass introduced in the interval. To avoid confusion in the figure, the lines from the origin are only drawn for the earliest date. The *joints* added to these lines, therefore, represent the additional forces introduced in each interval.

This plate shows strikingly the contrast between the comparatively small and regular changes in the polar magnetism of the standard compass, and the large and irregular changes in the polar magnetism of the other compasses; but at the same time shows strikingly the general analogy in the changes in these three compasses.

An attentive study of it will also show, that while the changes in the polar magnetism of the standard compass are almost entirely from an increasing attraction to the south side of the ship, in the other compasses this is combined with an increasing attraction to, or rather a diminishing repulsion from, the point abaft the poop compass, to which a powerful north pole has been communicated.

In the interval between the 28th August and the 10th December, a general headward force on the three stern compasses is also added. What was the cause of this force I am unable to say; it may possibly be connected with the introduction of the five iron beams in front of these compasses, and the general hammering to which that part of the ship was consequently exposed.

The views which I have taken of the effect of the application of the electro-magnets are, I think, strongly confirmed by observations made on the 10th December, 1867, at four points surrounding the position of the supposed north pole produced by them.

Of these, the position of the poop compass was one; the second was 18 feet abaft the poop compass; the third, 7 feet three inches abaft the poop compass, and 4 feet to port of the midship line; the fourth, 7 feet 3 inches abaft the poop compass, and 4 feet to starboard of the midship line. The values of 𝔅 and ℭ for these compasses, were:

Compasses.	𝔅	ℭ
No. 1. Poop compass	—.215	+.541
No. 2. 18 feet abaft poop compass	—.641	+.482
No. 3. 7¼ feet abaft poop compass, 4 feet to port	—.457	+.260
No. 4. 7¼ feet abaft poop compass, 4 feet to starboard	—.458	+.692

An inspection of these values will show that they indicate a generally attractive force to the stern and starboard sides, but modified by a repulsive force emanating from a point nearly centrically situated with respect to the four compasses. We may, in fact, I think, infer that the mean of these values, or a ℭ of — .443, and a ℭ of + .494, is due to the general magnetism of the ship, and as regards ℭ partly to the new iron beams, and that the difference from these values as to each compass arises from local magnetization. The differences (which are also multiplied by λ (.860) to express them in terms of the Earth's magnetic force as unit) will be—

Compasses.	𝔅	ℭ	λ𝔅	λℭ
No. 1. Station, (poop)	+.228	+.047 }	+.196	+.040 }
No. 2. do	—.198	—.012 }	—.170	—.010 }
No. 3. do	—.014	—.234 }	—.012	—.201 }
No. 4. do	—.015	—.198 }	—.013	+.170 }

The interpretation of which table is, that besides the general magnetization of the ship, there is a horizontal force nearly equal to one-fifth of the Earth's horizontal force, repelling the north end of each needle from a point situated nearly in the centre of the compasses. This I conceive to be the remains of the strong north pole to which I have referred, which it will be remembered affected the poop compasses with a repelling force = .648, and now reduced to .200; so that more than two-thirds of the force introduced in the operations of January, 1867, seem to have disappeared in the course of eleven months; and the general result of these operations may be described as the introduction at a point in the poop deck, a few feet abaft the poop compass, of a north pole acting on the compass with a force of nearly two-thirds of the Earth's horizontal force, and which force in the course of eleven months diminished to about one-fifth of the Earth's force, or to less than one-third of its original amount.

The effect of the forces introduced by the operations of January, 1867, and of the gradual decay of these forces in the interval between January to December, is no less obvious in the heeling errors of the different compasses. This error, it may be remembered, is expressed by the deviation to windward, produced by an inclination of the ship of 1°, when its head is north or south by the disturbed compass.

In the interval between the 1st and 26th January, 1867, there is a diminutoin of the heeling error of the poop compass from 2° 1′ to 0° 37′, but an increase of the heeling error of the starboard compass from 1° 4′ to 1° 45′. The diminution is caused by the upward force on the poop compass; the increase by the downward force on the starboard steering compass introduced in the interval.

