THE AUTOMATIC RAIN-GAUGE OF SIR CHRISTOPHER WREN, F.R.S.

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[*Plates 25 and 26*]

Introduction

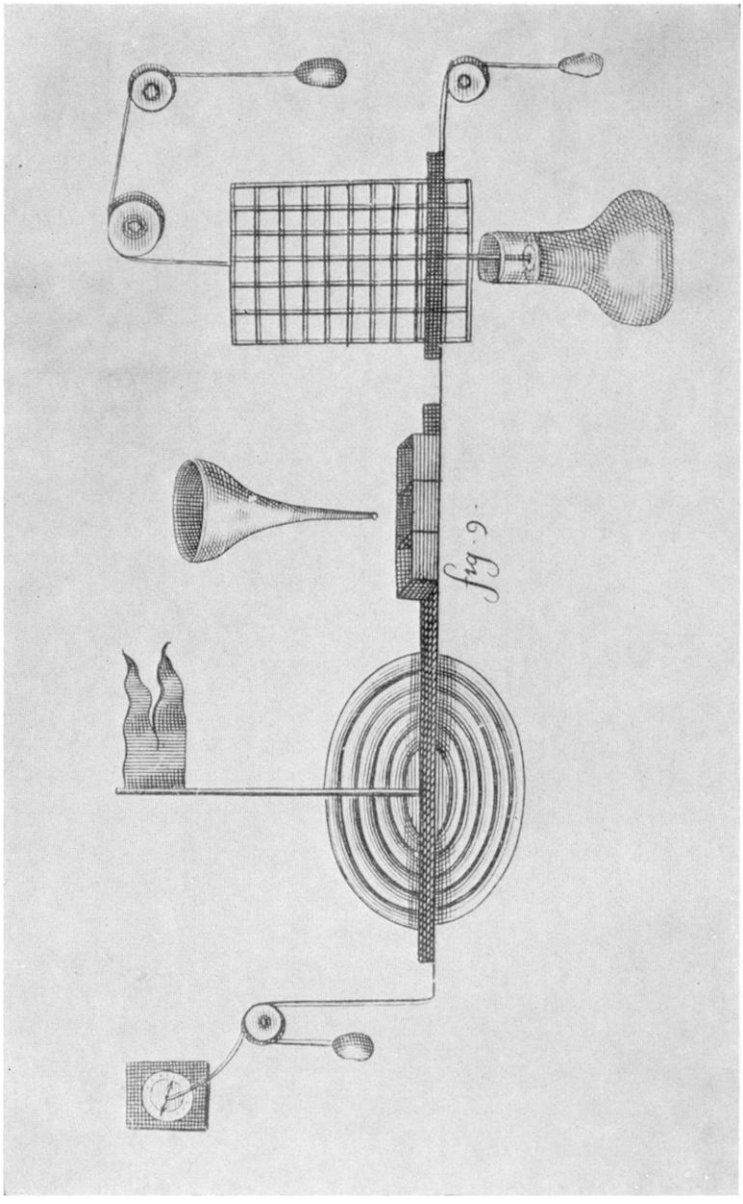
SAMUEL JOHNSON once said 'when two Englishmen meet their first talk is of the weather. They are in haste to tell each other what each must already know, that it is hot or cold, bright or cloudy, windy or calm'. More than two hundred years have elapsed, but, not surprisingly, the preoccupation of the English with the weather has still persisted. The interest in meteorological phenomena, however, could be traced to the old Babylonian culture (3000-1000 B.C.) when the priests were interested in Astro-Meteorology which became an integral part of the Assyric-Babylonian religion. The astrological cuneiform library of Assurbanipal (at present in the British Museum) indicates that the Chaldeans (race name of the Babylonians) made observations of clouds, winds, storms and thunder.

