Physics. — *On the Variability of Old Standard Kilogrammes.* By Prof. L. H. SIERTSEMA. (Communicated by Prof. P. ZEEMAN.)

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In 1886 a number of old standard kilogrammes were weighed by J. A. C. OUDEMANS [1]), who examined at the same time in how far these had changed in value after a great number of years. The preparation of standard kilogrammes for the Inspection of Weights and Measures by the Committee of Supervision of the standards of the metre and the kilogramme (kilogramme-metre Committee), through which the Committee at the same time came into possession of secondary standards, which had been compared with the Dutch platinum-standard kilogramme, was an inducement to undertake again a similar investigation. The variability of the kilogrammes weighed by OUDEMANS could now be ascertained more fully than before, since more earlier weighings, and more reliable ones are at our disposal in consequence of OUDEMANS' work.

Besides OUDEMANS' weights a number of others have been included in the investigation.

The determinations of weight have been performed with a simple balance of BECKER's Sons of the physical laboratory of the Technical University at Delft. This balance has no particularly great sensitiveness, but on the other hand it is very constant. The graduation, in mm, was read with a telescope, erected at about a metre's distance from the balance, to $^1/_{20}$ of the scalar divisions. Each position of equilibrium was derived from three points of inversion taken as soon as the series of points of inversion showed regularity. The weighing has further been performed according to GAUSS' method of transposition. After a position of equilibrium had been determined a few times with sufficient uniformity, the weights were changed, again positions of equilibrium were determined, and this was continued till a series of values was obtained, which were in good harmony with each other. Then a scalar value was determined. Before and after each series of weighings two thermometers and a hygrometer, which were placed in the balance case, and a mercury barometer, erected in the same room, were read.

Of a couple of the weights examined the volume was not known, so this had to be determined first. For this purpose the same balance was used with auxiliary apparatus for hydrostatic weighing corresponding to those that have been used for similar weighing experiments in the Bureau international des Poids et Mesures [2]). In such weighing there is almost always

[1]) Versl. en Med. K. Akad. v. Wet. Amsterdam, (3) 3 (1887) p. 141; 4 (1888) p. 97.

[2]) Cf. Trav. et Mém. du Bureau int. des poids et mesures part 2.

some loss of weight, which amounted to as high a value as 12 mg in weighings of kilogramme-weights by STAMKART [1]). In order to eliminate a possible cause of this, care was always taken that the weights in the water rested on amber, so that there is no conductive connection with the metal of the suspending frame, and no danger of electrolytic actions. Before the hydrostatic weighing the weights have been carefully weighed, so that their loss of weight is known. It has appeared that, as OUDEMANS found, there was in the older weights always an appreciable loss, probably because in the course of years the surface of the weights will not have remained perfectly clean, and was cleaned now. In new weights the variation of weight was, on the contrary, insignificant.

In the table on the next page all the weights treated, also the above-mentioned standards of the Committee and the standards of the State Mint, have been inserted.

Most of these weights have been treated in papers by MOLL [2]), STAMKART [3]), OUDEMANS, and HOITSEMA [4]), and kindly put at my disposal by the said institutions for this investigation. It is notewortly that the kilogrammes L_{10}, v Sw and Aen, made by FORTIN, were brought from Paris by VAN SWINDEN in 1799, thus being among the oldest kilogramme-weights. The weight L_{10} was then presented to the government of the Batavian Republic, and served as legal standard of weight from 1819 to 1839.

The weights A, B, and C came from Paris with the platinum standard kilogramme in 1839.

The weights have been combined into groups of four or five, of which every weight was compared with each of the others, and from which then the difference of weight with one of them was derived. Thus the following groups were formed. The mean error reached is every time indicated. By Pt the Dutch platinum standard kilogramme is denoted: for its volume 47122 mm³ is taken at 15° C.

Groups:	I, II, III, P″, Pt	m.e. = 0.06 mg
	A, B, C, P″	,, = 0.06 ,,
	L_1, L_2, L_3, I	,, = 0.11 ,,
	L_{10}, v Sw, Aen, II	,, = 0.07 ,,
	F_1, F_2, G_2, I	,, = 0.09 ,,
	St 1, St 2, St 5, I	,, = 0.08 ,,
	Sl, Contr, Del, I	,, = 0.07 ,,
	St 6, St 7, K I, I	,, = 0.05 ,,

[1]) Cf. OUDEMANS, Versl. en Med. K. Akad. v. Wet. Amsterdam, (3) 3 (1887) p. 173.