The changes so introduced in both compasses diminishes as time passes. By the 10th December, that of the poop compass had risen to 1° 14′, that of the starboard steering diminished to 0° 56′. During the whole of this period the heeling error of the standard compass is hardly altered; the slight apparent changes being not greater than can be accounted for by unavoidable errors of observation.

We are now in a position to form an opinion as to the real nature of the changes effected by the operations of January, 1867, and the advantages and disadvantages of these changes.

The process was in no sense of the word one of "depolarization," either of the whole ship or of any part of it. It was, on the contrary, the "polarization" to a high degree of intensity of a particular portion of the iron in the neighborhood of three of the compasses. The iron so magnetized was iron capable of receiving only sub-permanent magnetism, and which, from its forming part of the structure of the vessel, was subject to strains and concussions from which detached magnets are wholly free. The magnetism so communicated was therefore necessarily unstable and transient, and from its liability to change suddenly and unexpectedly, was a source of danger to the vessel. So strongly was I impressed with the danger, that in an official report to the Admiralty of 31st January, 1867, after a careful reduction of the observations, the results of which are already given, I expressed the hope that, should further experiments be permitted in Her Majesty's ships for depolarizing their hulls, the so-called "depolarization" should not be allowed "within 20 feet of any compass that may be placed for the navigation of the ship."

Nor could the effect produced, even if it had been much more permanent than it proved to be, be considered an advantage. In two out of the three compasses to which it was applied, the semicircular deviation was reduced within the limits which make tabular corrections possible, not within those which allow it to be dispensed with. In the third, (the starboard steering compass,) the effect, though considerable, was rather a change in the direction, than a reduction of the amount, of the semicircular deviation; for it exceeded 36°, and a reduction by a magnet was still necessary. In the two compasses in which the process was effective to the extent we have mentioned, the requisite reduction might have been effected with greater ease and certainty, as well as permanency, by the application of a single magnet to each compass.

In dismissing this subject, it may seem that some apology is necessary for occupying the time of the society with the details of a process which had so little to recommend it, and which has proved injurious, not beneficial; it is, however, a process to which many persons looked with hope, and from which no one apprehended danger; both were mistaken, and in both respects it is desirable that the results of the trials should be known.

The tables and the discussion will, also, I hope, be accepted as an interesting example of the method now constantly practised in the Royal navy of supplementing the observations made in "swinging" a ship, by observations of deviation and horizontal and vertical force made on one azimuth.

As regards the observations generally, the conclusions to be drawn from them, or rather which, having been already drawn from numerous other observations, are supported by those made in the "Northumberland," seem to be—

1. That in an iron-built ship, and in that part of her within which the

standard compass is generally placed, the polar force is that from the magnetism of the whole body of the ship, and is nearly uniform.

2. That we cannot escape from the action of that force by any care in the selection of a place for the compass.

3. That though positions may be found, where from the magnetism of particular masses of iron counteracting that of the ship, the deviation will be small, yet that such positions are in general to be avoided, as the change of magnetic force in such positions will probably be larger and less regular than when the compass is only acted on by the general magnetism of the whole ship. Any attempt to produce this counteraction by magnetizing artificially masses of iron in the vicinity of a compass is to be deprecated.

4. That in iron-built ships, as at present constructed, the ship's polar force is generally so great as to make it necessary to employ magnets to equalize the directive force on different azimuths of the ship's head, even at the most carefully selected position; but that the use of correcting magnets does not dispense with the necessity of ascertaining from time to time by observations the amount of the remaining deviations.

GENERAL TABLE.

Her Majesty's ship "Northumberland."

