HADLEY'S OCTANT (A. D. 1731).

On the occasion of the second centenary of the invention of reflecting instruments and in accordance with the usual custom of reproducing in the *Hydrographic Review* documents of particular interest connected with the history of nautical and hydrographic science, the communication made by John HADLEY to the Royal Society of London on 13th May, 1731, is reproduced hereafter in facsimile. This communication was published in N° 420 of the *Philosophical Transactions.*

It appears that the oldest document in which allusion is made to the principle of reflection by plane mirrors, as applied to the measurement of angles, is the *History of the Royal Society of London* by BIRCH. In this book, under the date of 22nd August, 1666, it is stated :- "Mr. HOOK mentionned a new astronomical instrument for making observations of distances by reflection". In another place it may be read that on the 29th August of the same year, HOOK spoke of this instrument again, it being then under construction, to the members of the Society. They invited him to submit it as soon as possible and this was done on 12th September of that year.

The instrument submitted by HOOK differed in important details from the modern sextant; it was provided with but one mirror and thus was a single reflecting instrument. This was the fundamental defect which made it impossible for HOOK's invention to be a success.

However, the idea of using reflection from a plane mirror for the measurement of angles was not forgotten and, in spite of HOOK's want of success the principle was taken up by others who sought to correct the disadvantages of the instrument as first invented.

HARRISON, who was the author of the work entitled "*Idea longitudinis*", informs us that STREETE had invented an instrument for observing angles by reflection, but he adds that he had not succeeded in bringing it to the desired perfection. Right up to the 6th May, 1731, the general public was unaware that the goal had been reached, for Dr. HALLEY, seaman, astronomer and physicist of note, reported on that date to the Royal Society an investigation on the subject of the variation in the movements of the moon and, when citing the advantages which would accrue from the establishment of an accurate theory of these movements which alone could provide a practical method of obtaining longitude at sea, he lamented the lack of an instrument by means of which the angular distances between the moon and other heavenly bodies could be measured, and he suggested, as the only possible observation which could be made on board ship, that of the occultations of stars behind the lunar disc. The requirements of Dr. HALLEY were satisfied at the next meeting of the Society, for it was then that HADLEY, who had been present at the meeting of the 6th May, 1731, and he was probably stimulated by HALLEY's communication, submitted to his colleagues on 13th May, the results of his research relative to the measurement of angles at sea; he read a description of the instrument (octant) which he had invented during the summer of 1730.

The information given above is extracted from the work entitled: "*Gli 'strumenti a riflessione per misurare angoli*" by G. B. MAGNAGHI (Publ. Hoepli, 1875).

Thanks are due to the Italian Hydrographic Office for the photographic reproduction of the pages which are included herein (photostats) from the copy of the *Philosophical Transactions* now in the Library of the Istituto Idrografico della R. Marina at Genoa.

