III. *An Account of* Mr. Thomas Godfrey's *Improvement of* Davis's Quadrant, *transferred to the* Mariner's-Bow, *communicated to the* Royal Society, *by Mr.* J. Logan.

BEing inform'd that this Improvement, propoſed by *Thomas Godfrey* of this Place, for obſerving the Sun's Altitude at Sea, with more Eaſe and Expedition than is practicable by the common Inſtruments in uſe for that purpoſe, was laſt Winter laid before the *Royal Society*, in his own Deſcription of it; and that ſome Gentlemen wiſh'd to ſee the Benefit intended by it more fully and clearly explained: I, who have here the Opportunity of knowing the Author's Thoughts on ſuch Subjects, being perſwaded in my Judgment that if the Inſtrument, as he propoſes it, be brought into Practice, it will in many Caſes be of great ſervice to Navigation, have therefore thought it proper to draw up a more full Account of it, than the Author himſelf has given, with the Advantages attending it; which if approved of by better Judgments, to whom what I offer is entirely ſubmitted, 'tis hoped the Uſe of it will be recommended and further encouraged, as alſo the Author. The Riſe of the Improvement with its Conveniencies, as alſo a Deſcription of it, are as follows.

Tho. Godfrey, having under the greateſt Diſadvantages (as I obſerved in my firſt Letter to Dr. *Halley*, giving an Account of his Invention of the Reflecting Inſtrument) made himſelf Maſter of the Principles of Aſtronomy and Optics, as well as other

Parts of Mathematical Science, applied his Thoughts to conſider the Inſtruments uſed in that moſt momentous Part of Buſineſs, Navigation. He ſaw that on the Knowledge of the Latitude and Longitude of the Place a Ship is in, the Lives of thouſands of uſeful Subjects, as well as valuable Cargoes, continually depend; that for finding the firſt of theſe, certain and eaſy Methods are furniſh'd by Nature, if Obſervations be duly made: But *Davis*'s *Quadrant*, the Inſtrument generally uſed by Britiſh Navigators, (tho' ſeldom by Foreigners) he perceived was attended with this Inconveniency, that the Obſerver muſt bring the Shade or Spot of Light from the Sun, and the Rays from the Horizon, to coincide exactly on the fiducial Edge of the horizontal Vane: That tho' this can be done in moderate Weather and Seas with a clear Sky, and when the Sun is not too high, without any great Difficulty; yet in other Caſes it requires more Accuracy than can in ſome Junctures poſſibly be applied, and more Time than can be allowed for it. In *European* Latitudes, or to thoſe nearer the Northern Tropick, when the Sun is in the Southern Signs, and near the Meridian, he riſes and falls but ſlowly: Yet in Voyages to the *Eaſt* and *Weſt-Indies*, of which very many, eſpecially to the latter, are made, he is at Noon, often and for many Days together, in or near the Zenith, and when approaching to, or leaving it, he riſes and falls, when he has Declination, faſter than even at the Horizon; for it is well known to Perſons acquainted with the Sphere, that when his diurnal Courſe takes the Zenith, he there riſes and falls a whole Degree or 60 Minutes, in the Space of four Minutes

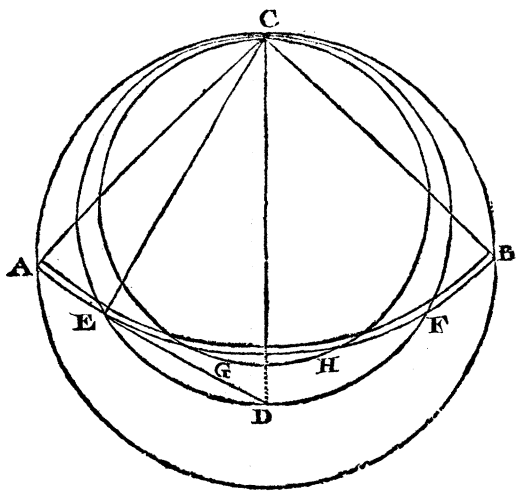
Minutes of Time; ſo that the Obſerver has but one Minute, to come within 15 Minutes of the Truth in his Latitude: While in a middle Altitude, as 45 Deg. he is at Noon above 5 Minutes and a half in Time, in riſing or falling one ſingle Minute of Space, the Odds between which is more than 80 to 1. And yet, perhaps, no Parts of the World require more Exactneſs in taking the Latitude than is neceſſary in Voyages to the *Weſt-Indies*: For it is owing to the Difficulty of it, that Veſſels have ſo frequently miſs'd the Iſland of *Barbados*, and when got to the Leeward of it have been obliged to run down a thouſand Miles further to *Jamaica*, from whence they can ſcarce work up again in the Space of many Weeks, againſt the conſtant Trade-winds, and therefore generally decline to try for, or attempt it.

