John Bird (1709-1776)

Mathematical Instrument-Maker in the Strand

1. The progress of practical astronomy depends in a great measure on the accuracy of the equipment with which the astronomers work. Consequently, the names of the makers of astronomical instruments should be rescued from the oblivion into which neglect is throwing them, and the men should be honored in accordance with the merit of their work. During their life-times these men often filled important positions and commanded both attention and respect. The scientific world recognized their abilities and called upon them for advice and assistance. Often they were the collaborators and intimate associates of renowned astronomers.

2. JOHN BIRD was an eminent mathematical instrument-maker, known throughout Europe for the accuracy of his instruments. (1) His advent on the scene of English instrument-making was a fortuitous one, and his efforts were furthered by the advice and instruction of GEORGE GRAHAM.

3. BIRD was born in Bishop Auckland in the County of Durham, and was a friend of WILLIAM EMERSON, the mathematician, of Hurworth, Durham County, and of JEREMIAH DIXON of the parish of Cockfield, in the same county. BIRD had some connection with Woolwich Academy, the Royal Military School, which enabled him to recommend DIXON as the person to be sent to St. Helena to make observations of the transit of Venus. (2) This same DIXON, with CHARLES MASON, later was sent to America to measure

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(1) *Gentlemen's Magazine, (Gent. Mag.)*, XLVI, 192, 1776.

(2) FORDYCE, WILLIAM, *The History and Antiquities of the County Palatine of Durham;...*, I, 558 footnote (Newcastle). For EMERSON see I, 499-501 and also the *Dictionary of National Biography (D. N. B.)*.

the boundary between Pennsylvania and Maryland, whence the common reference to the « Mason and Dixon Line ». (3) According to LUDLAM (4), BIRD prepared for the profession of a cloth weaver. In a clock-maker's shop he accidentally observed the irregular divisions of the minutes and seconds on a clock dial plate, and was offended by them. This incident first turned his attention to the art in which he later excelled. With great neatness and accuracy, he himself divided another plate, and for some time amused himself by dividing dial plates for the clock-maker, engraving all the figures on his own instruments. About 1740 he went to London, and by 1745 was in business for himself. In 1740 he invented an instrument for finding the latitude at sea. (5)

4. In the capital he divided instruments for SISSON, the well known instrument-maker, and the neatness and accuracy of his work attracted the attention of GRAHAM, of whose friendly communications he availed himself, and on whose work he later improved. (6)

5. LUDLAM says that GRAHAM had both a skill in practical mechanics and a love of astronomy and that he brought such perfection into the art of constructing and graduating instruments that a new era in astronomy dates from his time. (7) LUDLAM says it was important for the public that BIRD arrived on the scene towards the end of GRAHAM's life and was peculiarly endowed to supplement the latter's work in dividing and constructing

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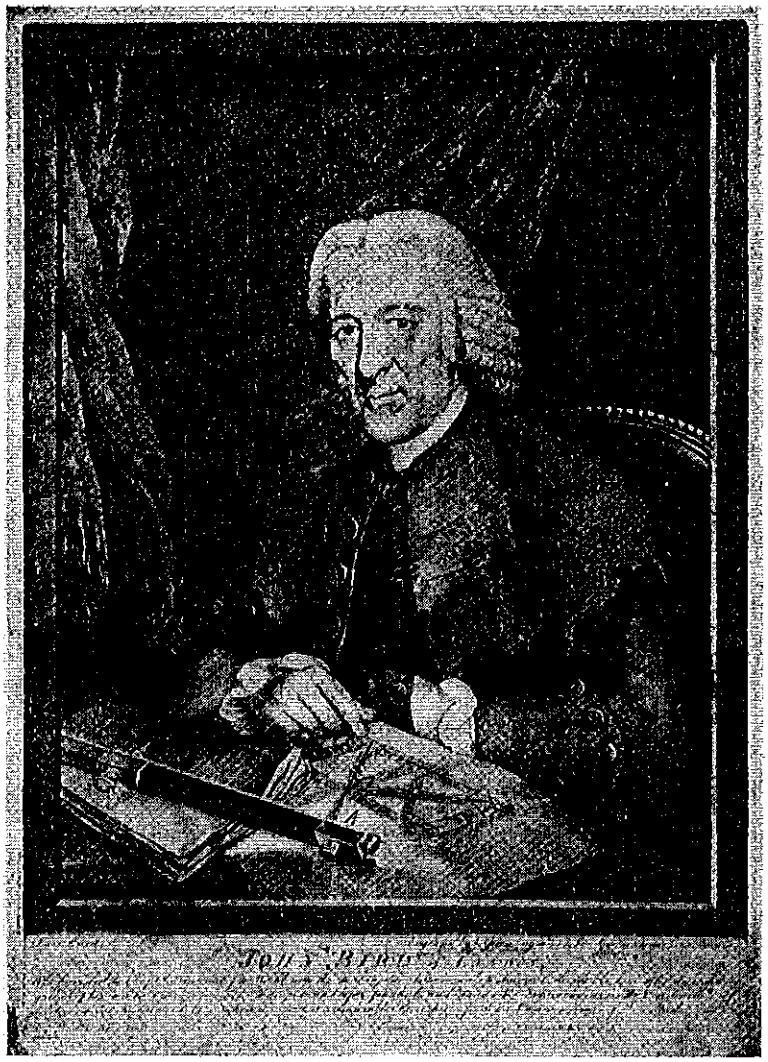
(3) This subject will be brought up later in connection with the instruments BIRD made for the undertaking. DIXON is not mentioned in the *D. N. B.*, except in the article *Mason, Charles*, nor in the new dictionary of American biography. Something of his early life can be found in FORDYCE, W., *op. cit.*, II, 78-79 footnote. Those who wrote on him as the surveyor seem not to have known of this. The story of his birth in a coal mine is scarcely credible.

(4) LUDLAM, W., *An Introduction and Notes, on Mr. Bird's Method of Dividing Astronomical Instruments. To which is added, a Vocabulary of English and French Technical Terms*, preface iv, note (London 1786).

(5) FORDYCE, W., *op. cit.*, I, 558 footnote and SYKES, JOHN, *Local Records...* [of Durham etc.] I, 165 (Newcastle 1833).

(6) LUDLAM, W., *op. cit.*, preface iv.

(7) *Ibid.*, preface iii. For further information about GEORGE GRAHAM see my essay in *Popular Astronomy*, April 1931 and the more complete version in the *Vassar Journal of Undergraduate Studies*, May 1931.