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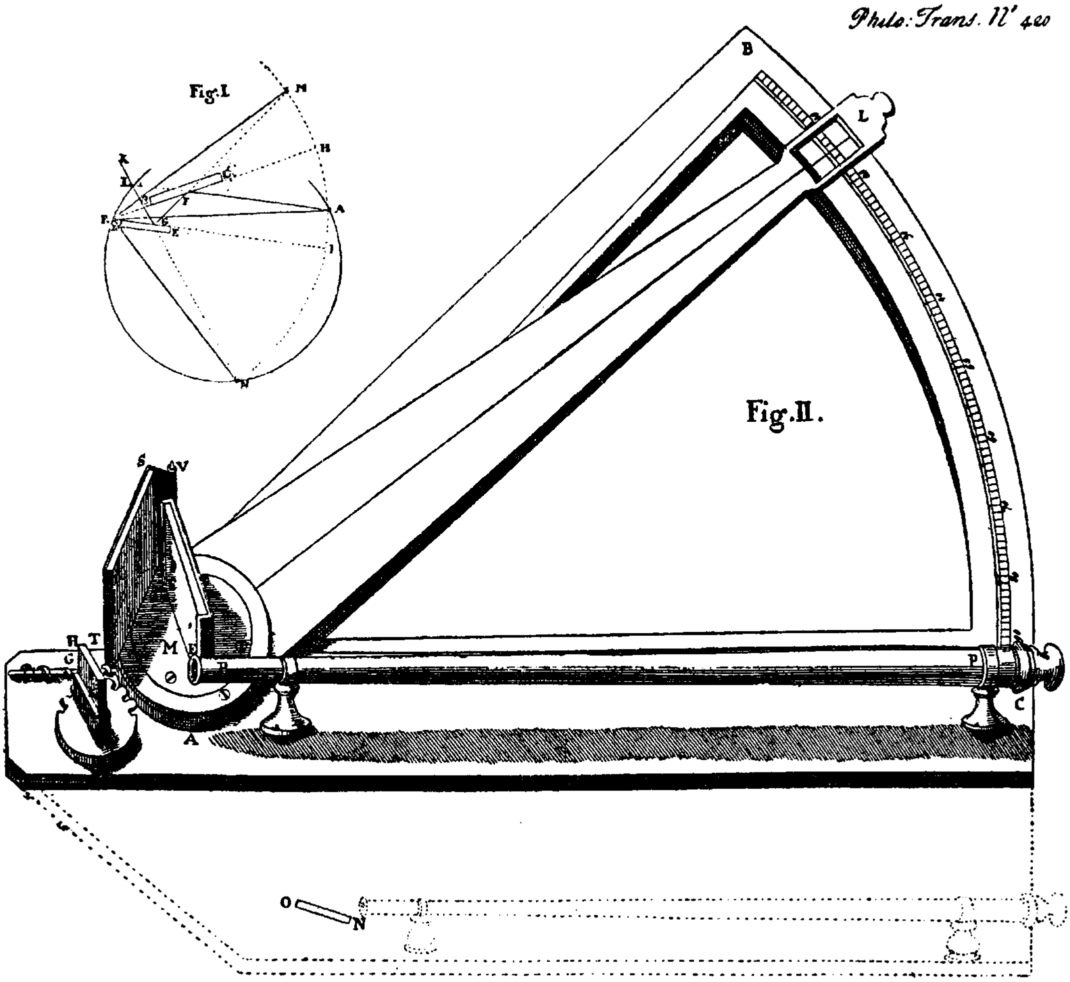

I. *The Description of a new Instrument for taking* Angles. *By* John Hadley, *Esq; Vice-Pr. R. S. communicated to the Society on* May 13. 1731.

THE Instrument is design'd to be of Use, where the Motion of the Objects, or any Circumstance occasioning an Unsteadiness in the common Instruments, renders the Observations difficult or uncertain.

The Contrivance of it is founded on this obvious Principle in Catoptricks: That if the Rays of Light diverging from, or converging to any Point, be reflected by a plane polish'd Surface, they will, after the Reflection, diverge from, or converge to another Point on the opposite Side of that Surface, at the same Distance from it as the first; and that a Line perpendicular to the Surface passing through one of those Points, will pass through both. Hence it follows, that if the Rays of Light emitted from any Point of an Object be successively reflected from two such polish'd Surfaces; that then a third Plane, perpendicular to them both, passing through the emitting Point, will also pass through each of its two successive Images made by the Reflections: All three Points will be at equal Distances from the common Intersection of the three Planes; and if two Lines be drawn thro' that common Intersection, one from the original Point in the Object, the other from that Image of it which is made by the second Reflection; they will compre-

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hend an Angle double to that of the Inclination of the two polish'd Surfaces.

Fig. I. Let R F H and R G I represent the Sections of the Plane of the Figure by the polish'd Surfaces of the two Specula B C and D E, erected perpendicularly thereon, meeting in R, which will be the Point where their common Section, perpendicular likewise to the same Plane, passes it, and H R I is the Angle of their Inclination. Let A F be a Ray of Light from any Point of an Object A falling on the Point F of the first Speculum B C, and thence reflected into the Line F G, and at the Point G of the second Speculum D E reflected again into the Line G K, produce G F and K G backwards to M and N, the two successive Representations of the Point A; and draw R A, R M, and R N.