[2]) G. MOLL, Bijdragen tot de natuurk. wetensch. **6** (1831) p. 119.

[3]) F. J. STAMKART, Cf. Versl. en Med. K. Akad. v. Wet. Amsterdam, **6** (1857) p. 92; **7** (1858) p. 32.

[4]) C. HOITSEMA, Muntverslag over 1902, p. 113.

A. BRASS WEIGHTS.

	Old name	Property of	Prepared in	Form	Surface	Remarks
I		Committee	1909	sphere	gilt	Secondary standard
II		"	"	"	"	" " [1]
III		"	"	"	"	" "
L_{10}		Insp. W. and Meas.	1799	cyl. w. knob	bare	Legal stand. 1819—1839
v Sw	kg of v. Swinden	Nat. lab. Utrecht	"	"	"	
Aen	kg of Aeneae	Insp. W. and Meas.	"	"	"	
F_1	kg of Fortin	Nat. lab. Utrecht	± 1800	"	"	
F_2	kg of Fortin	Insp. W. and Meas.	± 1800	"	"	
M	kg of Gandolfi	State Mint	± 1810	"	"	
Sl	Slaper	" "	1818	"	lacquered	
Contr	Contraslaper	" "	"	"	"	
A		Insp. W. and Meas.	1838	cylinder	bare	
B		Nat. lab. Leiden	"	"	"	
C		Insp. W. and Meas.	"	"	"	
Del	kg of Deleuil	State Mint	1837	cyl. w. knob	"	
S		"	1839	"	lacquered	
L_1		Nat. lab. Leiden	1838	"	"	
L_2		" " "	unknown	"	"	
L_3		" " "	"	"	"	
K I		K. Ak. v. Wet.	"	"	bare	
St 1	N° 1 (Oudemans)	Teyler's Gen.	1856	cylinder with screwed-on kn	gilt	The kg St. have been made according to STAMKART's direction
St 2	N° 2 (")	K. Ak. v. Wet.	"	" "	"	
St 5	N° 5 (")	Nat. lab. Utrecht	"	" "	"	
St 6	N° 6 (")	" " Gron.	"	" "	"	
St 7	N° 7 (")	" " Amst.	"	" "	"	
P″		" " Delft	1872	" "	"	
V		State Mint	1899	sphere	"	Present standard of Mint

B. GLASS WEIGHTS.

G_2		K. Ak. v. Wet.	1856	bottle w. Hg		OUDEMANS' comparing weight
G_1		State Mint	1886	" " "		Cf. OUDEMANS l.c., p. 252

[1] Handed over to the Inspection of Weights and Measures in Holland.

The kilogrammes M, S, V, and G_1 of the State Mint had been weighed already before.

A full account of the weighings and the calculations is found in the Archives of the Committee, here only the results will be given. Under the heading "mass" it is stated in the following table how much this is greater (+) or smaller (—) than that of Pt.

1. Weights of the Committee:

	Vol. in mm³	At temperature	Mass in 1926
I	118868	14°5	+ 1.32 mg
II	118828	12°	— 0.24 „
III	118860	14°	+ 1.59 „