But farther, as the Latitude cannot be found by any other Method, that our Mariners are generally acquainted with, than by the Sun or a Star on the Meridian: In a cloudy Sky, when the Sun can but now and then be ſeen, and only between the Openings of the Clouds for very ſhort Intervals, which thoſe who uſe the Sea know frequently happens: As alſo in high tempeſtuous Seas, when tho' the Sun ſhould appear, the Obſerver can ſcarce by any Means hold his Feet; it would certainly be of vaſt Advantage to have an Inſtrument by which an Obſervation could alſo be, as it were, ſnatched or taken in much leſs Time, than is generally required in the Uſe of the common Quadrant.

Tho. Godfrey therefore conſidering this, applied himſelf to find out ſome Contrivance by which the Neceſſity of bringing the Rays from the Sun, and thoſe from the Horizon to coincide (which is the moſt difficult part of the Work) on one particular Point or Line from the Centre, might be removed. In order to which he conſider'd, that by the 21. 3d *Elem. of Eucl.* all Angles at the Periphery of a Circle, ſubtended by the ſame Segment within it are equal, on whatever part of the Circumference the angular Point falls; and therefore, if inſtead of a Quadrant, a Semicircle were graduated into 90 Degrees only, accounting every two Degrees but one; this would effectually anſwer: For then, if an Arch of the ſame Circle were placed at the End of the Diameter of the Inſtrument, every Part of that oppoſite Arch would equally ſerve for taking the Coincidence of the Rays above-mentioned. But ſuch an Inſtrument would manifeſtly be attended with great Inconveniencies; for it would in great Altitudes be much more unmanageable, and the Vanes could not be framed to ſtand, as they always ought, perpendicular to the Rays. He therefore further reſolved to try whether a Curve could not be found to be placed at the Centre of a Quadrant, which would, at leaſt for a Length ſufficient to catch the Coincidence of the Rays, with Eaſe fully anſwer the Intention.

A Curve that in all the Parts of it would in geometrical ſtrictneſs effect this, cannot be in Nature, any more than that one and the ſame Point can be found for a Centre to different Circles, which are not concentric. It is certain that every Arch on the Limb may have a Circle that will paſs through the

the Center, and be a Locus or geometrical Place for the Angle made by that Arch to fall on: but then every Arch has a different one from all others; as in the Figure. Let ABC be the Quadrant, and AB, EF, GH be taken as Arches of it: Circles drawn through each two of theſe reſpectively, and through the Center C as a third Point, will manifeſtly be ſuch Loci or Places: For every Pair of theſe



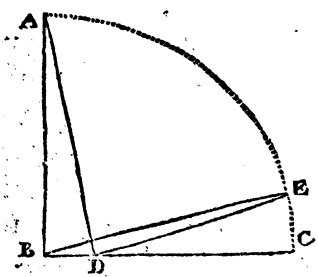
Points ſtand in a Segment of their own Circle, as well as on a Segment of the Quadrant; and therefore by the cited 21. 3d *Elem.* the Angles ſtanding on theſe firſt Segments will every where be equal at the Periphery of their reſpective Circles, and their Radius will always be equal to half the Secant of half the Arch on the Quadrant. For in the Circle CEDF (for Inſtance) the Angle CED is right, becauſe 'tis in a Semicircle, CE is the Radius of the Quadrant,

ED

E D the Tangent of the Angle D C E = ½ the Arch E F, and G D is the Secant of the ſame = the Diameter of the Circle C E D F, and therefore its Radius is half that Secant.

Now from the Figure 'tis plain, that in very ſmall Arches the Radius of their circular Place will be half the Radius of the Quadrant, that is, putting this Radius = 10, the other will be 5. And the Radius for the Arch of 90, the higheſt to be uſed on the Quadrant will be the Square Root of half the Square of the Radius = Sine of 45 Degrees = 7.071, and the Arches at the Center drawn by theſe two *Radij* are the Extreams, the Medium of which is 6.0355. And if a circular Arch be drawn with this Radius ⅒th Part of the Length of it, that is, in an Inſtrument of 20 Inches Radius, the Length of one Inch on each Side of the Center affording two Inches in the whole, to catch the Coincidence of the Rays on, which muſt be own'd is abundantly ſufficient, the Error at the greateſt Variation of the Arches, and at the Extremity of theſe 2 Inches, will not much exceed one Minute.