Since the Point A is in the Plane of the Scheme, the Point M will be so also by the known Laws of Catoptricks. The Line F M is equal to F A, and the Angle M F A double the Angle H F A or M F H; consequently R M is equal to R A, and the Angle M R A double the Angle H R A or M R H. In the same manner the Point N is also in the Plane of the Scheme, the Line R N equal to R M; and the Angle M R N double the Angle M R I or I R N: Substract the Angle M R A from the Angle M R N, and the Angle A R N remains equal to double the Difference of the Angles M R I and M R H, or double the Angle H R I, by which the Surface of the Speculum D E is reclin'd from that of B C; and the Lines R A, R M and R N are equal.

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Corol. 1. The Image N will continue in the ſame Point; altho' the two Specula be turn'd together circularly on the Axis R, ſo long as the Point A remains elevated on the Surface of B C: provided they retain the ſame Inclination.

Corol. 2. If the Eye be plac'd at L, (the Point where the Line A F continued cuts the Line G K;) the Points A and N will appear to it at the angular Diſtance A L N, which will be equal to A R N: For the Angle A L N is the Difference of the Angles F G N and G F L; and F G N is double F G I; and G F L double G F R, and conſequently their Difference double F R G or H R I: Therefore L is in the Circumference of a Circle paſſing through A, N, and R.

Corol. 3. If the Diſtance A R be infinite, thoſe Points A and N will appear at the ſame angular Diſtance, in whatever Points of the Scheme the Eye and Specula are placed: Provided the Inclination of their Surfaces remain unaltered, and their common Section parallel to itſelf.

Corol. 4. All the Parts of any Objects will appear to an Eye viewing them by the two ſucceſſive Reflections, as before deſcribed, in the ſame Situation as if they had been turn'd together circularly round the Axis R, keeping their reſpective Diſtances from one another, and the Axis, with the Direction H I, *i. e.* the ſame Way the ſecond Speculum D E reclines from the firſt B C.

Corol. 5. If the Specula be ſuppos'd to be at the Center of an infinite Sphere; Objects in the Circumference of a great Circle, to which their common Section is perpendicular, will appear remov'd by the two

 Reflections,

Reflections, through an Arch of that Circle, equal to twice the Inclination of the Specula, as is before ſaid. But Objects at a Diſtance from that Circle will appear removed thro' the ſimilar Arch of a Parallel: Therefore the Change of their apparent Place will be meaſured by an Arch of a great Circle, whoſe Chord is to the Chord of the Arch equal to double the Inclination of the Specula, as the Sines Complements of their reſpective Diſtances from that Circle are to the Radius: And if thoſe Diſtances are very ſmall, the Difference between the apparent Tranſlation of any one of theſe Objects, and the Tranſlation of thoſe which are in the Circumference of the great Circle aforeſaid, will be to an Arch equal to the verſed Sine of the Diſtance of this Object from that Circle, nearly as double the Sine of the Angle of Inclination of the Specula, is to the Sine Complement of the ſame.

FIG. II. The Inſtrument conſiſts of an Octant A B C, having on its Limb B C an Arch of 45 Degrees, divided into 90 Parts or half Degrees; each of which anſwers to a whole Degree in the Obſervation. It has an Index M L moveable round the Center, to mark the Diviſions: And upon this, near the Center, is fix'd a plane Speculum E F perpendicular to the Plane of the Inſtrument, and making ſuch an Angle with a Line drawn along the middle of the Index, as will be moſt convenient for the particular Uſes the Inſtrument is deſigned for; (for an Inſtrument made according to Fig. 2. the Angle L M F may be of about 65 Degrees.) I K G H is another ſmaller plane Speculum, fix'd on ſuch Part of the Octant as will likewiſe be determin'd by its particular Uſe, and having its Surface in ſuch Direction, that when the Index is brought to mark the

