XXIII. *An account of the re-measurement of the cube, cylinder, and sphere, used by the late Sir* GEORGE SHUCKBURGH EVELYN, *in his enquiries respecting a standard of weights and measures.* *By Captain* HENRY KATER, *F. R. S.*

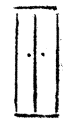
Read June 7, 1821.

THE valuable experiments made by the late Sir GEORGE SHUCKBURGH EVELYN, for the determination of a standard of weights and measures, are detailed in the Philosophical Transactions for 1798. It may there be seen that a cube, a cylinder, and a sphere of brass were employed, the respective dimensions of which being given, as well as the weight of water displaced by each, the weight of a cubic inch of distilled water might thence be readily ascertained.

In reviewing these experiments, so much care appears to have been bestowed on those parts of the enquiry which relate to *weight*, as to leave no reason to doubt their accuracy; but as SIR GEORGE SHUCKBURGH has not entered into so full a detail of the method he pursued in the *measurement* of the cube, the cylinder, and the sphere, I felt it to be desirable that this operation should be repeated, before the Commissioners of Weights and Measures should make their final Report.

The Honourable CHARLES C. JENKINSON, to whom the valuable apparatus of the late Sir GEORGE SHUCKBURGH now belongs, very obligingly confided it to the care of the Commissioners. I found the sphere in the most perfect state of preservation. The cube and the cylinder were in some parts covered with an oxide, which was, however, readily removed without their sustaining any injury, by a very weak mixture of sulphuric acid and water.

Two small rectangular pieces of plate brass were prepared, of the same size, and about the tenth of an inch thick; one of the surfaces and one side of each were ground perfectly flat, and the surfaces being placed in contact, two fine dots were made on the plane sides, close to the edges, as in the accompanying figure. These pieces were intended to be applied to the extremities of the object to be measured, the dots serving as points, the distance between which was to be ascertained.



In order to keep the brass pieces in their proper position, and at the same time to ensure, in every case, an equal pressure, two springs were made to slide along a mahogany rule, divided into inches. These springs projected nearly at right angles from the rule, and being set at the required distance from each other, retained by their pressure the brass pieces steadily in the situation in which they were placed.

The micrometer microscope used on this occasion, differed essentially from that which is commonly employed. The microscope itself was carried along by the micrometer screw, instead of the motion being confined to its cross wires.

By this construction, which was suggested by Dr. YOUNG, no error could arise from the image not being in the same plane with the wires; and it gave me, besides, the advantage of applying an object-glass, of whatever power I pleased, to the microscope, without altering the value of the divisions of the micrometer.

Having placed the rectangular pieces of brass, with their surfaces in contact, and the sides on which the dots were made in the same plane, they were confined in this position between the springs before described.

The following observations were then made with the

micrometer microscope to determine the distance between the dots.

Readings of the Micrometer.		Distance between the Dots.
Divisions.		Divisions.
10	314	304
14	317,5	303,5
13	316,5	303,5
4,5	309	304,5
84	388	304
85	389	304
9,5	314	304,5
	Mean	304

The value of one division of the micrometer was found by a number of trials to be ,00009758 of an inch; the distance between the dots is therefore equal to ,029658 2 of an inch.

For a particular description of the cube, sphere, and cylinder, I shall beg leave to refer the reader to Sir GEORGE SHUCKBURGH'S paper in the Philosophical Transactions for 1798; and for the correction of some errors in computation, to a paper by J. FLETCHER, Esq. given in the 4th vol. of NICHOLSON'S Journal, 8vo.

The letters used in the following detail, indicate the same parts as in Sir GEORGE SHUCKBURGH'S paper. The letters and lines made by Sir GEORGE SHUCKBURGH on the cube, sphere, and cylinder, in black lead pencil, still remained, and afforded the means of examining each step in succession.

Great care was taken by leaving the apparatus together more than 24 hours, and by other precautions, to guard against errors which might arise from difference of temperature; and the same portions of Sir GEORGE SHUCKBURGH'S standard scale were used, as were employed by himself.

The microscopes were attached to a strong frame of well seasoned wood, and were transferred from the dots to the scale at each reading.

Measurement of the cube.

The brass pieces being properly placed, the excess of the distance between the dots and 5 inches, taken upon the standard scale between 27 and 32, was measured by the micrometer. This being added to 5 inches, and ,0296582 subtracted, we have the length of the side of the cube.

Cube.