2. Kilogrammes that have also been compared by OUDEMANS. The volumes have been determined by STAMKART and by OUDEMANS.

	Volume in mm³	At temp.	Observer	Mass in mg		Change per year
				1886	1926	
v. Sw	123312	0°	O.	+ 0.19	+ 0.74	+ 0.01
F_1	126060	0°	O.	+ 152.36	+ 186.49	+ 0.85
Sl	119127	0°	O.	+ 40.78	+ 39.90	— 0.02
Contr	119043	0°	O.	+ 47.06	+ 46.21	— 0.02
B	122424	0°	O.	+ 0.05	+ 2.85	+ 0.07
Del	129449	0°	O.	+ 573.83	+ 716.94	+ 3.58
S					+ 59.79	(+ 2.3)[1]
L_1	122553	0°	O.	— 14.66	— 12.19	+ 0.06
L_2	122347	0°	O.	+ 54.47	+ 56.58	+ 0.05
L_3	123327	0°	O.	— 40.32	— 39.60	+ 0.02
KI	122050	0°	O.	+ 77.43	+ 84.74	+ 0.18
St 1	121615	0°	St.	+ 1.14	+ 1.58	+ 0.01
St 2	120816	0°	St.	— 12.23	— 11.71	+ 0.01
St 5	120169	0°	St.	— 2.73	— 2.92	— 0.00
St 6	122710	0°	St.	— 2.05	+ 0.15	+ 0.05
St 7	120059	0°	St.	— 0.49	+ 0.37	+ 0.02
P″	121496	15°	St.	— 6.87	— 12.61	— 0.14
G_2	99805	0°	O.	+ 5.52	+ 6.53	+ 0.03

[1]) The weight was re-adjusted in 1889.

3. Other kilogrammes. The volumes of them have been determined by the Committee LIPKENS etc. of 1838, by OUDEMANS, HOITSEMA, or SIERTSEMA.

	Volume in mm³	Temp.	Observer	Mass in mg		Mass in mg			Change per year
							Before the hydr. w.	After the hydr. w.	
L_{10}	121387	15.5°	S.	1839	— 12.93 [1]	1926	— 17.89	— 18.97	— 0.05
Aen	123135	15.5°	S.	1909	— 12.05 [2]	1927	— 8.83	— 10.78	+ 0.18
F_2	124257	16.0°	S.			1927	— 73.69	— 76.64	
M				1902	— 8.2 [3]	1925	— 5.98		+ 0.10
A	123755	0°	L.			1926	— 7.52		
C	121759	0°	L.	1839	— 1.02	1926	— 5.76		— 0.05
V	118486	0°	H.	1902	— 7.85 [4]	1925	— 8.46		— 0.03
G_1	104458	0°	O.	1902	— 3.3 [5]	1925	— 18.91		— 0.68

The volumes of S and M are not known. In the calculations they have been put equal to that of V.

It appears that of the very old weights some (v. Sw, Sl, Contr, L_3) have changed very little. Perhaps L_{10} and Aen may also have kept better than the values found would lead us to suppose; the losses of weight in the hydrostatic weighings indicate that the surface may have been dirty. Also STAMKART's gilt weights St 1—St 7 have kept well. It is a pity that on account of the screwed-on knob these weights are useless as standard weights. The GANDOLFI's weight M should be very constant as HOITSEMA supposed [6]), finds no confirmation here.

Some weights show a remarkably great increase. This is the case in a very high degree with the weight Del of the Mint, which OUDEMANS also already observed, at the same time drawing attention to the abnormally large volume. Externally there is nothing to be perceived in this weight that would account for the continued increase, only the surface is slightly tarnished.

Slightly less great is the increase in F_1, an old weight of FORTIN. If this weight was originally (about 1800) accurate, this would also furnish a case of a progressing unaccountable increase. The change of the

[1]) According to a weighing of the Committee LIPKENS etc. of 1838. Cf. OUDEMANS (1887) l.c. p. 232.

[2]) According to a weighing by KIST.

[3]) Cf. HOITSEMA, Muntverslag 1908 p. 42.

[4]) According to a written statement of HOITSEMA.

[5]) Cf. HOITSEMA, Muntverslag 1902 p. 134.

[6]) HOITSEMA, Muntverslag 1902 p. 116.

glass weight G_1 of the Mint might perhaps be explained by the condition of the surface, and would call for further confirmation. Also K I of the Royal Academy of Sciences, a to all appearances well preserved weight, has greatly increased.

An unexplained decrease may be observed in the Delft weight P″. This decrease, too, drew already the attention in 1886, and has continued ever since, though in a slightly less degree. It is a weight gilt in the fire, the exterior of which shows nothing that can account for the decrease.

Summarizing it may be said that many old weights, especially the gilt ones, have changed very little. The galvanically gilt St 2, St 5, St 6, St 7 are not inferior to St 1 and P″ gilt in the fire. The unaccountable great variability of some weights, however, shows the need of caution, and renders it necessary often to verify standard weights.

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