the beginning of the Divifions (*i. e.* 0°) it may be exactly parallel to that of the other; this Speculum being turned towards the Obferver, and the other from him. PR is a Telefcope fix'd on one Side of the Octant, having its Axis parallel to that Side, and paffing near the middle of one of the Edges IK or IH of the Speculum IKGH; fo that half its Object-Glafs may receive the Rays reflected from that Speculum, and the other half remain clear to receive them from a diftant Object. The two Specula muft alfo be difpos'd in fuch manner, that a Ray of Light coming from a Point near the middle of the firft Speculum, may fall on the middle of the fecond in an Angle of 70 Degrees or thereabouts, and be thence reflected into a Line parallel to the Axis of the Telefcope, and that a clear Paffage be left for the Rays coming from the Object to the Speculum EF by the Side HG. ST is a dark Glafs fix'd in a Frame, which turns on the Pin V; by which Means it may be plac'd before the Speculum EF, when the Light of one of the Objects is too ftrong: Of thefe there may be feveral.

FIG. III. In the diftinct Bafe of the Telefcope, reprefented by the Circle *a b c d e f*, are placed three Hairs, two of which, *a c* and *b d*, are at equal Diftances from, and parallel to the Line *g h*, which paffes through the Axis, and is parallel to the Plane of the Octant: The third *f c* is perpendicular to *g h* through the Axis.

The Inftrument, as thus defcribed, will ferve to take any Angle not greater than 90 Degrees; but if it be defign'd for Angles from 90 to 180 Degrees, the polifh'd Surface of the Speculum EF (Fig. 2.) muft be turn'd towards

towards the Obferver; the fecond IKGH muft be brought forward to the Pofition NO fo as to receive on its Middle the Rays of Light from the middle of the firft in an Angle of about 25 Degrees, their Surfaces being perpendicular to one another when the Index is brought to the End of the divided Arch next C; and this fecond muft ftand five or fix Inches wide of the firft, that the Head of the Obferver may not intercept the Rays in their Paffage towards it, when the Angle to be obferv'd is near 180°. The fmaller Speculum is fix'd perpendicularly on a round brafs Plate, tooth'd on the Edge; and may be adjufted by an endlefs Screw.

In order to make an Obfervation, the Axis of the Telefcope is to be directed towards one of the Objects, the Plane of the Inftrument paffing as near as may be through the other, which muft lie to that Hand of the Obferver, as the particular Form of the Inftrument may require; *viz.* the fame Way that the Speculum EF does from IKGH, if it be compofed according to this Figure and Defcription. The Obferver's Eye being applied to the Telefcope, fo as to keep fight of the firft Object; the Index muft be moved backward and forward till the fecond Object is likewife brought to appear through the Telefcope, about the fame Diftance from the Hair *c f* (Fig. 3.) as the firft: If then the Objects appear wide of one another, as at *i* and *k*, the Inftrument muft be turn'd a little on the Axis of the Telefcope, till they come even, or very nearly fo, and the Index muft be remov'd till they unite in one, or appear clofe to one another in a Line parallel to *c f*, both of them being kept as near the Line *g h* as they can. If the Inftrument be then turn'd turn'd a little on any Axis perpendicular to its Plane, the two Images will move along a Line parallel to *g h*, but keep the same Position in respect of one another; so that in whatever Part of that Line they be observed, the Accuracy of the Observation will be no otherwise affected than by the Indistinctness of the Objects. If the two Objects be not in the Plane of the Instrument, but equally elevated on, or depress'd below it, they will appear together at a Distance from the Line *g h*, when the Index marks an Angle something greater than their nearest Distance in a great Circle: And the Error of the Observation will increase nearly in Proportion to the Square of their Distance from that Line; but may be corrected by help of the fifth Corollary. Suppose the Hairs *a e* and *b d*, each at a Distance from the Line *g h*, equal to $\frac{100}{4446}$ of the focal Length of the Object-Glass, so as to comprehend between them the Image of an Object, whose Breadth to the naked Eye is a little more than $2^{\circ}\frac{1}{4}$; and let the Images of the Objects appear united at either of those Hairs: Then as the Sine Complement of half the Degrees and Minutes mark'd by the Index, is to the doubled Sine of the same; so is one Minute to the Error which is always to be substracted from the Observation. Other Hairs may also be plac'd in the Area *a b c d e f*, parallel to *g h*, and at Distances from it proportional to the square Roots of the Numbers 1, 2, 3, 4, &c. and then the Errors to be substracted from the same Observation made at each of those Hairs respectively, will be in Proportion to the Numbers 1, 2, 3, 4, &c. This Correction will always be exact enough if the Observer take care