Reading of the Micrometer at the Scale.	Reading of the Micrometer at the Dots.	Difference.	Distance between the Dots in Inches.	Length of the side of the Cube in Inches.	Mean.
Side 1. (the top.)					
	a to *b*				
22	217	195	5,0190242	4,9893660	4,98935
	a to *c*				
22	217	195	5,0190242	4,9893660	
	c to *d*				
22	220	198	5,0193169	4,9897687	
	b to *d*				
22	212	190	5,0185364	4,9888782	
Side 2. (the bottom.)					
	a to *b*				
22	220,6	198,6	5,0193754	4,9897172	4,98935
	a to *c*				
23	221	198	5,0193169	4,9896587	
	c to *d*				
22	215	193	5,0188291	4,9891709	
	b to *d*				
17,8	207,5	189,7	5,0185071	4,9888489	
Height from side 1 to side 2.					
	a to *a*				
18,2	211	192,8	5,0188095	4,9891513	4,98912
	b to *b*				
19	210	191	5,0186340	4,9889758	
	c to *c*				
19	214	195	5,0190242	4,9893660	
	d to *d*				
18	209	191	5,0186340	4,9889768	

Taking the mean of the above three means for the true length of the side of the cube, we have its content 124,1969 inches.

Measurement of the cylinder.

Each of the ends of the cylinder was crossed by Sir G. SHUCKBURGH by two diameters, the extremities of which were connected by lines drawn parallel to its axis. These lines, as well as the letters indicating their terminations, were distinctly visible.

Length of the cylinder.

The brass pieces being properly arranged, the excess of the distance between the dots and 6 inches, taken upon the scale between 52,1 and 58,1 was measured, which being added to 6 inches, and ,0296582 deducted, we obtain the length of the cylinder.

Cylinder. (Length.)

Reading of the Micrometer at the		Difference.	Distance between the Dots in Inches.	Length of the Cylinder in Inches.	Mean.
Scale.	Dots.				
	a to *a*				
3,2	264,5	261,3	6,0254925	5,9958343	
	b to *b*				
3	270,5	267,5	6,0260973	5,9964391	5,99619
	c to *c*				
3	270	267	6,0260485	5,9963903	
	d to *d*				
3	267	264	6,0257558	5,9960976	
	a to *a*				
5,5	263,5	258	6,0251705	5,9955123	
	b to *b*				
3,2	270	266,8	6,0260290	5,9963708	
	c to *c*				5,99590
6,5	268	261,5	6,0255120	5,9958538	
	d to *d*				
3,5	265	261,5	6,0255120	5,9958538	
	a to *a*				
1	260	259	6,0252681	5,9956099	
	b to *b*				
1	266	265	6,0258534	5,9961952	
	c to *c*				5,99590
0	264	264	6,0257558	5,9960976	
	d to *d*				
1	261	260	6,0253656	5,9957074	

The mean of these three means being taken, we have 5,99600 for the length of the cylinder.

Diameter of the cylinder.

The brass pieces were most carefully placed, so that the dots were precisely in the direction of the diameters, and the surfaces tangents to the circumference. The distance between the dots was then compared with 4 inches on the scale, from 54 to 58, and the diameter obtained in the manner before described.

Cylinder. (Diameter.)

End 1.

Readings of the Micrometer at the		Difference.	Distance between the Dots in Inches.	Diameter of the Cylinder in Inches.	Mean.
Scale.	Dots.				
	a to *b*				
40	313,7	273,7	4,0267022	3,9972050	3,99721
	c to *d*				
41	318	277	4,0270242	3,9973660	

End 2.

	a to *b*				
41	313	272	4,0265363	3,9968781	3,99703
	c to *d*				
41	316,2	275,2	4,0268485	3,9971903	

The mean of these means gives 3,99712 for the diameter of the cylinder.

On a subsequent day I repeated the measurement of the diameter, with the following results :

Cylinder. (Diameter.)

End 1.

Reading of the Micrometer at the		Difference.	Distance between the Dots in Inches.	Diameter of the Cylinder in Inches.	Mean.
Scale,	Dots.				
	a to *b*				
42,6	316,5	273,9	4,02672168	3,9970635	3,99702
	c to *d*				
43,4	316,5	273,1	4,02664364	3,9969854	
End 2.					
	a to *b*				
43	317,7	274,7	4,02679973	3,9971415	3,99725
	c to *d*				
42	319	277	4,02702412	3,9973669	

The mean of these measurements scarcely differs from that of the former. We have then the diameter of the cylinder,

by the 1st measurement - 3,99712
by the 2nd, - - - 3,99714

Mean - 3,99713

The length being 5,99600, and the diameter 3,99713, the capacity of the cylinder will be 75,2398 inches.