The first rain-gauge, in any form, ever used was in India around the fourth century B.C. and was probably the brain-child of a very resourceful 'Chancellor of Exchequer', Kautilya (equally well known as Vishnugupta Chanakya), who devised a system of taxation of lands based on the amount of rainfall they received. The next use of rain-gauges was by the Jews of Palestine around the first century A.D. The first recorded use of snow-gauges was in China (*chu chhi yen hsueh*) in A.D. 1247. The Koreans copied the Chinese rain-gauges around the middle of the fifteenth century. The Italian Benedetto Castelli (1577-1644) was the first to devise a rain-gauge in Europe in 1639 (1). The earliest English rain-gauge was made by Sir Christopher Wren (1632-1723) (2, 3), one time President of the Royal Society, and unlike the previous instruments which were all of the non-recording type, the inventor made an automatic tipping bucket rain-gauge.

Description by Monconys

B. D. Monconys, a Frenchman, who visited England in June 1663, gave an account of an automatic rain-gauge which was made by one 'M. Renes' (4). It is highly likely that 'M. Renes' was actually Sir Christopher Wren. How

Plate 25



Rain-gauge attributed to 'M. Renes' by Monconys

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was the poor Frenchman to know that the surname pronounced 'Ren' was actually spelt Wren? Hence Monconys probably settled for 'Renes' and it is submitted that such a mistake was very likely and in fact happened in this case. The rain-gauge attributed to Sir Christopher Wren by Monconys is shown in Plate 25 and it can be seen that it was a part of a meteorograph. Below the catch funnel was a three-compartment container on an arm which was moved horizontally by a rack device operated by a clock so that one box was under the rain funnel for one hour and then the second box moved below it to collect the rain water. If Wren did make a rain-gauge of this type, and on Monconys' evidence it seems that he did, it means that he devised not one but two automatic instruments—quite an achievement considering none was available before his time.

Tipping bucket type rain-gauge

The chronology of Wren's recording rain-gauge can be seen in the *History of the Royal Society* by Thomas Birch (1705-1766)—the then Secretary of the august society. It is as follows:

22 January 1662—'Dr Wren shewed his experiment of filling a vessel with water, which emptied itself when filled at a certain height' (5).

23 September 1663—'Dr Wilkins was desired to write to Dr Wren for his scheme of the instrument for observing all kinds of weather' (6).

2 December 1663—'Dr Wilkins acquainted the Society, that he had received an answer from Dr Christopher Wren, concerning his promised weather-cock, together with the scheme thereof. The amanuensis was ordered to draw the scheme in great [make a sketch] against the next meeting, at which it should be considered, together with a letter describing it' (7).

9 December 1663—Wren described his weather clock at the society meeting—but for some reason it was only for recording wind. 'Upon some debate, it was referred to the Council to consider the expenses, and the most convenient way of reducing this engine into practice; as also, of additions to be made thereunto, whereof some were mentioned by Mr Hooke' (8).

14 December 1663—For some reason, the Council was not happy with the additions and 'It was ordered, that Dr Wren be desired to make an estimate of the charges of a plain weather-clock, such as he himself had desired, and to consider of the earliest contrivance to put it in practice' (9).

19 May 1670—'It was ordered, that a weather-cock should be bespoken by Mr Hooke, such a one, as Dr Wren had formerly contrived, for observing not only the winds and their quarters and degrees of strength, but also the quantities of rain, and other particulars relating to the temperature of the air' (10).

For the next 9 years, there are many entries in Birch's journal on the weather clock. Finally it was reported on 22 May 1679, that Hooke had finished the instrument but it could not be shown till the next meeting on 29 May because of the presence of a stranger!

29 May 1679—'The society then went to take a view of the new weather-clock, which was set up in Mr Hunt's lodgings, made to keep an account of the quantity and time of all changes, that happen in the air, as to its heat and cold, its dryness and moisture, its gravity and levity; as also of the time and quantity of the rain, snow, and hail, that fall: all which it sets down in a paper, so as to be very legible and certain' (11).

2 April 1684—Hooke was ordered to write a description of the weather-clock and its parts so that it could be entered in the Register Book. He was also asked to give his directions and assistance to Hunt so as to 'reduce into writing some of the first papers marked by the weather-clock, that thereby the society might have a specimen of the weather-clock's performances before they proceed to the repairing it' (12). Obviously something had gone wrong with the clock and refitting of it was mentioned on 18 December 1690.