care (especially when the Angle comes near 180°) to keep the Plane of the Instrument from varying too much from the great Circle passing thro' the Objects.

In regard to the Workmanship, if an Exactness be required in the Observations, the Arch ought to be divided with the greatest Care; because all Errors committed in the Division are doubled by the Reflections. The Index must have a steady Motion on the Center, so that the Axis of it remain always perpendicular to the Plane of the Octant; for if that alter, it will be liable to vary the Inclination of the Speculum it carries to the other: The Motion must likewise be easy, lest the Index be subject to bend edge-ways: For the same reason it should be as broad at that End next the Center as conveniently can be. The Specula should have their Surfaces of a true flat; because a Curvature in either of them, beside rendering the Object indistinct, will vary its Position, when seen by Reflection from different Parts of them: They must also be of a sufficient Length and Breadth for the Telescope to take in a convenient Angle without losing the Use of any Part of the Aperture of its Object-Glass, and that in all the different Positions of the Index. They may be either of Metal or Glass Plates foil'd, having their two Surfaces as nearly parallel as they can; yet a small Deviation may be allowed; provided either their thickest or thinnest Edges (and consequently the common Section of their Surfaces) be parallel to the Plane of the Octant: For in that Case, though there are several Representations of the Object, they will be always very near one another in a Line parallel to *c f*; and any of them may be used,

uſed, except when the Angle to be obſerved is very ſmall. The chief Inconvenience will be, that a ſmall Star will be more difficultly diſcerned, the Light being divided among the ſeveral Images. The Teleſcope may be contrived to alter its Situation, ſo as to receive the reflected Rays on a greater or leſs Part of its Object-Glaſs, if the Objects differ in Brightneſs. The ſecond Speculum may have a Part unfoil'd, that if either of them be ſufficiently luminous, the leſs bright may be ſeen through it by the whole Aperture. If the Sun be one of the Objects, or the Moon be compared with a ſmaller fix'd Star; their reflected Images muſt be ſtill farther weakened by the Interpoſition of one or more of the dark Glaſſes S T. An exact Poſition of the Teleſcope is not neceſſary; and the Inſtrument may be uſed without one, the Diſpoſition of the Specula, with regard to the Sector and Index, being ſuch as may allow the Eye to be brought as near the ſecond Speculum as may be, and make the Inſtrument the moſt commodious for the Obſerver.

It will be eaſy to judge, that ſcarce any greater Degree of Steadineſs is requiſite in the Pedeſtal, or Machine which carries this Inſtrument, than what is ſufficient for the Teleſcope us'd with it: For although the vibrating Motion of the Inſtrument may occaſion the Images of the Objects alſo to vibrate croſs one another; their apparent relative Motion will be very nearly in Lines parallel to cf; and it will not be difficult to diſtinguiſh whether they coincide in croſſing one another, or paſs at a Diſtance: And if the Objects are near one another, and the Teleſcope magnify but about four or five Times, it may be held in

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the Hand without any ſtanding Support. In this Manner the Altitude of the Sun, Moon, or ſome of the brighter Stars from the viſible Horizon may be taken at Sea, when it is not too rough.