Isis, XVII, pl. 8 JOHN BIRD C. D. HELLMAN.
1709-1776
Painter: LEWIS (? JOHN, F. S. A., fl. 1762-1776)
Engraver: VALENTINE GREEN, 1739-1813.
By courtesy of Sir FRANK DYSON, Astronomer Royal,

Isis, XVII, pl. 9. GEORGE GRAHAM C. D. HELLMAN.
1673-1751
Painter: THOMAS HUDSON, 1701-1779
Engraver: JOHN FABER, the younger, 1695?-1756.
By courtesy of Sir FRANK DYSON, Astronomer Royal.

astronomical instruments. (8) RIGAUD, in his famous BRADLEY memoirs, also stresses this point. (9)

6. It does not seem that BIRD was as proficient an astronomer as GRAHAM. At least, there are but few observations by BIRD on record, and while those few testify to his knowledge of the theory of observing, they do not point him out as a skilled observer. The first of these which I have found is the transit of Venus on June 6, 1761 communicated to the Royal Society by NATHANIEL BLISS in a letter to the Right Honourable GEORGE Earl of MACCLESFIELD. In this letter BIRD is listed as having observed the transit of Venus, using a reflector of 18 inches focal length of his own making. BLISS also speaks of a 12-foot telescope and micrometer made by BIRD and used by HORNSBY for similar observations at Shirburn. (10) BLISS again mentioned BIRD in connection with the solar eclipse of April 1, 1764, when BIRD used a 2-foot reflecting telescope and when BIRD and BLISS measured the moon's diameter. (11)

7. Beyond this, references to BIRD merely concern his mechanical skill. HORNSBY, the Savilian Professor of Astronomy, a fellow of the Royal Society, communicated a paper to that society on the proper motion of Arcturus and on the obliquity of the ecliptic. In doing this, he had occasion to refer to BIRD's services at Shirburn. In 1743 that observatory was using a mural quadrant of five French feet, constructed by SISSON. The body of this quadrant was not sufficiently strong and the linear divisions were less accurate than expected. So in the summer of 1745, after the body of the instrument had been strengthened, the Earl of MACCLESFIELD employed BIRD to put a set of points on the limb. (12) According to RIGAUD, the quadrant bore GRAHAM's division of 96 as well as that of 90°. (13) BIRD began by determining the 96 parts and subdividing each into 8. (14) In June

(8) LUDLAM, W., *op. cit.*, preface iii.

(9) RIGAUD, STEPHEN PETER, *Miscellaneous works and correspondence of the Rev. James Bradley, D.D. F.R.S.*, lxxvi (Oxford 1832).

(10) *Philosophical Transactions (Phil. Trans.)*, LII part I, 175-176.

(11) *Ibid.*, LIV, 142-143.

(12) *Ibid.*, LXIII, 93 ff.

(13) RIGAUD, S. P., *op. cit.*, lxxxiii.

(14) *Ibid.*, lxxxiv.

1751, he bisected the distances between the points he had added, the line of collimation being found to have varied, making the zenith distances too small from the end of 1746 to June 1751. (15) After BIRD's divisions had been added the quadrant was placed on a table, and SISSON's quadrant was found to be 10″ less than 90°. (16) The beam compass, adjusted to 60°, was applied to a number of BIRD's points, none of which were found to vary from their true positions by more than one second. Quoting Lord MACCLESFIELD, RIGAUD gives the date of July 22, 1751 for BIRD's insertion of the intermediate divisions. The quadrant was so arranged that it could be moved to the opposite sides of the pier on which it was hung. (17)

8. About this time BIRD was called upon to provide some instruments for BRADLEY at the Royal Observatory. From 1742 to 1750 BRADLEY had contented himself with the same instruments HALLEY had used (GRAHAM's iron 8-foot mural quadrant). BIRD made him a brass mural quadrant of 8-foot radius and a transit instrument of 8-foot focal length. With these instruments BRADLEY began a series of observations of the sun, moon, planets, and fixed stars, which was carried on by others after his death. In 1776 MASKELYNE published the Greenwich observations for 1765 to 1774 and said of BIRD's instruments, then still in use, that « the exactness of the instruments is so great, and their rectifications so nice, that the place of any heavenly body may be always found by them within ten seconds of a degree, both in Longitude and Latitude, and generally much nearer. » (18)

9. GRAHAM's instruments had been remarkable, testifying to a true mechanical genius and a knowledge of practical astronomy, but improvements in astronomical instrument-making had been devised in the twenty-five years that had passed since GRAHAM's construction of BRADLEY's instruments, and the latter's request to the King for better ones and for a more convenient building

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(15) *Phil. Trans.*, LXIII part I, 110.

(16) RIGAUD, S. P., *op. cit.*, lxxxiii.

(17) *Ibid.*, lxxxiv and note. According to the *D. N. B.*, XV, 234, the Shirburn Castle observing books are in the Savilian Library at Oxford.

(18) MASKELYNE, the Reverend NEVIL, B. D., *Astronomical Observations made at the Royal Observatory at Greenwich, from the year MDCCLXV to the year MDCCLXXIV*, I, preface i (London 1776).

to house those used for meridian observations was not an unreasonable one. The grant of His Majesty as a result of this application made BIRD's work possible. This grant provided for a transit instrument with an 8-foot telescope, having an axis of 4½ feet and for an 8-foot quadrant, of the size made by GRAHAM in 1725, and also for other instruments which might help to advance astronomical knowledge. (19) At the completion of the new building, the Royal Observatory was provided with a moveable quadrant of 40-inch radius, made by BIRD. (20)

10. The work of alteration and new construction began in 1746 as is shown by the schedule of expenses given below, although the year 1750 is usually given as the year of the renovation of the observatory and its instruments. (21) RIGAUD gives the year 1748 for the grant of the £1000 from the king (GEORGE II) and WELD in his history of the Royal Society agrees with this. (22) The schedule includes the following work by BIRD :

		£.	s.	d.
1746 Feb. 11	By an apparatus for trying the line of collimation, by Mr. BIRD	2	12	6
—— May 29	By an arch for the transit instrument, by Mr. BIRD	8	13	0
1747 July 9	By a level by Mr. BIRD	1	11	6
1748 Oct. 12	By alterations in the transit instrument, &c. by Mr. BIRD	5	15	6
1743-1748	....			
	By a brass mural quadrant (23) by Mr. BIRD	300	0	0
	By a moveable quadrant p^{r} ditto	200	0	0
	By a transit instrument ditto	73	13	6
	By a 20 feet refracting telescope p^{r} ditto	7	10	0
	By a barometer p^{r} ditto	2	12	6

(19) HORNSBY, THOMAS, editor, *Astronomical Observations, made at the Royal Observatory at Greenwich, from the year MDCCL. to the year MDCCLXII. by the Rev. James Bradley*, I, preface ii-iii (Oxford 1798).

(20) *Ibid.*, preface iii, and MASKELYNE, N., *op. cit.*, I, preface ii.

(21) 1750 may be considered as the year the new instruments were first used. The instruments were furnished in 1750 according to ABRAM ROBERTSON (editor), *Astronomical Observations, made at the Royal Observatory at Greenwich, from the year MDCCL. to the year MDCCLXII. by the Rev. James Bradley*, II, preface iii (Oxford 1805).

(22) WELD, CHARLES RICHARD, *History of the Royal Society*, I, 491 (London 1848); RIGAUD, S. P., *op. cit.*, lxxiii-lxxiv.

(23) BIRD, J., *The Method of Constructing Mural Quadrants*, 7 (London 1768). This part is quoted later in this article.

By a thermometer p^r ditto 1 15 0
By alterations to the old mural quadrant
p^r ditto 32 10 0 » (24)

11. BIRD's brass quadrant was made for the west side of the wall, GRAHAM's being on the east side. (25) It is the one which BIRD described in 1768 in his book, *The Method of Constructing Mural Quadrants*, and to which we shall consequently return

AN

INTRODUCTION

AND

NOTES,

ON

MR. BIRD'S

METHOD of DIVIDING

ASTRONOMICAL INSTRUMENTS.