Reference to Wren's tipping bucket rain-gauge can be seen in the review of the book *De l'origine des Fontaines* by Pierre Perrault in the *Philosophical Transactions* for 1675 which stated that: 'The like to which (estimation of the quantity of rain) hath been attempted here, and proposed to the *R. Society*, some years since, by *Sr. Chrs. Wren*, who by the contrivance of a Rain-bucket had taken an account of all the Water that fell for a considerable time; and by his Weather-clock had, among other particulars, not only taken in the measuring of the quantity of Rain that falls, but also the time when it falls, and how much at each time. Which Instrument, if put into practice, would be of excellent Use, forasmuch as it may also serve, by some additions made thereunto by *Mr Hooke*, to record the weight of the Air, the drought, moisture, heat and cold of the Weather, the Sun-shine, the quarters and strength of the Winds: And all this to be performed by one only motion, driving all the parts of the instrument; which is therefore the more considerable, that itself records its own effects' (13).

Thomas Sprat (1635-1713) also referred to the rain-gauge of Wren in his *History of the Royal Society* (14) and so did Robert Plot (1640-1696), a Fellow of the Royal Society, in *The Natural History of Staffordshire* (15). Both of them are brief references and Plot's description is worth quoting—only if to introduce the personal note in the passage. 'I know that the right Worshipful the Learned Sr. Christopher Wren the now worthy *President* of the *Royal*

Society ha's contrived a *Rain-bucket* to measure the quantity of *Rain* that falls, which as soon as 'tis full, empties it self into a Cistern, and so receives more; which how often it performs is recorded by a *Weather Clock*, as may be seen in the *Repository* of the *R. Society* at *Gresham* College, . . . ' (15).

Christopher Wren, Jr., in his biography (16) of his illustrious father, pointed out that Robert Hooke had first suggested to the Royal Society 'for augmenting' Wren's weather-clock in 1674 and he showed the members of the Society parts of his all-purpose 'Weather-wiser' on 5 December 1678. According to Hooke it 'was to keep an account of all the changes of weather, which should happen, viz. 1. The quarters and points, in which the wind should blow. 2. The strength of the wind in that quarter. 3. The heat and cold of the air. 4. The gravity and levity of the air. 5. The dryness and moistness of the air. 6. The quantity of rain, that should fall. 7. The quantity of snow or hail that shall fall in the winter. 8. The times of the shining of the sun' (17). Five weeks later on 9 January 1679 as already has been stated, the members of the Society visited Hooke's turret to see the weather-wiser and it was well approved by them (18).

The weather-clock was described by Nehemiah Grew (1641-1712) one time Secretary of the Royal Society, as follows:

> Begun by *Sir Chr. Wren*, now President of the Royal Society. To which other Motions have since been added, by Mr *Robert Hooke* Professor of Geometry in *Gresham-Colledge*. Who purposes to publish a Description hereof. I shall therefore only take notice, That it hath six or seven Motions; which he supposeth to be here advantagiously made altogether. First a *Pendulum* Clock, which goes with $\frac{3}{4}$ of a 100 *Lib.* weight, and moves the greatest part of the work. With this, a Barometre, a Thermometre; a Rain-Measure, such an one as is next describ'd; a *Weather-Clock*, to which subserves a piece of Wheel-Work analogous to a way *Wiser*; and a Hygroscope. Each of which have their Regester, and the *Weather-Cock* hath *Two*, one for the *Points*, the other for the *Strength* of the Wind. All working upon a Paper falling off a Rowler which the *Clock* also turns.
>
> An Instrument for MEASURING the quantity of RAINS that fall in any space of time, on any one piece of Ground, as suppose upon one Acre in one year. Contrived by Sir *Christopher Wren*. In order to the *Theory* of Vapours, River Seas, &C. A triangular Tin-Vessel hanging in a Frame, as a Bell, with one Angle lowermost. From whence one side rises up perpendicular, the other sloaped; whereby the water, as it fills, spreads only on one side from the centre, till at length it fills and

empties it self. Which being done, a leaden poise, on the other side, immediately pulls it back to fill again (19).