F I G. IV. ſhews an Inſtrument deſigned for this Purpoſe; differing from the foregoing Deſcription chiefly in the placing the Specula and Teleſcope, with regard to the Sector and Index; it has alſo a third Speculum N O diſpos'd according to the Directions when the Angle is greater than 90 Deg. whoſe Uſe is to obſerve the Sun's Altitude by Means of the oppoſite Part of the Horizon. In placing theſe two ſmaller Specula, it will be farther neceſſary to take care that the Speculum I K G H do not ſtand ſo as to intercept any of the Rays coming from the greater one fix'd on the Index to the third N O, nor either of them hinder the Index from coming Home to the End of the divided Arch. W Q is a Director for the Sight; which is neceſſary when the Teleſcope is not made uſe of. This conſiſts of a long narrow Piece, which ſlides on another fix'd on the back of the Octant, and carries at each End a Sight erected perpendicularly on it: It may be removed at Pleaſure, and exchanged for the Teleſcope, which ſlides on in the ſame manner, both ſerving indifferently with either of the two ſmaller Specula. The Eye is to be plac'd cloſe behind the Sight at W; and the Thread ſtretch'd acroſs the opening of the other Sight at Q perpendicular to the Inſtrument is to aſſiſt the Obſerver in holding it in a vertical Poſture, who is to keep this Thread as near as he can parallel to the Horizon, and the Object near the upright one. How far an Inſtrument of this

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Kind may be of Use at Sea to take the Diſtance of the Moon's Limb from the Sun or a Star, in order to find the Ship's Longi·ude, when the Theory of that Planet is perfected, I leave to Trials to determine.

The Society have the Satisfaction of knowing that Theory to be already brought to a good Degree of Certainty and Exactneſs, thro' the conſummate Skill in Aſtronomy, and indefatigable Diligence in obſerving, of a very learned Member; and have great Reaſon to hope, that this uſeful and difficult Part of Aſtronomy will in a little time appear to be abſolutely compleated by the continued Labour and Application of ſome of their own Body.

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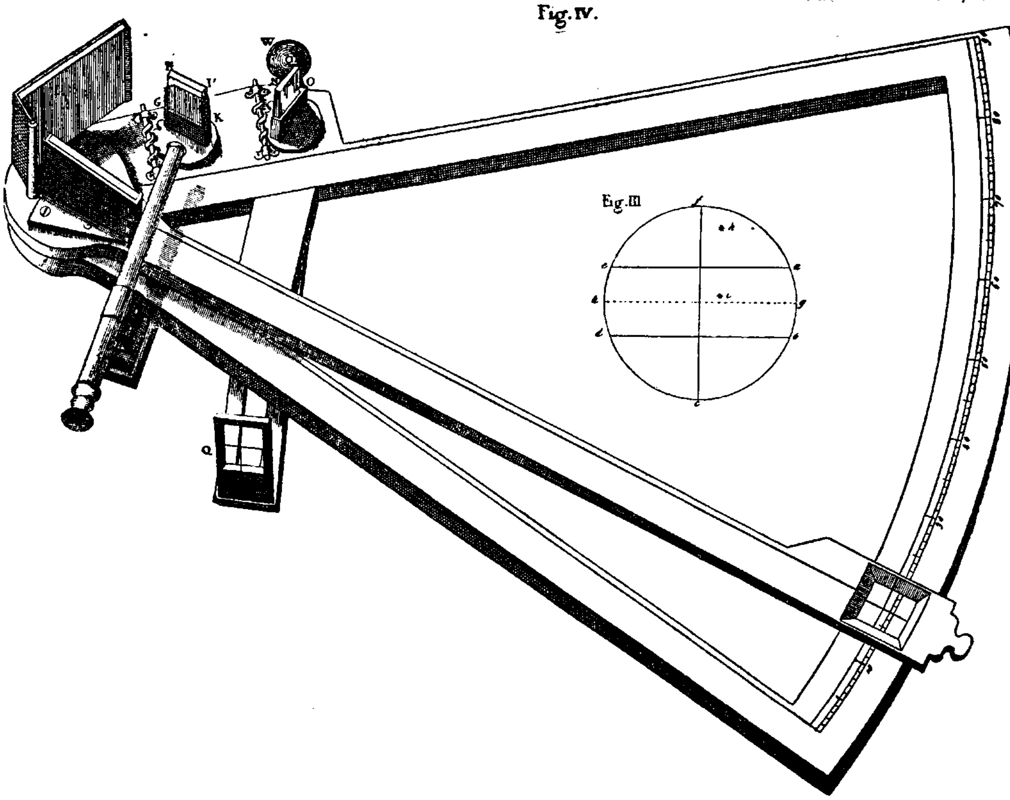
Fig. IV.