TO WHICH IS ADDED, A

VOCABULARY

OF

ENGLISH AND FRENCH

TECHNICAL TERMS.

By W. LUDLAM,

LATE FELLOW OF ST. JOHN'S COLLEGE, CAMBRIDGE.

LONDON:

Sold by JOHN SEWELL, No. 32. CORNHILL.

MDCCLXXXVI.

FIG. 1. The title page of Ludlam's *Notes*, a 4° of 42 pages. By courtesy of the library of Bowdoin College.

when discussing BIRD's two books. The two quadrants, BIRD's and GRAHAM's, continued in use for a considerable time, and in 1776 MASKELYNE wrote of them :

(24) RIGAUD, S. P., *op. cit.*, lxxiv.

(25) RIGAUD, S. P., *op. cit.*, lxxvii. [One description of the quadrant can be found in *Phil. Trans.* for 1806, II, 424 ff. It is also discussed in the memoirs of the French Academy for 1752 on pages 424 and 425.

« This [the division of 96] was first applied by Mr. Graham to the iron quadrant which he made for Dr. Halley, which was fixed up, on the east side of the pier with the telescope looking to the south, in the year 1725; but in the year 1753 it was taken down, and, after a new set of divisions had been applied to it by Mr. BIRD, was fixed upon the west side of the pier with the telescope looking to the north; the brass quadrant made by Mr. Bird, which had been placed for the three preceding years on the west side of the pier, for settling the latitude and refractions by the circumpolar stars, having been previously taken down and removed to the opposite or eastern side of the pier : and thus fixed both quadrants have continued ever since. » (26)

12. MASKELYNE also testified to the great accuracy of the brass quadrant, saying that its plane was so true and so well adjusted to the meridian that the stars passed its vertical wire within a few seconds of the true meridian transit as observed with the transit instrument, the greatest difference not exceeding 6 seconds of time. (27)

13. HORNSBY in his preface to BRADLEY's observations gives us more data concerning the quadrant, taking the date of its suspension, February 16, 1750, and its fitness for use in June, from BIRD's statement in the *Method of Constructing Mural Quadrants*. He then continues by saying that two loose sheets of paper show that several stars were observed at first with only the 90° arch, but that no observations were entered in the journal before the 10th of August, and that from then to the 24th of November the instruments were used without the telescope having been balanced. November 24th a counterpoise was applied, rendered necessary by the fact that the weight of the telescope upon the cylinder at the center, a variable quantity, was sufficient to affect the position of the instrument and to necessitate a constant rectification of the plumb-line after every observation. (28)

14. BIRD did not limit his work at Greenwich to the manufacture of new instruments, but also intelligently repaired the old. He admired the general construction of the old quadrant, and considered its greatest defect to be the considerable use of iron, which could not be forged as well as brass and thus contributed greatly to the alteration of the figure of the instrument. (29) He

(26) MASKELYNE, N., *op. cit.*, I, preface vii.
(27) *Ibid.*, I, preface viii.
(28) HORNSBY, T. (editor), *op. cit.*, I, preface vii.
(29) RIGAUD, S. P., *op. cit.*, lxxvii.

had contrived a small arc by which in 1750 and some of the preceding years the error of the line of collimation of the old quadrant had been measured and determined, by a mean of several trials, to be -6″.0 by which the zenith distances were given too large, comparing with the zenith sector -3″.9, from January 1751 to August 1752, -2″.9, and from September 1752 to July 1753, -2″.3. After the quadrant was directed to the north the zenith distances had to be diminished by 8″.4. (30) This was after BIRD had furnished it with a new set of divisions, and it had been placed on the western side of the pier, (31) which, as we have seen, happened in 1753.

15. In 1787 (February 22) MASKELYNE read a paper before the Royal Society concerning the latitude and longitude of the Royal Observatory, which gave him occasion to speak again of the brass quadrant, and in glowing terms. He said that for over three years BRADLEY observed the pole star and other stars north of the zenith. After the positions of the old and the new quadrants had been interchanged, BRADLEY started the series of star and planet observations which was continued for so long. (32) MASKELYNE said that to confirm further confidence in the astronomical refractions, and the latitude of the observatory as determined by BRADLEY, an examination of the total arc of BIRD's quadrant had been made, from which BRADLEY found it to be accurate, differing at one time only a fraction of a second from 90° and at another time being perfect. MASKELYNE added that GRAHAM's quadrant had been similarly examined and found to be 16″ less than a quadrant, but that after BIRD redivided it in 1753 it was probably as accurate as the other. BRADLEY used the new divisions to redetermine the old, and to this effect MASKELYNE gave the following quotation from BRADLEY :

' « August 12, 1753, I measured with the screw of my micrometer the difference of the arcs (of $\frac{64}{96}$) as set off by Mr. GRAHAM originally, and by Mr. BIRD when he put on a new set of divisions upon the old quadrant, and I have found that Mr. GRAHAM's arc was less than Mr. BIRD's by $\frac{8}{40}$ divisions of my micrometer,

(30) HORNSBY, T., (editor), *op. cit.*, I, preface vii.
(31) *Ibid.*, I, preface xiv.
(32) *Phil. Trans.*, LXXVII, 154.

which to a radius of 96 inches answers to 10", 6; so that the whole arc of 96 differs from a true quadrant 15", 9, which is the same difference that I formerly found by means of the level, &c.» ' (33)

16. In the new building a short passage connected the room in which the quadrants were fixed with that intended for the transit. (34) This was a skillfully constructed instrument of BIRD's fabrication. POUND's and HALLEY's, among the first such instruments made, were probably supported by the walls, but the one which BIRD made for BRADLEY was supported by strong stone pillars. The axis of the instrument was originally intended to be four feet long, but was made to be four and a half feet. The telescope was 8 feet long. A counterpoise was applied to the ends of the axis to diminish the effect of friction on them by taking off part of the instrument's weight. An elliptical screen for illuminating the wires diminished the size of the aperture from 2.7 inches in diameter to 1.5. At first there was a single eyeglass which rendered the field of vision indistinct toward the edges, but in January 1753 a double eyeglass was applied as a remedy. The lenses were fixed, and when MASKELYNE entered into office he had BIRD make the nearest glass draw out so that the distance from it to the wires could be accommodated to the eye of each observer. In August 1772, only, did MASKELYNE apply a sliding eye piece to the telescope thus both avoiding the oblique view of the side wires and removing the occasion for the compound eyeglass. (35) The magnifying power of the instrument was 50 times the original. Five wires, as nearly as possible parallel to each other, were placed in the common focus of the eyeglass and the 8-foot focal-length object glass. The middle wire passed through the center of the telescope and was crossed by a sixth at right angles. Unfortunately, star observations were not made at each of the wires but only at the middle one. Such observations would have been useful in giving the time of passage over the central wire if not observed provided the distances between the wires were accurately known. BIRD had aimed to make these distances equal and by observation they

(33) *Ibid.*, LXXVII, 159-160.
(34) RIGAUD, S. P., *op. cit.*, lxxviii.
(35) *Idem.* See also MASKELYNE, N., *op. cit.*, I, preface iv.