Hooke did describe the construction of the rain-gauge. Figure 1 is the original geometrical drawing of Hooke as given by Derham in his book on *Philosophical Experiments and Observations of the Late Eminent Robert Hooke* (20), published in 1726, and later reproduced by Gunther (21) in *Early Science in Oxford*, Volume 7, published in 1930. Figures 2, 3 and 4 show the probable make-up of the instrument.

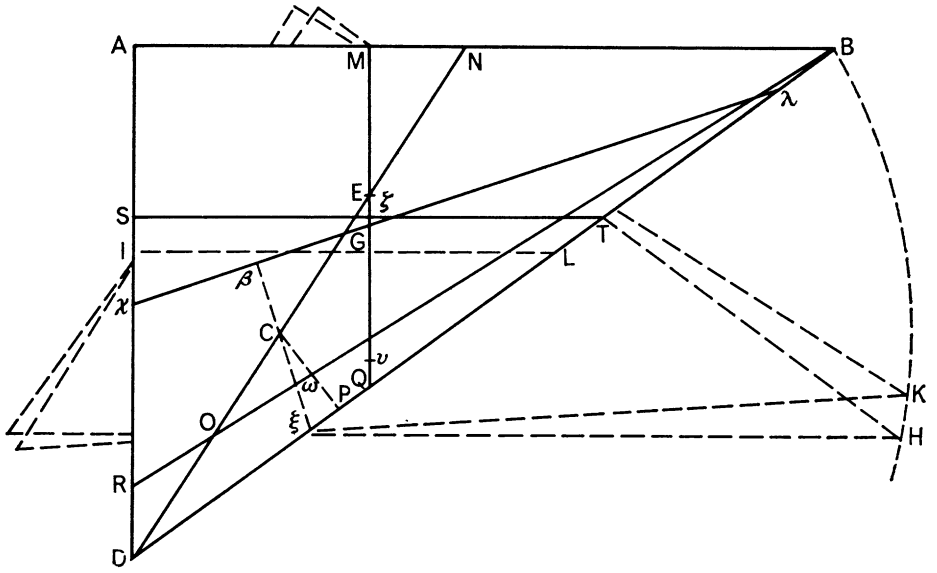


FIGURE 1. The original drawing by Hooke used to work out the theory for the design of the rain-gauge (20, 21).

Two methods for counterpoising the suspension of the bucket were contrived so that its position was uniquely defined depending on the amount of rainwater collected. The first method was the utilization of a string of bullets so that when the bucket was empty all the bullets were on a table. The bullets were lifted up one after another as more and more water accumulated in the bucket. When all the bullets were lifted up from the table, the bucket emptied itself. Hooke rejected the procedure on the ground that the movement of the bucket was neither smooth nor continually equal.

The second method was that the 'counterpoise to the bucket, when empty was a cylinder immersed into water, mercury or any other fluid; which cylindrical counterpoise, according as the bucket received more and more water, was continually lifted higher and higher out of the water by spaces,

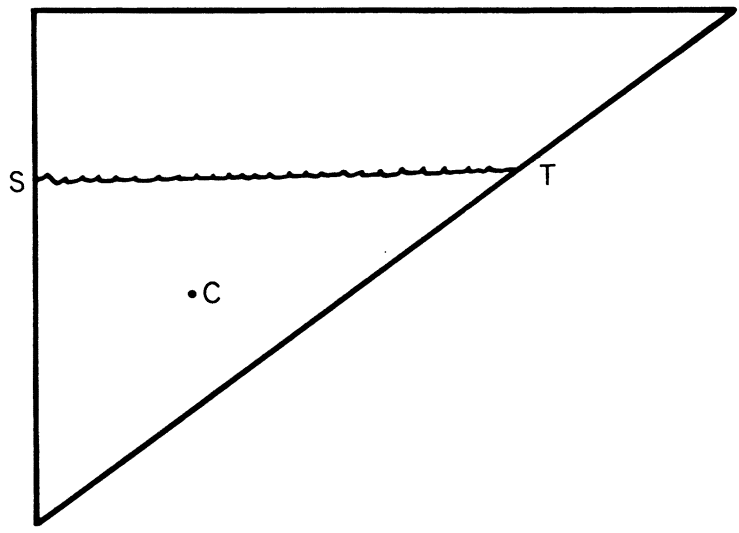


FIGURE 2. Here all the construction lines have been removed. Point C is the centre of gravity of the prism of water contained in the vessel when it has been filled to the elevation of S-T (the incipient point above which tipping will occur).