But in fixing the Curvature or Radius of this Central Arch, ſomething farther than a Medium between the Extreams in the Radius is to be conſidered: For in ſmall Arches the Variation is very ſmall, but in greater it equally encreaſes, as in the Figure where it appears, the Difference between the Angles A B C and A D C is much greater than the Difference between



tween EBC and EDC, though both are ſubtended by the ſame Line BD: for their Differences are the Angles BAD and BED. Therefore this Inequality was likewiſe to be conſidered; and compounding both together, *Tho. Godfrey* pitched on the Ratio of 7 to 11, for the Radius of the Curve to the Radius of the Inſtrument, which is 6.3636 to 10. But on further Adviſement he now concludes on $6\frac{4}{10}$; and a Curve of this Radius of an Inch on each Side of the Center to an Inſtrument of 20 Inches Radius or of $\frac{1}{20}$th of the Radius, whatever it be, will in no Caſe whatever, as he has himſelf carefully computed it, produce an Error of above 57 Seconds; and 'tis very well known that Navigators (as they very ſafely may) in their Voyages intirely ſlight a Difference of one Minute in Latitude.

This Radius is the true one for the circular Place to an Arch of 77° 15′, and the Variation from it is nearly as great at 90 Degrees as at any Arch below it, the greateſt below being at about 44 Degrees, which is owing to the Differences expreſſed by the laſt Figure above, and not to thoſe of the Curvatures or circular Places. Yet this Variation of 57 Seconds ariſes only when the Spot or Coincidence falls at the Extremity of the horizontal Sight or Vane, or a whole Inch (in an Inſtrument of 20 Inches Radius) from the Center, and then only in the Altitudes or Arches of about 44 or 90 Degrees. And in theſe, at the Diſtance of half an Inch from the Center, the Variation is but $\frac{1}{4}$ ſo much, *viz.* about 14″; and at $\frac{1}{4}$ of an Inch, not 4″; at the Center tis preciſely true. Therefore as an Obſervation may be taken with it in one fourth of the Time, that *Davis*'s *Quadrant*, on which

which three Things muſt be brought to meet, in a general way requires: I ſay, conſidering this, and the vaſt Importance of ſuch Diſpatch, in the Caſe of great Altitudes, or of tempeſtuous Seas, or beclouded Skies, tis preſumed the Inſtrument thus made will be judged preferable to all others of the kind yet known. Some Maſters of Veſſels, who ſail from hence to the *Weſt-Indies*, have got of them made as well as they can be done here; and have found ſo great an Advantage in the Facility and in the ready Uſe of them, in thoſe Southerly Latitudes, that they reject all others. And it can ſcarce be doubted, but when the Inſtrument becomes more generally known, it may upon the *Royal Society*'s Approbation, if the Thing appear worthy of it, more univerſally obtain in Practice.

'Tis now four Years ſince *Tho. Godfrey* hit on this Improvement; for his Account of it, laid before the Society laſt Winter, in which he mentions two Years, was wrote in 1732. And in the ſame Year, 1730, after he was ſatisfied in this, he applied himſelf to think of the other, *viz.* the reflecting Inſtrument by Speculums, for a help in the Caſe of Longitude, though 'tis alſo uſeful in taking Altitudes, and one of theſe, as has been abundantly proved by the Maker, and thoſe who had it with them, was taken to Sea, and there uſed in obſerving the Latitude, the Winter of that Year, and brought back again hither before the End of *February*, $173\frac{0}{1}$, and was in my keeping for ſome Months immediately after. It was unhappy indeed, that having it in my Power, ſeeing he had no Acquaintance nor Knowledge of Perſons there, that I tranſmitted not an Account of it ſooner: But I had

had other Affairs of more Importance to me: And it was owing to an Accident which gave me ſome Uneaſineſs, *viz.* his attempting to publiſh ſome Account of it in Print here, that I did it at that Time, *viz.* in *May* 1732, when I tranſmitted it to Dr. *Halley*; to whom I made not the leaſt Doubt but the Invention would appear entirely New. This, on my part, was all the Merit I had to claim, nor did I then, or now aſſume any other, in either of theſe Inſtruments. I only wiſh that the ingenious Inventor himſelf might by ſome means be taken Notice of, in a Manner that might be of real Advantage to him.