Ship.	Compass.	Place.	Date.	Approximate co-efficients.					Exact co-efficients.					Maximum of semicircular deviation.		
				A	B	C	D	E	𝔄	𝔅	ℭ	𝔇	𝔈	Amount.	Mean horizontal force of ship $\sqrt{𝔅^2+ℭ^2}$*	Direction.
				° ′	° ′	° ′	° ′	° ′						°		°
NORTHUMBERLAND.	Standard...	On stocks....	Mar. and Apr., 1866	By deviation, horizontal and vertical forces on one point					....	—.157	.427	.133a	....	27¼	.461	110
6,621 tons, 26 guns, 1,350 horse-power.		Off Deptford	April 19, 1866........						....	—.001	.416	+.133a	....	24¼	.416	90¼
		Sheerness....	January 1, 1867......	+0 50	—36 53	+4 35	+7 02	—0 24	+.015	—.646	.071	+.122	—.007	40¼	.650	173¾
Iron hull, iron plated.		Sheerness....	January 26, 1867.....	+1 12	—36 13	+7 02	+7 22	—0 35	+.021	—.637	.108	+.128	—.010	40¼	.646	170¼
		Sheerness....	February 28, 1867..	+0 01	—36 13	+7 09	+7 19	+0 59	+.001	—.637	.110	+.127	+.017	40¼	.646	170
Armor bulkheads.		Sheerness......	March 2, 1867........	—0·14	—4 55	+0 14	+7 13	+1 15	—.004	—.091	+.004	+.126	+.022	5¼	.091	177¼
		Devonport...	June 26, 1867.........	By deviation, horizontal and vertical forces on one point. Ship in dock, head S. 84° E., magnetic						—.576	+.277	+.123a	....	39¾	.639	154¼
Rifle-tower on quarter-deck.		Devonport...	August 29, 1867......							—.569	+.256	+.120a	....	38¼	.623	156
		Devonport...	December 10, 1867.*							—.593	+.329	+.120a	....	42¾	.678	151
Built at Millwall, River Thames, head N. 39¼° E., magnetic.	Poop.........	On stocks....	Mar. and Apr., 1866	By deviation and forces on one point...........						—.788	+.358	+.090a	....	59¾	....	155¼
										—.801	.361	+.104a	....	61¾	.880	155¼
		Off Deptford	April 19, 1866........	From swinging through a quadrant..............						—.877	+.296	.090a	....	67¼	....	161¼
										—.890	+.291	+.104a	....	69¼	.936	161¾
Plated on stocks.		In Victoria docks......	April 21, 1866.........	By deviation and forces on one point, (head S. 22° W., magnetic.) Two iron-plated ships alongside. Steam machinery, iron masts, &c., placed on board during this interval...						—.800	.135	+.090a	....	54½	.811	170¼
			May 29, 1866..........							—.742	.129	+.090a	....	48¾	.753	170
Launched April 17, 1866.			July 12, 1866..........							—.900	+.075	+.090a	....	64¼	.902	175¼
			August 10, 1866......							—.821	+.099	+.090a	....	55¾	.827	173¼
			September 1, 1866..							—.842	.076	+.090a	....	57¾	.847	174¼
			October 24, 1866.....							—.814	.003	.090a	....	54¼	.814	180
			December 17, 1866.							—.825	.025	.090a	....	55¼	.825	178
		Sheerness....	January 1, 1867......	+1 15	—48 43	+15 13	+5 55	—0 35	+.022	—.803	+.228	+.103	—.010	56¼	.834	164½
		Sheerness......	*January* 26, 1867.....	+2 14	— 3 16	+12 20	+5 39	—0 48	+.039	—.059	+.203	+.098	—.014	12¼	.211	104¾
		Sheerness......	*February* 28, 1867...	+0 35	— 3 51	+13 59	+6 07	+0 29	+.010	—.070	+.230	+.107	+.008	14	.240	107
		Devonport.....	*June* 26, 1867..........	By deviation, horizontal and vertical forces on one point. Ship in dock, S. 84° E., magnetic						—.153	+.360	+.100a	....	23	.391	112
		Devonport.....	*August* 29, 1867......							—.340	+.365	+.100a	....	30	.499	133
		Devonport.....	*December* 10, 1867...							—.215	+.541	+.100a	....	35¼	.580	111¼
		Devonport.....	*December* 10, 1867...							—.221	+.516	+.117a	....	31	.561	113

NOTE.—The co-efficients marked thus (a) are assumed values.

* Mean force to North, (λH) being unit.

General Table—Continued.