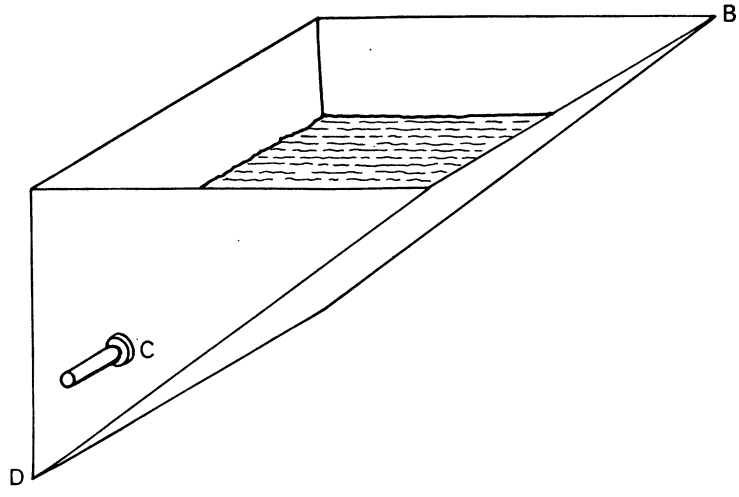


FIGURE 3. This shows the vessel in three dimensions.

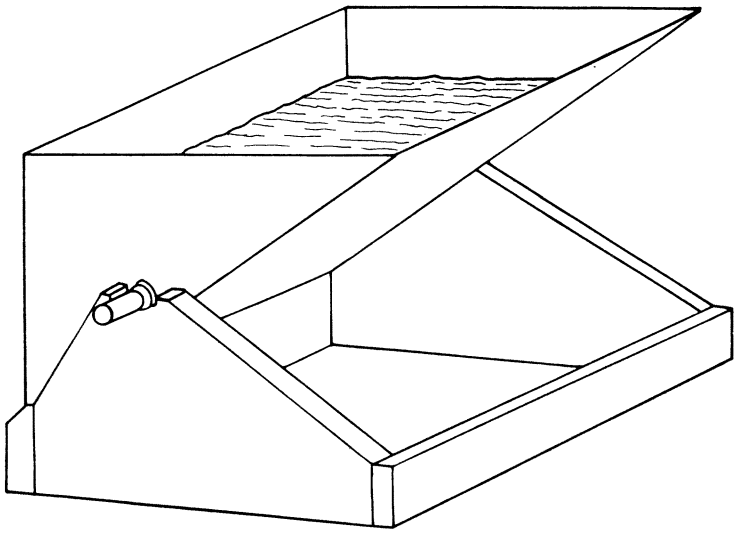
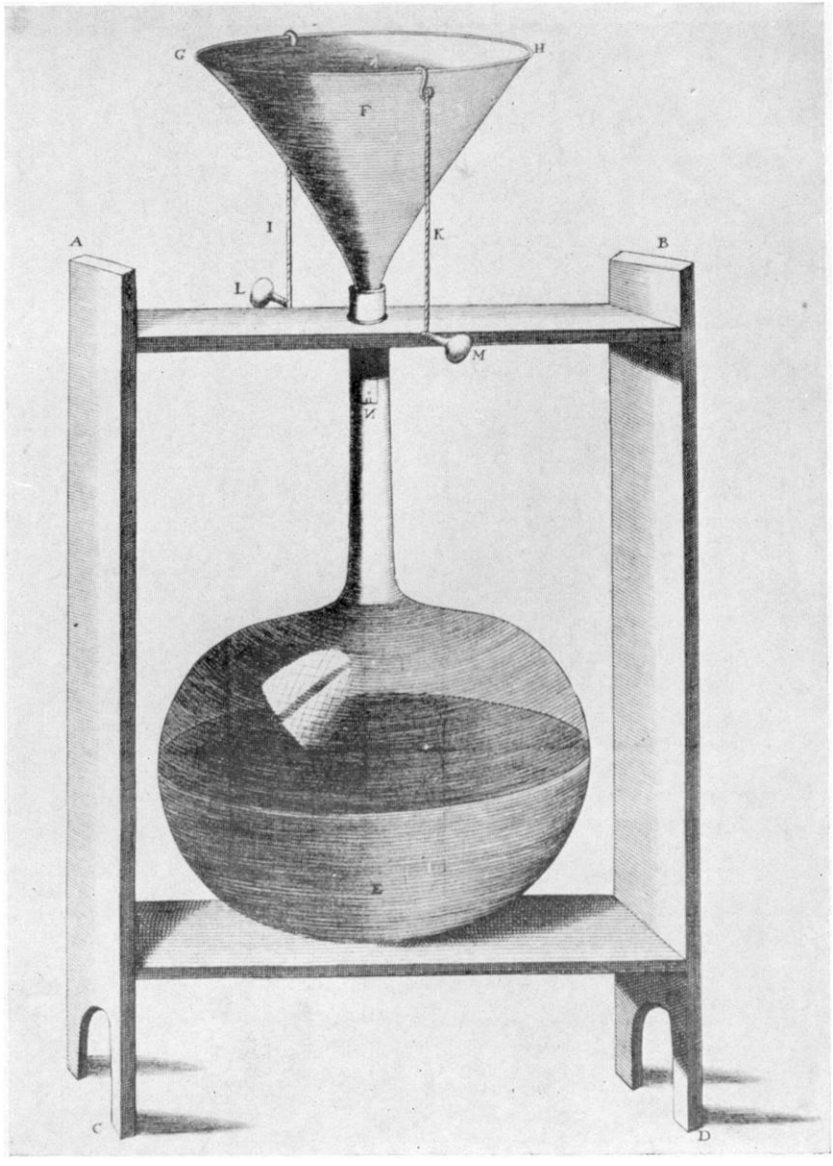