were found to be nearly so. (36) Although the diameter of the tube was adapted to a common object glass of aperture less than 1.6 inches, the weight of the 8-foot transit instrument was so great that it was considered necessary to make provision against any alteration which the cylindrical ends of the axis might produce in the form of the metalline notches in which they moved. To do this, a lever was placed on each stone pier and applied to each end of the axis, and the counterpoise moved to adjust the weight on the axis. (37) According to BRADLEY the weight of the instrument was 55 pounds. January 4, 1755, by the above described arrangement, he placed the weights supporting it so that the pressure of each cylinder on the brass notch was three pounds. (38) According to MASKELYNE, the collimation error of this transit instrument was seldom more than 1″ and never more than 2″ except once in 1768. (39)

17. BRADLEY's schedule of expenditure included minor apparatus as well as the large quadrant and transit. BIRD made him a Fahrenheit thermometer which was sent to Paris to be kept for a time in the cave of the Royal Observatory, and returned to Greenwich with a mark on the scale about half a degree above the 50th division. Fifty degrees was considered the mean height of the thermometer in tabulating mean refraction. (40) BIRD also made a moveable quadrant, originally intended to be 4 feet in radius, but made 40 inches instead because of the inconvenience of the larger size. (41)

18. When the Imperial Academy of Sciences at St. Petersbourg refitted its observatory in the middle of the eighteenth century, the services of BIRD were enlisted. April 2, 1751 the astronomer A. N. GRISCHOW wrote to BRADLEY, asking him to supervise the work, although he realized BIRD was a skilled workman. (42) He explained that the observatory wanted to have an 8-foot mural quadrant made at London by BIRD, like the one in Green-

(36) HORNSBY, T., (editor), *op. cit.*, I, preface iii.
(37) *Ibid.*, I, preface iv.
(38) RIGAUD, S. P., *op. cit.*, lxxviii, note i.
(39) MASKELYNE, N., *op. cit.*, I, preface v.
(40) HORNSBY, T., (editor), *op. cit.*, I, preface xv.
(41) RIGAUD, S. P., *op. cit.*, lxxvii.
(42) *Ibid.*, 466-469, a letter from GRISCHOW to BRADLEY.

wich. The telescope was to roll on four little wheels and the frame was to have a double counterpoise like the mural belonging to the Earl of MACCLESFIELD. The frame was to be of a strong copper alloy. The divisions on the limb were to be of 90° and 96. By means of the nonius division and the little micrometer it would be possible to calculate the seconds. The limb was to include about 100°. He proposed a method for dividing the arc, and suggested that there be two plumb-lines. BIRD was to have the instrument ready to ship on the last boat leaving London for St. Petersbourg in 1751, since the observatory wished to make some observations corresponding to those of LACAILLE at the Cape of Good Hope (concerning the parallax of the moon).

19. I have found no statement to the effect that BIRD ever made such an instrument, but it is highly probable that he did. In the first place, GRISCHOW made observations for which he needed such a mural quadrant (43), and in 1750 he refers to his instrument as being of English make, saying :

« Zu diesem ende (nehmlich eine oder 2 gantze perioden vom monde zu observiren) haben besonders mein grosses englisches instrument und die exactitude, mit welcher es verfertiget worden, beigetragen, dass ich im stande bin die ascensionem rectam exactissime zu observiren, welches mit einem quadrantem Murali niemals so genau geschehen kann, weil man noch keinen einzigen verfertiget hat, wovon der limbus ein accurates planum ist. » (44)

At the end of the letter he speaks of the « grosser quadrant » and gives its cost as 600 Reichsthaler. (45)

20. Another instrument by BIRD was the 6-foot mural quadrant for TOBIAS MAYER of the University of Göttingen, (46) who was making solar and lunar observations. In 1754 MAYER was made director of the Göttingen observatory and King GEORGE II presented him with the instrument. (47)

21. Among the smaller instruments made by BIRD were several

(43) See *Methodus investigandi parallaxin Lunae et Planetarum eclipsibus stellarum fixarum a luna et planetis inmixa. Auct. A. N. Grischow* in *Novi Commentarii Academiae Scientiarum Imperialis Petropolitanae*, IV, 451-474 (St. Petersbourg 1758).

(44) Letter by A. N. GRISCHOW in *Materials for the History of the Imperial Academy at St. Petersbourg for* 1750 (title in Russian), 698.

(45) *Ibid.*, 701.

(46) *Phil. Trans.*, LXXVII, 176-177.

(47) *Nouvelle Biographie Générale*, XXXIV, 538. For TOBIAS MAYER (1723-1762) see the *Allgemeine Deutsche Biographie*.

HADLEY's quadrants, (48) and HADLEY's sextants. (49) MASKELYNE speaks of a 6-foot sector by BIRD, which was used in settling the boundary between Maryland and Pennsylvania. (50) As we have seen above, this boundary was measured by MASON and DIXON, (51) who later measured the length of a degree, using the same instrument. (52) The sector was particularly accurate, having an altered suspension of the plumb-line which passed over and bisected a point at the center of the instrument. (53) According to MASKELYNE, BIRD made a similar alteration in the GRAHAM zenith-sector, substituting a fine piece of gold for the notch. (54) MASON and DIXON also used an instrument by BIRD which was serviceable as either an equal-altitude or a transit instrument, (55) and they had a 5-foot brass standard which on its return to London was compared with BIRD's scale, and reduced to the French measure. (56) MASKELYNE describes the method used by BIRD in finding the length of his scale in toises. (57)

22. BIRD's scale was, no doubt, the one made for the committees of the House of Commons in 1758 and 1759. These committees were desirous of ascertaining the original standards of weights

(48) *Tabulae motuum solis et Lunae novae et correctae; auctore Tobia Mayer: quibus accedit Methodus Longitudinum Promota eodem auctore.* [edited by MASKELYNE], CXXVII « *Extract of a Letter from Mr.* BENJAMIN ROBINS, *Engineer to the East-India Company, to Mr.* JOHN BIRD, *Mathematical-Instrument-maker, dated* Fort St. David's, Sept. 24, 1750. » (London 1770); also see, *Gent. Mag.*, XXVIII, 254 (June 1758).

(49) *Ibid.*, CXIII, CXIV and CXVI.

(50) MASKELYNE, N., *op. cit.*, I, preface x.

(51) *Phil. Trans.*, LVIII, 270; also *D. N. B.*, XXXVI, 417 (article *Mason, Charles*). For an account of the measurements see *Historical Magazine*, V, 199-202 (New York, July 1861).

(52) *Phil. Trans.*, LVIII, 270 ff. « *Introduction to the following Observations, made by Messieurs* CHARLES MASON *and* JEREMIAH DIXON, *for determining the Length of a Degree of Latitude, in the Provinces of* Maryland *and* Pennsylvania, *in* North America; *by the Reverend* NEVIL MASKELYNE, *B. D. F. R. S. Astronomer Royal.* » Read Nov. 24, 1768.

(53) *Idem.*

(54) MASKELYNE, N., *op. cit.*, I, preface x.