There needs not, I ſuppoſe, much more of a Deſcription of the Inſtrument than has been given: I ſhall only ſay, the Bow had beſt be an Arch of about 100 Degrees, well graduated, and numbered both ways; the Radius of 20 or 24 Inches; the Curve at the Center to be $\frac{1}{20}$th of the Radius on each Side, that is, $\frac{1}{10}$th of it in the whole; the Radius of that Curve $\frac{64}{100}$ Parts of the Radius of the Inſtrument; that the Glaſs for the Solar Vane ſhould not be leſs, but rather larger, than a ſilver Shilling, with its Vertex moſt exactly ſet. And that the utmoſt Care be taken to place the Middle of the Curve at the Centre exactly perpendicular to the Line or Radius of 45 Degrees. As the Obſerver muſt alſo take Care that the two Vanes on the Limb be kept nearly equidiſtant from that Degree; to which I ſhall only add, that it may be beſt to give the horizontal Vane only one Aperture, and not two. The reſt I ſuppoſe may be left to the Workmen. Thus doubting I have already been too prolix on the Subject, to which nothing but a ſincere Inclination to promote

any thing that might contribute to a publick Benefit, and to do ſome juſtice to Merit, could induce me, I ſhall only requeſt that what I have here offered may be conſtrued by that Intention.

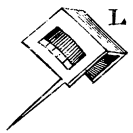
Philad. 28th of *June*, 1734.

J. LOGAN.

Note, That the Radius of the Quadrant being divided into 20 equal Parts, the Center × (in *Fig.* 1.) of the Curvature of the Horizon-Vane (A B) muſt be 12 $\frac{8}{10}$ of thoſe Parts from the Center (C) of the Quadrant. The Breadth (A B or *g h*) of that Vane ſhould be $\frac{1}{10}$ of the whole Radius, that is, $\frac{1}{20}$ on each Side of the Center (C).

IV. *The Deſcription and Uſe of an Inſtrument for taking the Latitude of a Place at any time of the Day*; *by Mr.* Richard Graham, *F. R. S.*

THE neceſſity of finding the Latitude, a Ship is in, is too well known to be inſiſted on: Frequent opportunities of obſerving the Latitude muſt conſequently



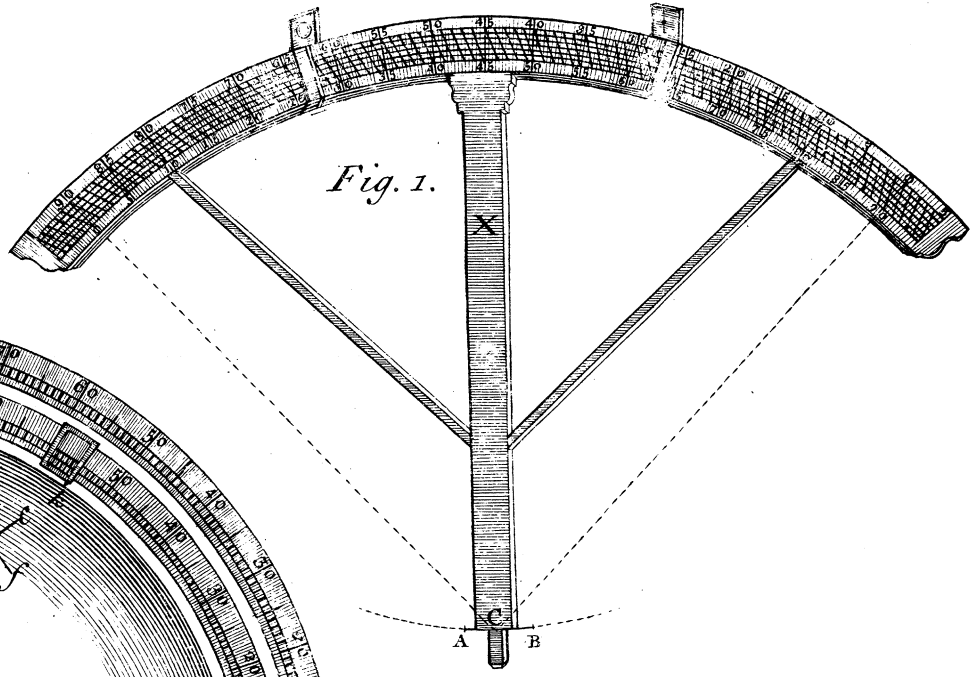


Fig. 1.

Fig. 2.