FIGURE 4. When assembled, Hooke's Tipping Bucket Rain-Gauge might have looked like this. Hooke mentioned that the vessel was 'Poiz'd like a balance upon a foot'. Maybe the 'Foot' was as shown above.

always proportioned to the quantity of water, that was contained in the bucket. And when the bucket was filled to its designed fullness, it immediately emptied itself of the water, and the cylinder plunged itself into the water, and raised the bucket to the place where it was again to begin its descent (20, 22, 23).

The weather-clock, of which the self-measuring rain-gauge was a part, consisted of two parts. The first part was a strong and large pendulum-clock for measurement of time as well as to rotate a cylinder twice a day, thus unwinding a paper strip on which records could be punched every 15 minutes. The second part consisted of five meteorological instruments—the barometer, the thermometer, the hygroscope, the rain-bucket, and finally the wind-vane (revolving type). The readings of all the instruments were punched on the tape. 'The stations or places of the first four punches are marked on a scrowl of paper, by the clock-hammer, falling every quarter of an hour. The punches, belonging to the fifth, are marked on the said scrowl, by the revolutions of the vane, which are accounted by a small numerator, standing at the top of the clock-case, which is moved by the vane-mill' (20, 24). The punched records of the observations from the rain-bucket not only showed the number of tippings that had already occurred but also indicated the quantity of water that remained in it.