(55) *Phil. Trans.*, LVIII, 274 ff. « *Observations for determining the Length of a Degree of Latitude in the Provinces of* Maryland *and* Pennsylvania, *in* North America, *by Messieurs* CHARLES MASON *and* JEREMIAH DIXON. » A description of the transit instrument is given on page 274.

(56) *Phil. Trans.*, LVIII, 324-328.

(57) *Ibid.*, LVIII, 326-327.

and measures, and were greatly aided by BIRD. For the 1758 committee, in order to determine the capacity measures, he made an apparatus, under the direction of HARRIS, His Majesty's Assay Master of the Mint, by which the standard measures were placed on a plane leveled by four adjusting screws. Four brass cubes containing 300 cubic inches, sixty, twelve, and two, respectively, were also placed on brass planes and filled with water and made level by brass screws. (58) BIRD also furnished the committee with two brass rods made pursuant to the suggestions of HARRIS, who believed that a lineal measure ought to be the standard of all measures of capacity. The committee report gives HARRIS' ideas as follows :

« ... and as the Law seemed already to have made the Yard the Standard, he thought that to prevent Variations, it should be a clean strait Brass Rod, of about Thirty-eight, or Thirty-nine Inches long, and about an Inch broad and thick; near each End of this Rod, a fine Point should be made, and a fine Line drawn through it at right Angles to the Sides of the Rod; the Distance between the said two Points to be the true Standard Length of a Yard, and as the Edges of Points made in Brass were liable to decay, he would recommend two Gold Studs or Pins to be fixed in the Brass Rods, on which the Points were to be made, which ascertain the Length of the Yard. This Rod should be fitted in a proper Box and placed in safe Custody, to be used occasionally; but that for the ordinary sizing of Yards, there should be another Rod made in the same Manner with the former, only it should have two upright fixed Cheeks; by these Cheeks, anything placed between them might be more readily and exactly measured than by the Standards now at the Exchequer;... » (59)

Having a fixed standard yard the legislature could declare what proportion of it should be an inch, foot etc. To compare BIRD's two rods, the rod at the Exchequer, and GRAHAM's rod made for the Royal Society in 1742, the committee used beam compasses supplied by BIRD. (60)

23. BAILY in a report to the Royal Astronomical Society in 1835 speaks not only of the two rods by BIRD determining the standard yard of 1758 but also of a copy made in 1760 by the

(58) *Reports from Committees of the House of Commons, which have been printed by Order of the House,* and are not inserted in the Journals. Reprinted by Order of the House, II, 433. The report of the committee of 1759 is in the same volume.

(59) *Ibid.*, II, 434.

(60) *Idem.*

same artist, (61) both of which were destroyed in the fire in the Houses of Parliament in October 1834. (62)

24. The best sources of information concerning the mechanical part of BIRD's work are his own two books, *The Method of Dividing Astronomical Instruments* (1767) and *The Method of Constructing*

THE

METHOD

OF

Dividing ASTRONOMICAL INSTRUMENTS.

By Mr. JOHN BIRD,
MATHEMATICAL INSTRUMENT-MAKER, in the STRAND.

Published by ORDER of the
COMMISSIONERS of LONGITUDE.

LONDON,
Sold by JOHN NOURSE, in the Strand; and Mess. MOUNT and PAGE, Tower-Hill.
MDCCLXVII.

FIG. 2. The title page of BIRD's tract on the division of astronomical instruments, a 2° of VI plus 14 pages. By courtesy of the New York Public Library.

Mural Quadrants (1768). These attracted attention both in England and on the Continent, but some of the comment was derogatory. PIAZZI, the Italian astronomer, in a letter to LALANDE prefixed to LALANDE's French translation of RAMSDEN's (63) *Description of an engine for dividing mathematical instruments* (64) wrote :

(61) *Memoirs of the Royal Astronomical Society*, IX, 43-49, *Report on the Standard Scale of this Society* (London 1836).

(62) *Ibid.*, 79-82.

(63) JESSE RAMSDEN, 18th century English mechanician. See *D. N. B.*, XLVII, 265-267.

(64) Published by order of the Commissioners of Longitude (London 1777), 4°, 14 pp. The French translation is *Description d'une machine pour diviser*

« Graham et Bird se servoient du compas à verge ; celui-ci faisoit un mystere de sa méthode. Avant que le bureau des longitudes l'eût achetée pour la publier, M. Ramsden s'étoit fait déja une méthode comme Bird, et il l'avoit surpassé pour l'exactitude : ... » (65)

PIERRE-CHARLES LE MONNIER, (66) the French astronomer, was not gracious, either, concerning BIRD's books, although he recognized their value. He wrote as follows :

« La Commission nommée pour perfectionner la science des Longitudes, fit distribuer à Londres une grosse somme qu'elle avoit refusée à l'Auteur de l'Horloge Marine, pour qu'on décrivît avec soin l'Art de construire les Quarts de cercles muraux, comme aussi l'Art de les diviser : l'Artiste qui a reçu cette somme s'est contenté de produire un Ecrit avec trois planches gravées pour ce qui concerne la fabrication de l'Instrument ; & dès l'an 1767, un autre Ecrit concernant la division, avec une seule planche ou figure relative à son discours. On a cru devoir détailler ici davantage cette construction, en y joignant d'autres équipages très-utiles & leurs accessoires: le nombre des planches s'est accru nécessairement jusqu'au triple & au quadruple, ainsi que l'exigeoient les principaux détails où il a fallu entrer, & le Public loin d'être prévenu contre de pareils détails, en saura d'autant plus de gré à la Nation Françoise, qu'elle a su gratuitement les porter aussi loin que la chose sembloit le requérir. » (67)

LE MONNIER also disapproved of the apparatus for measuring the length of the whole arc, writing,

« La planche de sapin ou regle de 7 pieds & demi [Bird writes ' eight feet six inches '], avec deux arcs solides tracés à l'équerre, ou avec les arcs circulaires qui la terminent, qu'on a décrite à la *page* 24 de la *Méthode de construire les Quarts de cercles*, publiée à Londres en 1768, ne doit pas trouver place ici, étant d'une exécution trop difficile : cette méthode est d'ailleurs moins simple que celle de M. Graham, qui y employoit pareillement le niveau à bulle d'air, pour vérifier si l'axe répond à 90 degrés : ce célébre [sic] Méchanicien vouloit qu'on fît usage indépendamment de la lunette de l'alidade. » (68)

Explaining the construction of the frame-work of a quadrant,

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les instruments de mathematiques,... Traduite de l'anglois ; ... Par M. de la Lande, ... (Paris 1790), 4°, 46 pp., Plates.

(65) RAMSDEN, J., *Description d'une machine ...*, 6.

(66) *Nouvelle Biographie Generale*, XXX, 621-622.

(67) LE MONNIER, [PIERRE-CHARLES], *Description et Usage des Principaux Instruments d'Astronomie, Ou l'on traite de leur Stabilité, de leur Fabrique, et de l'Art de les Diviser*, 2, (1774) in Institut de France, *Description des Arts et Metiers*. This article has excellent plates. The maker of the « Horloge Marine » mentioned in this quotation is, probably, JOHN HARRISON.

(68) *Ibid.*, 4.