We also asked the Library of the British Admiralty for documents which it possessed on the subject of John HADLEY'S invention.

The Admiralty Librarian has kindly sent us the following information which will not fail to be of interest to the readers of the *Hydrographic Review.*

JOHN HADLEY (1670-1744.)

The Admiralty Library possesses a copy of the now scarce pamphlet: "*A description of a New Instrument invented by John Hadley, Esq., for taking the Latitude or other Altitudes at Sea. With directions for its use*" (30 pages, 8vo, *with diagram*, 9 ½ in × 7 ½ in), published in London, in 1734, at the price of six pence.

As the result of a search made at the Public Record Office, it is found that on the 15th August 1732 the Board of Admiralty passed the following Minute:—

> "Upon reading a letter from Mr. John HADLEY relating to an Instrument which he hath contrived for taking Angles at Sea: Resolved that directions be sent to the Commissioner at Chatham, that when he applys to him, he sends his yacht with him, and Mr. YOUNG, one of the Masters Attendants at that Yard, so far below the Buoy of the Nore as shall be judged convenient for trying the said Experiment, and then the Master Attendant is to report his opinion of the same."

The observations made on the occasion referred to in the foregoing paragraph are set out in the *Philosophical Transactions* (Abridged: Vol.VII, covering the period 1724-1734; published in 1809).

Attention may be called to the fact that there are points of difference in the instrument as shown in the diagrams contained in this volume, and in that published with the pamphlet of 1732.

In the course of the search at the Public Record Office, no specimen of HADLEY'S handwriting was met with, his letters having been "weeded".

An account of HADLEY given in the "*Dictionary of National Biography*"; also in the "*Biographical Account of John Hadley, Esq., V. P. R. S., the Inventor of the Quadrant, and of his Brothers George and Henry*", contained in the fourth volume of the *Nautical Magazine* (1835). The latter (p. 145) shows Bohun Lodge, his Hertfordshire residence, and mentions (p. 142) that "a portrait of him has been preserved: it is only a sketch in crayons, but it is highly characteristic, and exhibits a countenance replete with benignity as well as intelligence".

An old catalogue of the Library of the Royal Geographical Society, which is in the possession of the Admiralty Library, but which does not show the date of publication contains the following entry:—

> RIGAUD, Stephen Peter: Miscellaneous Tracts
>
> HADLEY, John, Biographical Account of, and of his Brothers George and Henry. *Portrait* and Fac-simile.

Among the collection of portraits of bygone mathematicians formed by the late W. W. ROUSE BALL, of Trinity College, Cambridge, is one catalogued as that of John HADLEY. The catalogue is printed in "*Modern Instruments of Calculation*" (published by Geo. BELL & SON, in 1914, in connection with the Napier Tercentenary Exhibition). The catalogue entry, p. 330, is:—

> J. HADLEY (of London), 1670-1744. Brought the sextant into general use.

The work of HADLEY is referred to in "*The Telescope*", by Louis BELL, Ph. D. (McGraw-Hill Book Company, 1922), which includes a plate (p. 25), "The First Reflector, John HADLEY, 1722".