Plate 26



The non-recording rain-gauge of Robert Hooke

[*Facing page* **101**

Months	*Days*	℔	℥	*Gr.*
Auguſt	19	2	6	216
	26	4	6	246
September	2	9	4	96
	9	3	10	397
	16	0	1	204
	23	0	6	336
	30	4	1	444
October	7	2	3	96
	14	0	2	60
	21	0	1	234
	28	0	0	45
November	4	0	0	207
	11	[illegible]	11	65
	18	1	1	309
	25	0	9	285
December	2	0	8	126
	9	3	7	324
	16	1	3	435
	23	0	1	60
	30	5	8	93
January	6	4	10	105
	13	0	1	12
	20	1	10	450
	27	1	5	82
February	3	6	11	372
	10	4	9	242
	17	0	6	291
	24	0	2	180

Months	*Days*	℔	℥	*Gr.*
March	2	0	9	12
	9	0	2	459
	16	0	0	396
	23	4	4	263
	30	1	5	285
April	6	2	3	375
	13	1	0	294
	20	2	1	000
	27	0	7	390
May	4	4	10	45
	11	7	6	000
	18	6	2	105
	25	1	7	60
June	1	0	0	99
	8	6	6	150
	15	0	2	120
	22	7	5	285
	29	1	5	84
July	6	0	1	120
	13	16	1	000
	20	1	7	240
	27	6	1	256
Auguſt	3	1	10	120
	10	1	11	90
	12	0	0	0
The Sum		131	7	113

=to 29 $\frac{1}{10}\frac{1}{2}$ Inches in a Cylinder of the aforeſaid Diameter, *viz.* 11 $\frac{7}{10}$ Inches.

FIGURE 5. The rain-gauge readings of Hooke for the year 1695.

The meteorograph obviously worked, if but intermittently, as Hooke was asked to help his assistant to 'reduce into writing' some of the data from the punched tapes. The punched tape method of data collecting has come into vogue only during the last decade or two, and its utilization as early as 1678 clearly indicates that Hooke was way ahead of his time. So far as I could find out, no sketch or specimen of the actual punch tape used is now in existence. In this connexion, however, it may be worthwhile to mention that Jacob Leupold in his book *Theatri Machinerum Supplementum*, published in 1739, describes with sketches (25) the use of punched tapes to record results from way-wisers (odometers). It is too tempting to speculate that Leupold obtained his idea from the works of Robert Hooke!

Hooke also did contrive a non-recording type of rain-gauge (26) as shown in Plate 26. It was used in 1695 at Gresham College where Hooke was the

Professor of Geometry. A large flask capable of holding more than two gallons called a 'large bolt head' was supported by a wooden frame having presumably a glass catch funnel of 11·4 inches in diameter.The funnel was held steady against the wind by two stays or pack threads strained by two pins. The container had a neck 20 inches long and 0·2 inches in diameter to minimize the evaporation as much as possible. The rain water which accumulated in the container was measured every Monday and the total precipitation over a period of time was expressed as a vertical depth which had fallen during that time interval as shown in Figure 5.

Conclusion

The most complex problem about the self-measuring rain-bucket is the relative credit that should be given to Christopher Wren and Robert Hooke. From the references already cited, it can be concluded with confidence, that Wren did make a tipping bucket type automatic rain-gauge, probable a crude model, which was shown at a meeting of the Royal Society on 22 January 1662. Unfortunately he has left no account of the instrument, and it is hardly surprising, as Wren was not very keen to put his ideas into print. Thus, for a description of the gauge we will have to refer to his friend Robert Hooke, who far from being jealous of Wren, was in fact jealous for him (27). Hooke himself freely acknowledged that the rain-bucket was the brain-child of his friend (the note from the review (13) of Pierre Perrault's book *De l'Origine des Fontaines* was in fact written by Hooke) (28). The description of the instrument, as given by Hooke, was probably of a modified one based on Wren's original invention. This surmise is further strengthened by Hooke's detailed calculations for the design of his instrument.

Wren probably did make some rainfall observations as it appears from the quotation from the review of Perrault's book on the origin of fountains. However, it is extremely doubtful if Wren used his instrument to record rainfall regularly. G. J. Symons believed that he did (29) but it must be remembered, that no records are available. Also the statement 'Which instrument, if put into practice, would be of excellent use' rather makes one think that the rain-gauge was not 'put into practice'.