LE MONNIER preferred to refer to BIRD's book, describing his quadrant for the Greenwich Observatory, since GRAHAM's quadrant had not been forged from a single kind of metal. (69)

25. LUDLAM's *Notes* were written to make BIRD's pamphlet more clear, and contained the following none too gracious « attestation » by BIRD :

« When I wrote my Tract on the constructing and dividing of Astronomical Instruments, I thought I expressed myself so as to be understood by any common workman, a little used to this Business. What difficulties the *Learned* may find in it, I know not; if my friend can satisfy their scruples, so much the better. All I can say is that he has no where mistaken my meaning; and if he can (by what he has written) make those understand my method of dividing, who otherwise would not, he will not lose his labour.

JOHN BIRD.

June, 1773. » (70)

26. LUDLAM wrote that BIRD did not think it necessary to explain his « *principles* » to « common artificers », but that not every « Professor » would be acquainted with them. (71)

27. In 1767 the Commissioners of Longitude had offered BIRD a reward provided he would publish an account of his method of dividing astronomical instruments, and would demonstrate the process to persons chosen by the board, LUDLAM being among this number. In 1767, BIRD accordingly divided a 40-inch quadrant for the College of the Admiralty at Petersburgh before these people. LUDLAM also watched the dividing of an 18-inch quadrant in 1771 and took notes of what he thought was lacking in BIRD's tract. (72) Although LUDLAM referred to RAMSDEN's machine for dividing instruments he believed it still valuable to know the methods used for the Greenwich and Oxford (72a) instruments. He acknowledged his indebtedness to ALEX. AUBERT, Esq; F.R.S. & S.A. at whose expense his notes were published. (73)

28. Although LUDLAM did not think BIRD's tract sufficiently full in some details, he nevertheless appreciated all the refinements which BIRD had introduced into the process, and consequently

(69) *Ibid.*, 8.
(70) LUDLAM, W., *op. cit.*, v.
(71) *Ibid.*, preface iii.
(72) *Ibid.*, preface iv.
(72a) BIRD furnished the Radcliffe Observatory at Oxford.
(73) *Ibid.*, preface iv-v.

emphasized those difficulties which BIRD had satisfactorily met. For example, he wrote,

« The equality of the visible divisions will, therefore, depend partly upon the equality of the distances of the original points, and partly on the method of transferring the divisions from those. » (74)

And then he told how BIRD took care of this, writing,

« The equality of the original points will undoubtedly be affected by such partial expansions of the metal of which the instrument is made, as may take place while those points are setting out. Mr. Bird's method of guarding against this is, by setting out, first of all, a few capital points, distributed almost equally through the whole limb, leaving the intervals to be filled up afterwards; and thus shortening the time of the capital operations. Secondly, by taking care that both the scale of equal parts, and the quadrant to be divided from it, should be of the same temperature throughout, of course of the same degree of expansion; all of which is so clearly described by Mr. Bird, that it wants no comment. » (75)

29. BIRD worked with a beam compass. (76) He lay down his original points, following GRAHAM's principle of the practicability of bisecting an arch or right line but not trisecting, quinquesecting, etc. (77). Nor did BIRD approve of « stepping » or turning over the compasses, although he himself used that method in constructing his scale of equal parts. It was probably perfectly safe to step the compasses a few times, but not too many. (78) The arch of 96 which was introduced by GRAHAM and used by BIRD was based on the principle of bisection. (79)

30. By GRAHAM's method, the arch bounding the visible divisions was at some distance from the primitive circle, which was also the tangential circle. By BIRD's method, the bounding circle and primitive circle were very near and the tangential circle at some distance, because the radius with which the visible divisions were cut was long. (80)

31. In BIRD's method an alteration of the points of the compass was not serious. By GRAHAM's method, if the heat of the hand

(74) *Ibid.*, introduction 1
(75) *Idem.*
(76) *Idem.*
(77) *Ibid.*, introduction 2.
(78) *Ibid.*, introduction 3-4 and note.
(79) *Ibid.*, introduction 4.
(80) *Ibid.*, introduction 7.

should expand the beam compass in cutting divisions, the error of the expansion would be entirely repeated in the visible divisions, and similarly, if for any reason the distance of the points was changed; the expansion of the instrument would also occasion error. (81)

32. An expansion of the beam compass while cutting either nonius would make that nonius unequal, and so BIRD recommended holding the compass in the hand for a little while before cutting in order than it be of uniform temperature. (82)

33. LUDLAM gives the following excellent description of BIRD's scale of equal parts with its nonius :

« It contains, first of all, a scale of inches, each inch divided into tenths, and numbered at every inch from the left to the right, thus, 0. 1. 2. 3. &c. in the order of the natural numbers. The nonius scale is below this, but contiguous to it; so that one common line terminates the bottoms of the divisions on the scale of inches, and the tops of the divisions on the nonius; this nonius scale contains, in length, 101 tenths of an inch; this length is divided into 100 equal parts, or visible divisions; the left hand end of this scale is set off, from a point $\frac{1}{110}$ of an inch to the left of 0 on the scale of inches; therefore, the right hand end of the scale reaches to and coincides with the 10th inch on the scale of inches. Every tenth division on this nonius scale is figured from the right to the left, thus, 100. 90. 80. 70. 60. 50. 40. 30. 20. 10. 0. and thus 0 on the nonius coincides with 10 on the inches; and 100 on the nonius falls against the first subdivision (of tenths) to the left hand of 0 on the inches; and these two, viz. the first and last, are the only two strokes that do coincide in the two scales. » (83)

LUDLAM continues by saying that when the nature of the scale is known, it will not be difficult to understand the directions for dividing it, and that the scale is preferable to any diagonal scale because the latter has no check upon the errors. He adds,

« ... here the uniform manner in which the strokes of one scale separate from those of the other, is some evidence of the truth of both; but Mr. Bird's method of assuming a much longer line than what is absolutely necessary for the scale, subdividing the whole by a continual bisection and pointing the divisions as before explained, and guarding against partial expansions of the metal, is sure to render the divisions perfectly equal. The want of such a scale of equal parts (owing, perhaps, to their ignorance of constructing it) is one reason why Mr. Bird's method of dividing is not in so great estimation, among mathematical instrument makers, as it justly deserves. » (84)

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(81) *Ibid.*, introduction 8.
(82) *Ibid.*, notes 17.
(83) *Ibid.*, notes 21-22.
(84) *Ibid.*, notes 23-24.

34. According to LUDLAM, BIRD's first intention was to write on the construction of a quadrant before explaining how to divide it, but he was ordered to do otherwise (85). Thus his first tract, the one discussed by LUDLAM, is on the division of astronomical instruments. It is a folio of VI+14 pages with a preface by MASKELYNE and one by BIRD. It was published by order of the Commissioners of Longitude and printed in London in 1767. MASKELYNE in his preface gives the conditions laid down for BIRD by the Commissioners of Longitude, which were as follows: he was to receive £500 upon taking an apprentice for seven years and teaching him his art and method of making astronomical instruments and also instructing persons directed by the Commissioners from time to time; and also delivering in writing, on oath, to the Commissioners, a complete description of his method of constructing and dividing astronomical instruments, particularly like those he made for the Greenwich Observatory, accompanied by minute exact plates of those instruments for which he was to be allowed the further sum of £60. According to MASKELYNE, on March 21, 1767 BIRD delivered a plate and the tract on dividing the mural arc at Greenwich and on the improvements he had made meanwhile, whereupon the Commissioners published that account, intending that the part on constructing astronomical instruments should follow it. (86)

35. In his own preface BIRD said that his method was collected from 34 years of experience and from the teaching of SISSON. (87) He stressed the importance of accurate instruments in the following words:

« How far the Lunar Theory hath been improved by the observations of the late Dr. Bradley, and Mr. Mayer, I leave to the decision of those who have tried it by observations, in order to find the Longitude at sea, &c. I cannot help, however, being fully of opinion, that a still more perfect knowledge of the motion of the heavenly bodies may be obtained by future observations, skilfully made, with accurate Instruments. » (88)

36. BIRD's version of the origination of the book was this:

(85) *Ibid.*, introduction 9.