Ship.	Compass.	Place.	Date.	Mean force to North. λ *	$\frac{1}{\lambda}$	Co-efficients of horizontal induction. Head-ward. *a* *	To star-board. *e* *	Part of 𝔇 from Fore-and-aft induction.	Transverse induction.	Mean vertical force. μ †	Heeling co-efficient to windward.	Heeling co-efficient for Vertical induction in transverse iron.	Vertical force and induction in vertical iron.	Variable part of vertical force. $\frac{g}{\tan\theta}$ †	*g* †
								° ′	° ′		° ′	° ′	° ′		
Northumberland—Cont'd.	Standard	On stocks	Mar. and Apr., 1866	.860a						1.241	+1 25			+.007a	
		Off Deptford	April 19, 1866	.860a						1.164	+1 11				
		Sheerness	January 1, 1867	.869	1.151	—.025	—.237	—0 48	+7 50	1.223	+1 18	+0 40	+0 38	+.007	+.017
		Sheerness	January 26, 1867	.870	1.149	—.019	—.241	—0 34	+7 56	1.271	+1 27	+0 41	+0 46		
		Sheerness	February 28, 1867												
		Sheerness	March 2, 1867	.878	1.139	—.012	—.232	—0 21	+7 34	1.168	+1 07	+0 39	+0 28	+.013	+.032
		Devonport	June 26, 1867	.885a						1.272	+1 24			+.010a	
		Devonport	August 29, 1867	.885a						1.232	+1 17			+.010a	
		Devonport	December 10, 1867	.885a						1.266	+1 22				
	Poop	On stocks	Mar. and Apr., 1866	.800						1.637	+2 50			+.070a	
				.840						1.691	+2 48			.000	
				.800						1.646	+2 52			.070a	
		Off Deptford	April 19, 1866	.840						1.596	+2 30			.000	
		In Victoria docks	April 21, 1866	.800a						1.529	+2 30			.070a	
			May 29, 1866	.800a						1.531	+2 06			+.070a	
			July 12, 1866	.800a						1.383	+2 03			.070a	
			August 10, 1866	.800a						1.411	+2 08			.070a	
			September 1, 1866	.800a						1.449	+2 15			.070a	
			October 24, 1866	.800a						1.442	+2 14			.070a	
			December 17, 1866	.800a						1.355	+1 58			+.070a	
		Sheerness	January 1, 1867	.860	1.163	—.052	—.228	—1 44	+7 30	1.469	+2 01	+0 39	+1 22	—.001	—.003
		Sheerness	*January* 26, 1867	.854	1.171	—.062	—.230	—2 04	+7 43	.986	+0 37	+0 40	—0 03		
		Sheerness	*February* 28, 1867	.894	1.118	—.010	—.202	—0 21	+6 28	.929	+0 22	+0 34	—0 12	+.033	+.082
		Devonport	*June* 26, 1867	.880a						.996	+0 35			.030a	
		Devonport	*August* 26, 1867	.880a						1.044	+0 43			.030a	
		Devonport	*December* 10, 1867	.880a						1.230	+1 14			+.030a	
		Devonport	*December* 10, 1867	.860a											

Note.—The co-efficients marked (a) are assumed values. * Earth's horizontal force, (H) being unit. † Earth's vertical force, (Z) being unit.

General Table—Continued.