The weather-clock, of which the self-measuring rain-bucket was a part, was also first started by Wren, and it was later perfected by Hooke after nearly six years (1673-1678) of intermittent work. It was completed to everyone's satisfaction in May 1679. There is absolutely no doubt that the clocked worked—and as Professor Andrade has pointed out in his Wilkins Lecture on Robert Hooke: 'But what a project even if it had not worked' (30).

So far as I am aware, no detail of the rain-gauge of Sir Christopher Wren is available at present and it is hoped that the present article will clear the picture substantially.

ACKNOWLEDGMENTS

Grateful acknowledgement is made to Mr Arthur H. Frazier of the U.S. Geological Survey (Retd.) for the sketches of Figures 2, 3 and 4, Sir Harold Hartley, F.R.S., and Professor E. N. da C. Andrade, F.R.S., of Imperial College, for their constructive criticism of an earlier draft of the paper, and last but not least, Professor William Frazer of the University of Strathclyde for the constant encouragement received during my research on the development of the science of hydrology.

NOTES

(1) Asit K. Biswas, 'Development of Rain Gauges', History of Hydrology, Interim Report No. 5, University of Strathclyde, Glasgow, November 1966. Traces the origin of rain-gauges from fourth century B.C. to the present time.
(2) R. Bentley, 'The Growth of Instrumental Meteorology'. *Q. Jl Roy. met. Soc.* **31**, No. 135, July 1905, pp. 182-185.
(3) A. Wolf, *History of Science, Technology, and Philosophy in the 16th and 17th Centuries.* London: George Allen and Unwin, 1935, p. 310.
(4) B. D. Monconys, *Journal des Voyages de Monsieur de Monconys*, 1st part. Lyons: Chez Horace Boissat & George Remeus, 1666, pp. 54-55.
(5) T. Birch, *The History of the Royal Society of London*, London, 1757, Vol. 1, p. 74.
(6) Ibid. Vol. 1, p. 305.
(7) Ibid. Vol. 1, p. 377.
(8) Ibid. Vol. 1, p. 341.
(9) Ibid. Vol. 1, p. 344.
(10) Ibid. Vol. 2, p. 436.
(11) R. T. Gunther, *Early Science in Oxford*, Vol. 7. Oxford: University Press, 1930, pp. 518-519.
(12) R. T. Gunther, Ibid. p. 656.
(13) Anon., 'An account of the Book, Origin of Fountains', *Phil. Trans.* **10**, No. 119, 22 Nov. 1675, pp. 447-450.
(14) T. Sprat, *History of the Royal Society*, London, 1667, p. 313.
(15) R. Plot, *The Natural History of Staffordshire.* Oxford, The Theatre, 1686, p. 61.
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(17) T. Birch, Reference (5), Vol. 3, p. 445.
(18) T. Birch, Ibid. Vol. 3, p. 445.
(19) N. Grew, *Musaeum Regalis Societatis*, London, 1681, pp. 357-358.
(20) W. Derham, *Philosophical Experiments and Observations of the Late Eminent Robert Hooke.* London: W. & J. Innys, 1726, pp. 41-47.
(21) R. T. Gunther, Reference (11), pp. 520-522.
(22) R. T. Gunther, Reference (11), pp. 515-516.

(23) T. Birch, Reference (5), Vol. 3, pp. 476-477.
(24) R. T. Gunther, Reference (11), pp. 519-520.
(25) J. Leupold, *Theatri Machinerum Supplementum*, Leipzig, 1739, p. 20.
(26) [R. Hooke], 'An Account of the Quantities of Rain fallen in One Year in Gresham College, London, begun Aug. 12 1695', *Phil. Trans.* **19**, No. 223, Nov./Dec. 1695, p. 357.
(27) M. Espinasse, *Robert Hooke*, London: William Heinemann, 1956. p. 117.
(28) R. T. Gunther, Reference (11), p. 433.
(29) G. J. Symons, 'A Contribution to the History of Rain Gauges'. *Q. Jl Roy. met. Soc.* **17**, No. 79, July 1891, pp. 127-142.
(30) E. N. da C. Andrade, 'Robert Hooke' (Wilkins Lecture), *Proc. Roy. Soc.* A, **201**, 23 May 1950, pp. 439-473.