(86) BIRD, J., *The Method of Dividing Astronomical Instruments*, preface iii-iv (London 1767).

(87) *Ibid.*, preface v.

(88) *Ibid.*, preface v-vi.

« At a Board of Longitude, held at the Admiralty on the 10th of January, 1767, it was required of me to describe my method of dividing Astronomical Instruments, and the said description to be delivered at a subsequent Board, to be held on the 14th of March following. » (89)

37. He gave the following description of his tools :

« *The requisites for the performance of this work are as follow. A scale of equal parts, by which the Radius may be measured to* 0,001 *of an inch, must be provided. My scale is* 90 *inches long, each inch divided into* 10, *contiguous to which are nonius divisions, viz.* 10,1 *inches divided into* 100 *equal parts, shewing* 0,001 *of an inch; and by the assistance of a magnifying glass, of one inch focal length, a third of* 0,001 *may be taken off by estimation.*

Provide five Beam Compasses, to which magnifying glasses, of not more than one inch focal length, should be applied. Let the longest beam be sufficient to draw the Arcs, and measure the Radius : The 2d to measure the Chord of 42°:40' : *The 3d to measure the Chord of* 30° : *The 4th* 10°:20' : *The 5th* 4°:40' : *And if a 6th, to measure* 15°, *be made use of, so much the better....* » (90)

38. The care with which BIRD worked is well illustrated by his own description of the 8-foot quadrant for the Royal Observatory, which reads thus :

« *The Radius of the Arc of* 90°, *at the points,* = 95,938 *inches, from which the following numbers were computed, viz.* 49,6615 *inches* = *Chord of* 30° — 25,0448 *inches* = *Chord of* 15° — 17,679047 *inches* = *Chord of* 10°:20' — 7,81186 *inches* = *Chord of* 4°:40' *and* 69,80318 *inches* = *Chord of* 42°:40' *Having drawn the several Arcs, between which the divisions were to be cut, the Radius and the lengths of the above Chords were taken by the beam Compasses, which, together with the Scale, were laid upon the Quadrant, where they remained till the next morning; during which time the door of the room was kept locked. Before the sun-rise I measured the Radius, which required some correction; the Beam being of white fir, and the Scale of brass, which probably contracted, while the Beam remained unaltered : The other Beam Compasses also required correction.* » (91)

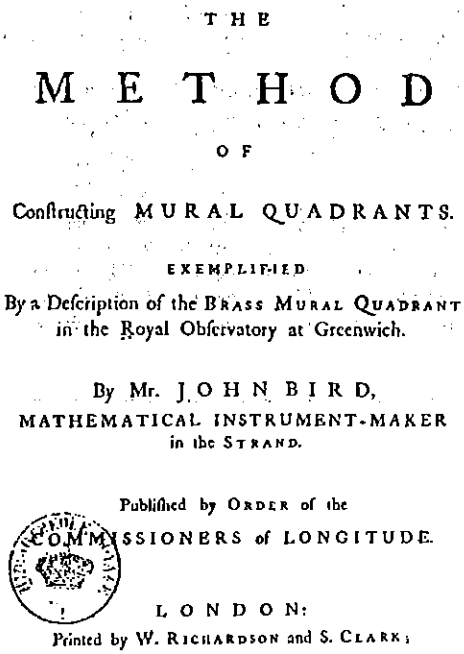
39. BIRD said that his arc of 96 was divided into three equal parts, like the 90° arc, and that each third contained 512 divisions, which gave 16 in each 96th part of the whole arc. (92)

40. Having learned by experience that the greatest difficulty in laying off the principal points, especially when this took several hours, was caused by the expansion or contraction of the instrument

(89) *Ibid.*, 1.
(90) *Ibid.*, 2.
(91) *Ibid.*, 2-3.
(92) *Ibid.*, 5.

to be divided, occasioned by the increasing or decreasing heat of the sun, BIRD contrived to lay them off in the least possible time before any expansion or contraction could take place. Three or four persons in the room might have the same effect as the heat of the sun, so BIRD only admitted one as an assistant. Nor did he allow a fire in the room until the principal points were laid. By having all the chords computed and measured the evening before they were to be laid off, he could in a few minutes accomplish what by trial would require some hours. To exercise further caution, he advised that the principal points be laid off before sunrise or on a cloudy morning. (93)

41. *The Method of Constructing Mural Quadrants* was published the year after the treatise on dividing instruments, namely, in



THE

METHOD

OF

Conſtructing MURAL QUADRANTS.

EXEMPLIFIED

By a Deſcription of the BRASS MURAL QUADRANT in the Royal Obſervatory at Greenwich.

By Mr. JOHN BIRD,
MATHEMATICAL INSTRUMENT-MAKER
in the STRAND.

Publiſhed by ORDER of the
COMMISSIONERS of LONGITUDE.

LONDON:
Printed by W. RICHARDSON and S. CLARK;
AND
Sold by JOHN NOURSE, in the Strand; and Meſſ. MOUNT and PAGE, Tower-Hill.
MDCCLXVIII.

FIG. 3. The title page of BIRD's tract on constructing mural quadrants, a 4° of 27 pages. By courtesy of the Bibliothèque Nationale, Paris.

(93) *Ibid.*, 10-11.

1768. It has one preface, written by MASKELYNE, and identical word for word with the preface by the same astronomer to the first tract except for the substitution in place of the last paragraph of a statement that the first tract had been published, and the addition of the following paragraph :

« Mr. Bird, in further pursuance of his engagements, having since delivered to the Commissioners three other plates, intituled N° 1, 2, 3, with a written paper, containing an explanation of the said plates, and an account of his method of constructing Mural Quadrants, exemplified by a description of the Brass Mural Quadrant in the Royal Observatory, the Commissioners have ordered this also to be published, which forms one work with the Method of Dividing, published before. An exact Model of the Brass Mural Arc in the Royal Observatory, to half the size, has been also provided by Mr. Bird, and is now deposited, by order of the Commissioners of Longitude, in the British-Musaeum. » (94)

42. In the first paragraph of the book BIRD tells how he started to work at Greenwich, and how he came to the conslusion that brass should be used in place of iron when forging quadrants. He expresses himself thus :

« In the year 1748, I was informed by the late Dr. Bradley, that application had been made for a new Mural Quadrant, to be fixed to the west side of the pier in the Royal Observatory, in order take [sic] observations to the North; that he had great hopes of success, and therefore desired that I would consider how to prevent a fault which he had found in the old Quadrant; which was, that it had altered its figure by its own weight, so as to render the whole Arc 16" less than a Quadrant or 90°. Accordingly, I made myself fully acquainted with the general construction of the old Quadrant, which was executed under the direction of the late Mr. Graham, and found the general plan, though little taken notice of at that time, to be such, as, I think, will be a lasting testimony of his great skill in mechanics. The reason of the alteration by its own weight, seems to be a defect in the manner of fastening the several parts together, probably owing to the cocks, and plates for that purpose, being of iron, which could not be forged in that advantageous shape, which I afterwards contrived to give to those that were cast of brass, for the new Quadrant; an order for the making of which, I received in February 1749. » (95)

43. The plates were drawn with unusual care and in great detail. Plate I shows the brass structure of the quadrant. BIRD tells why GRAHAM used 6 cocks cemented into the pier, and

(94) BIRD, J., *The Method of Constructing Mural Quadrants*, preface vi (London 1768).