Ship.	Compass.	Place.	Date.	Approximate co-efficients. A	B	C	D	E	Exact co-efficients. 𝔄	𝔅	ℭ	𝔇	𝔈	Maximum of semicircular deviation. Amount.	Mean horizontal force of ship $\sqrt{𝔅^2+ℭ^2}$*.	Direction.
				° ′	° ′	° ′	° ′	° ′						°		°
										—.846	+.499	+.105a	....	77¼	.976	149¾
NORTHUMBERLAND—Cont'd.	Starboard steering.	On stocks.....	Mar. and Apr., 1866	....					......	—.855	+.491	+.117a	....	79¾	.984	150¼
										—.882	+.455	+.105a	....	84¼	.995	152½
		Off Deptford	April 19, 1866.........	By deviation and forces on one point...					......	—.874	+.447	+.117a	....	78¾	.984	153
		In Victoria docks......	April 21, 1866.........	....					....	—.761	+.150	+.105a	....	51	.777	168½
			May 29, 1866.........	By deviation and force on one point, (head S. 22° W., magnetic) .... Two iron-plated ships alongside; steam machinery, iron masts, &c., placed on board during this interval........						—.635	+.018	+.105a	....	39½	.635	178½
			July 12, 1866.........							—.760	—.108	+.105a	....	50	.767	188¼
			August 10, 1866......							—.726	+.022	+.105a	....	46½	.726	178½
			September 1, 1866..							—.740	—.071	+.105a	....	48½	.744	185½
			October 24, 1866.....							—.668	—.107	+.105a	....	42½	.676	189
			December 17, 1866..							—.651	—.089	+.105a	....	41	.657	188
		Sheerness....	January 1, 1867......	+0 09	—39 50	+15 18	+6 39	+0 42	+.003	—.683	+.232	+.116	+.012	46¼	.721	161¼
		Sheerness....	January 26, 1867....	—0 24	— 2 37	+38 19	+6 24	—0 20	—.007	—.046	+.596	+.112	—.006	36¾	.598	94½
		Sheerness....	February 28, 1867...	+0 41	— 5 20	+40 41	+6 28	+2 40	+.012	—.098	+.625	+.113	+.046	39¼	.630	97
			March 2, 1867.......	**—0 18**	**—4 15**	**+1 04**	**+6 42**	**+1 44**	**—.005**	**—.078**	**—.018**	**+.117**	**+.030**	**4½**	**.080**	**193**
		Devonport.....	*August 29, 1867*......	By deviation and forces on one point.....					....	—.229	+.637	+.110a	....	42¾	.678	110
		Devonport.....	*December 10, 1867*...	Ship in dock, (head S. 84° E., magnetic)...					......	—.136	+.641	+.110a	....	40	.655	102
		Devonport.....	*December 10, 1867*...	....	....	....	....	....	......	—.141	+.617	+.127a	....	39¼	.633	103
	Port steering.	Sheerness....	January 1, 1867......	+1 13	+43 0	+19 48	+6 18	—0 28	+.021	—.725	+.302	+.110	—.008	51	.786	157¼
		Sheerness......	*January 26, 1867*.....	—0 39	— 4 13	—10 52	+7 40	—2 11	—.011	—.078	—.176	+.133	—.038	11	.193	246
		Sheerness......	*February 28, 1867*...	+0 53	— 3 55	— 7 50	+6 54	—0 12	+.015	—.071	—.126	+.120	—.003	8¼	.146	241
		Devonport.....	*August 29, 1867*......	By deviation and forces on one point.....					....	—.176	+.150	+.110a	....	13¼	.231	139½
		Devonport.....	*December 10, 1867*...	Ship in dock, (head S. 84° E., magnetic)..					......	—.212	+.508	....	....	33½	.550	112½
		Devonport.....	*December 10, 1867*...	....	....	....	....	....	......	—.218	+.481	+.127	....	31¾	.527	114
	Lower deck	Sheerness....	February 28, 1867...	—0 11	—3 23	+11 05	+13 02	+0 32	—.003	—.065	+.170	+.228	+.009	10½	.182	111
		Devonport ...	August 29, 1867......	By deviation and forces on one point.....					....	—.025	+.333	+.220	....	19½	.334	94
		Devonport ...	December 10, 1867..	Ship in dock, (head S. 84° E., magnetic)..					....	—.082	+.412	+.220	....	24¾	.420	101

NOTE.—The co-efficients marked thus (a) are assumed values.

* Mean force to North, (λH) being unit.

General Table—Continued.