Measurement of the sphere.

On referring to Sir GEORGE SHUCKBURGH's account, it will be seen, that for the measurement of the sphere, a brass square was employed, the side of which was a very little longer than the diameter of the sphere. The sphere being placed within the square, and properly supported, a micro-

meter screw, which passed through one of the sides of the square, was brought in contact with the diameter of the sphere, and the reading of the micrometer head noted. The sphere being then removed, a brass rule of known length was put in its place, and the micrometer screw being brought in contact with the end of the rule, the difference between its length and the diameter of the sphere was obtained, from which the latter could, of course, be readily determined.

Sir GEORGE SHUCKBURGH had drawn three great circles in pencil upon the sphere, which, as well as the letters designating their intersections, remained perfect.

Having arranged the apparatus, the following measurements of the diameter of the sphere were taken, two of which may be termed equatorial, and the third polar, every precaution being used to prevent errors arising from difference of temperature.

Diameter of the Sphere.	Readings of the Micrometer.	
A to B	37	
C to D	38,5	38,5 mean.
E to F	40	

The rule being now placed in the square, the following were the readings of the micrometer on different trials.

51,5
51,5
51
51,3
} 51,33 mean.

Hence, the diameter of the sphere exceeds the rule 12,83 divisions.

Second trial.

Diameter of the Sphere.	Readings of the Micrometer.	
A to B	38	
C to D	39,2	39 mean.
E to F	39,8	

The reading of the micrometer when the rule was placed in the square was 51,3; the diameter of the sphere, therefore, exceeds the rule 12,3 divisions.

Third trial.

Diameter of the Sphere.	Readings of the Micrometer.	
A to B	38	
C to D	38,3	38,43 mean.
E to F	39	

The readings of the micrometer when the rule was placed in the square were

51,7
51,3
51,5
50,5 } 51,25 mean.

By this last trial, the diameter of the sphere exceeds the rule 12,82 divisions.

	Divisions.
By the 1st trial the diameter of the sphere exceeded the length of the rule - - -	12,83
By the 2nd - - - -	12,30
By the 3rd - - - -	12,82
Mean	12,65

which converted into inches, gives 0,0012281 for the excess of the diameter of the sphere above the length of the rule.

Length of the brass rule.

The brass rule was laid upon the standard scale, where it remained for two days before the measurement was made, in order that it might acquire the same temperature. The rectangular pieces of brass were then applied to its extremities, and the distance between the dots compared with the distance from 26 to 32 inches upon the scale, in the manner which has been before described.

Readings of the Micrometer at the		Difference, deducting 304 divisions. *
Scale.	Dots	
25	396	67
24	393,5	65,5
23	391,7	64,7
21	391	66
20,5	389,5	65
21	388,4	63,4
	Mean	65,3

=,0063609 of an inch.

* The distance between the Dots. See page 318.

The length of the brass rule from this appears to be 6,0063609 inches, which added to ,0012281, gives 6,00759 inches for the diameter of the sphere; whence we have its solid content 113,5264 inches.

It may now be useful to collect under one view the data furnished by Sir GEORGE SHUCKBURGH'S experiments, and by the preceding measurements.

	Contents in Inches at 62°	Weight in Air, Grains.	Temp. of the Air.	Barom. Inches.	Weight of an equal bulk of Water, Grains.	Temperature when weighed in Water.
			°			°
Cube - -	124,1969	32084,82	62	29,00	31381,79	60,2
Cylinder -	75,2398	21560,05	62	29,00	19006,83	60,5
Sphere - -	113,5264	28722,64	67	29,74	28673,51	66,0

From these data the weight of a cubic inch of distilled water in a vacuum at 62°, deduced from the cube, appears to be - 252,907 of Sir G. SHUCKBURGH'S grains.
From the cylinder 252,851
And from the sphere 252,907

The mean of which is 252,888
which is equal to 252,722 grains of the Parliamentary Standard.

It is not my intention to enter into a detail of the various corrections necessary in the computation of the preceding results, as they may be found in the Appendix to the Third Report of the Commissioners of Weights and Measures.

London,
March, 1821.