(95) *Ibid.*, 7-8.

why he himself did not do this in the instruments which he made after the Greenwich quadrant. His argument was as follows :

« It is next to impossible to make the arch of a Quadrant so true a plane, as not to draw, in some places, the Telescope out of the plane of the Meridian; though this does not sensibly affect the observations, with regard to the Altitude, or Zenith distance, Mr. Graham thought proper to provide a remedy by cementing six cocks into the pier; those cocks having each two screws, which point towards each other, and receive between them other cocks, screwed to the inside of the perpendicular arch : by easing one screw, and screwing up the other, the limb of the Quadrant may be pushed towards or from the face of the pier, as occasion requires, which may be easily known by a Transit Instrument placed in the Meridian; for the difference in the times of a Transit shewn by the Transit Instrument and the Quadrant shews the error of the latter.

It was the intention of Dr. Bradley to put the old Quadrant and the new, in each other's place, after two or three years observations to the North with the new one; I was therefore obliged to make the new Quadrant of the same radius with the old, and in every respect to fit its place. I have mentioned above, that the cocks to reduce the plane of the arch to the Meridian, are cemented into the pier : these afterwards gave me a great deal of trouble, that I was, at first, not aware of; for it was not without the utmost difficulty that the Quadrant could be hung upon the pins; which difficulty was wholly occasioned by these cocks being in the way : I therefore, in all the Mural Quadrants which I have since executed, made them in the following manner. Let *xy* represent the face of the pier, *pz* two sections of a plug made fast in the pier with melted lead, *vv* two sections of the cock screwed to that plug, and K a section of the arch and cock, which falls in between the screws above mentioned : .... These being fixed on the outside of the perpendicular arch (on the inside of the instruments in the Royal Observatory) require the plugs with their cocks on the outside also : they may be taken away and replaced at pleasure, by which means all interruption from them is prevented. » (96)

44. The second plate pictures the front of the quadrant in a vertical position.

45. Plate III represents the telescope of the instrument with all its apparatus and is described in ten parts, each part represented by a separate figure. Concerning the bracing of the telescope, BIRD wrote :

« The late Dr. Bradley, Astronomer Royal, at the time when I made this instrument, was very desirous of having the Telescope to perform its office without bracing; I therefore hammered the tube extremely hard, and made the trial, but without success; it was therefore braced, in imitation of the Telescope of the old Quadrant. » (97)

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(96) *Ibid.*, 10-11. The letters in the quotation refer to BIRD's plate.
(97) *Ibid.*, 15.

He believed a counterpoise necessary, and therefore wrote :

« The Telescope of a large Mural Quadrant would scarce be manageable without a counterpoise, to keep it at rest in all parts of the arch... This counterpoise performs two parts; it does not only balance the Telescope, but the crank also, which lies on one side of the Telescope when perpendicular to the horizon : this is done by putting the brass socket, through which the iron arm goes, above the middle of the lead, which may be cast three or four pounds heavier than is necessary, to balance the Telescope, and then may be cut away, from that end which requires it. » (98)

46. After the telescope was fastened to the quadrant, BRADLEY noticed that when the eye-end of the telescope was brought down to 0° the cylinder bore all the weight, so BIRD contrived a method by which in all positions of the telescope the cylinder at the center would never bear more or less than half its weight. (99) BIRD described how he placed the wires in the reticule. (100)

47. His mechanical description of the instruments is followed by a history of the Greenwich quadrant, which reads as follows :

« On the 16th of February 1750, the Quadrant above described was suspended upon the west side of the pier in the Royal Observatory, and in June following was ready for observation. In the beginning of the year 1753 Dr. Bradley acquainted me, that he was fully resolved to have the two Quadrants put in each other's place, in the following summer, being satisfied with the observations which he had taken to the north, with the new one; but before this movement was effected, it would be proper to try if the Quadrant retained its true figure, having been in a vertical position near three years. Accordingly an apparatus for that purpose was provided, and about the latter end of January, the same year, the trial was made by Dr. Bradley, who found the whole Arc, to be two seconds less than a Quadrant : I also tried it and found it to be one second and a half less than a Quadrant. From hence we concluded, that as the deviation from a true Quadrant was so extremely small, the error lay in our trials, rather than in the instrument. However the doctor still remained unsatisfied, and was desirous of knowing if the Telescope described the same arc that was shewn by the divisions : a very simple apparatus (101), which I shall describe, was prepared, and the trial made by Dr. Bradley, who found the Telescope, when set to the 90th degree, to shew the whole Arc, to be three quarters of a second greater than a Quadrant, and by my trial half a second, greater than a Quadrant. This astonishing agreement is scarce to be believed, but the truth of it will, I hope, be confirmed, whenever Dr. Bradley's papers are referred to inspection.

(98) *Ibid.*, 16.
(99) *Ibid.*, 18-19.
(100) *Ibid.*, 19-20.
(101) By this apparatus both the Telescope and Arc are at once examined. (BIRD's footnote on page 23.)

In July 1753 I took down the old Quadrant, put a new set of divisions upon it, and put the new Quadrant in the place of the old, and the old one in the place of the new.

On the 28th of July 1759 the new Quadrant was again examined by Dr. Bradley and myself, when we found the whole Arc to be exactly 90°. The last examination was in very hot weather, and the first in very cold; so that it is evident, that neither hot nor cold weather, nor the weight of the instrument, have any material effect upon its figure. » (102)

48. BIRD ends his paper with a rather extravagant statement in praise of his instrument and its general construction, saying that if properly used it would last for many ages without diminishing in value. (103) He closed the paper by stating that the most critical examination of an instrument occurs in the very process of dividing it, and he recommended relying on the arch of 96 divisions rather than the 90° arch when computing from observations taken with the Greenwich quadrant. (104)

49. He died March 31, 1776 at the age of 67, (105) probably in London.

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(102) BIRD, J., *Method of Constructing Mural Quadrants*, 23-24.

(103) *Ibid.*, 26.

(104) *Ibid.*, 27.

(105) *Gent. Mag.*, XLVI, 192, and *Additional M. S.* 5728 of the British Museum, a volume of MUSGRAVE's Obituary, by letter from H. IDRIS BELL, Keeper of the MSS.

INDEX OF PROPER NAMES

Numbers refer to paragraphs.