Ship.	Compass.	Place.	Date.	Mean force to north. λ *	$\frac{1}{\lambda}$	Co-efficients of horizontal induction. Head-ward. a *	To star-board. e *	Part of 𝔇 from Fore-and-aft induction. ° ′	Transverse induction. ° ′	Mean vertical force. μ †	Heeling co-efficient to windward. ° ′	Heeling co-efficient for Vertical induction in transverse iron. ° ′	Vertical force and induction in vertical iron. ° ′	Variable part of vertical force. $\frac{g}{\tan\theta}$ †	g *
Northumberland—Cont'd.	Starboard steering.	On stocks....	Mar. and Apr., 1866	.800a	...	...	...	...	...	1.186	+1 28	...	...	+.100a	
										1.259	+1 43	...	...	—.005a	
		Off Deptford	April 19, 1866........	.800a	...	...	...	...	...	1.296	+1 49	...	...	+.100a	
										1.221	+1 36	...	...	—.005a	
		In Victoria docks.	April 21, 1866........	.800a	...	...	...	...	...	1.126	+1 17	...	...	+.100a	...
			May 29, 1866........	.800a	...	...	...	...	...	1.163	+1 24	...	...	+.100a	...
			July 12, 1866........	.800a	...	...	...	...	...	.996	0 58	...	...	+.100a	...
			August 10, 1866......	.800a	...	...	...	...	...	.821	0 37	...	...	+.100a	...
			September 1, 1866..	.800a	...	...	...	...	...	.935	+0 40	...	...	+.100a	...
			October 24, 1866.....	.800a	...	...	...	...	...	.949	0 43	...	...	+.100a	...
			December 17, 1866..	.800a	...	...	...	...	...	.924	0 39	...	...	+.100a	...
		Sheerness....	January 1, 1867......	.802	1.247	—.105	—.291	—3 45	+10 24	1.056	+1 04	+0 54	+0 10	—.005	—.012
		Sheerness....	January 26, 1867....	.783	1.277	—.105	—.304	—4 43	+11 12	1.250	+1 45	+0 57	+0 47	...	...
		Sheerness....	February 28, 1867...	...	...	...	...	...	...	...	...	...	...	...	...
			March 2, 1867......	.841	1.189	—.064	—.254	—2 11	+ 8 39	1.285	+1 35	+0 45	+0 50	+.041	+.102
		Devonport.....	*August* 29, 1867......	.820a	...	...	...	...	...	1.114	+1 10	...	...	+.041	...
		Devonport.....	*December* 10, 1867...	.820a	...	...	...	...	...	1.036	-0 56	...	...	+.041	...
		Devonport.....	*December* 10, 1867...	.800a											
	Port steering.	Sheerness....	January 1, 1867......	...	...	...	...	...	...	...	...	...	...	...	...
		Sheerness......	*January* 26, 1867.....	...	...	...	...	...	...	...	...	...	...	...	...
		Sheerness......	*February* 28, 1867....	...	...	...	...	...	...	...	...	...	...	...	...
		Devonport.....	*August* 29, 1867......	.820a	...	...	...	...	...	1.255	+1 36	...	...	+.041	...
		Devonport.....	*December* 10, 1867...	.820a	...	...	...	...	...	1.102	+1 08	...	...	+.041	...
		Devonport.....	*December* 10, 1867...	.800a	...	...	...	...	...	...	...	...	...	...	...
	Lower deck	Sheerness....	February 28, 1867...	.729	1.371	—.105	—.437	—4 05	+17 24	...	...	...	...	...	...
		Devonport...	August 29, 1867......	.740a	...	...	...	...	...	...	...	...	...	...	...
		Devonport...	December 10, 1867..	.740a	...	...	...	...	...	...	...	...	...	...	...

NOTE.—The co-efficients marked thus (a) are assumed values. * Earth's horizontal force, (H) being unit. † Earth's vertical force, (Z) being unit.

General Table—Continued.

$a = \lambda\mathfrak{D} \div (1-\lambda).$

$e = -\lambda\mathfrak{D} \div (1-\lambda).$

Part of $\mathfrak{D}$ from:

- Fore-and-aft induction $= \frac{a}{2\lambda} = \frac{\mathfrak{D}}{2} - \left(\frac{1}{\lambda} - 1\right).$
- Transverse induction $= -\frac{e}{2\lambda} = \frac{\mathfrak{D}}{2}\left(\frac{1}{\lambda} - 1\right).$

Heeling co-efficient to windward $= \left(\mathfrak{D} \cdot \frac{\mu}{\lambda} - 1\right)\tan\theta.$

Part of heeling co-efficient........

- From vertical induction in transverse iron............................... $= \left(\mathfrak{D} \cdot \frac{1}{\lambda} - 1\right)\tan\theta.$
- From vertical force and vertical induction in vertical iron......... $= \left(\frac{\mu}{\lambda} - \frac{1}{\lambda}\right)\tan\theta.$

Figure
Plan.

← Ship's

Figure 2.
Fore & Aft
Vertical Section.

← Ship's stern

0 ½ 1