Dent, and used by him for finding the longitudes of several observatories in this country.

On testing 100 chronometers in succession as they passed through the Observatory, the average alteration of daily rate caused by changing the temperature from 40° to 60° was $7^{s}\cdot 0$; and in ten per cent. of the hundred the average change was $30^{s}\cdot 6$.

The chronometer-room at the new Observatory now being erected at Bidston by the Mersey Docks and Harbour Board will be provided with the means of testing simultaneously between two and three hundred chronometers in the way shown by the examples in Table I. It is not necessary to test chronometers in this elaborate way on every occasion that they arrive in port, as the corrections for change of temperature remain the same for a long period. The *rate* may change, as in example 2, Table IV., while the thermal correction remains sensibly the same.

When the Greenwich mean time is communicated from an authorized establishment, as is now generally the case in our large sea-ports, the rates of chronometers in the temperature that prevails at the time can be easily ascertained. At present these rates are used on the assumption that the thermal adjustments are perfect. The corrections for change of temperature in Table II. show the improvement which might be effected by testing all chronometers when new, and supplying mariners with Tables of such corrections as may be found to exist. These corrections would require verifying periodically, as in cleaning and repairing timekeepers the thermal adjustment is sometimes altered.

December 21, 1865.

Sir HENRY HOLLAND, Bart., Vice-President, in the Chair.

The following communications were read:—

I. "On the Expansion of Water and Mercury." By A. MATTHIESSEN, F.R.S. Received December 7, 1865.

(Abstract.)

Before commencing a research into the expansion of the metals and their alloys, it was necessary to prove that the method I intended to employ, namely that of weighing the metal or alloy in water at different temperatures, would yield good and reliable results.

To check, therefore, the method, I was led to determine the coefficient of expansion of mercury, and, basing my calculations on Kopp's coefficients of expansion of water, I expected to obtain Regnault's coefficient of expansion of mercury. The coefficient deduced from experiments did not agree with Regnault's; and being unable to discover any source of error in the method of experimenting, I determined to reinvestigate the matter.

The memoir is divided into four parts.

I. On the determination of the coefficients of the linear expansion of certain glass rods.

These rods (1825 millims. long and of 20 millims. diameter) were kindly made for these experiments by Mr. F. Osler. The method used for the determination of their increment in length was that of measuring it with a micrometer-screw, with which a length could be measured with accuracy to 0·001 millim.

The rod was placed in a long trough, the one end of the rod resting against a fixed glass tube capped with zinc, the other against another glass tube the other end of which rested against the micrometer-screw. Water was allowed to flow through these glass tubes during the time of observation. The trough being filled with water at ordinary temperature and the position of the screw read off, the water was heated to boiling and another reading taken.

The mean of sixteen observations gave for the linear expansion of these rods

$$L_t = L_0 (1 + 0{\cdot}00000729t),$$

and therefore for the cubical expansion

$$V_t = V_0 (1 + 0{\cdot}00002187t).$$

II. On the method employed for the determination of the cubical expansion of water and mercury.

This part of the paper contains a full description of the apparatus employed, and the precautions taken.

The method consists of weighing the substances in water at different temperatures, and from the loss of weight in water deducing its volume. For this deduction, the expansion of water at different temperatures is required.

III. On the redeterminations of the coefficients of expansion of water.

To determine these, pieces of the glass rods (the linear expansion of which had to be determined), ground to the shape of a double wedge, were weighed in water of different temperatures. Three pieces of glass were used (making three Series), the weighings being made at temperatures between 0° and 100°, the whole number of observations being thirty-two.

From these it was found that the expansion of water between 4° and 100° may conveniently be expressed between 4° and 32° by the formula

$$V_t = 1 - 0{\cdot}0000025300\,(t-4) + 0{\cdot}0000083890\,(t-4)^2 - 0{\cdot}00000007173\,(t-4)^3,$$

and between 32° and 100° by

$$V_t = 0{\cdot}999695 + 0{\cdot}0000054724t^2 - 0{\cdot}000000011260t^3.$$

The values calculated from these formulæ for the volume occupied by water at different temperatures are given in Table I. from degree to degree, together with the differences for each degree.

Table I.

T°. C.	Volume of water at T°.	Difference per 1°.	T°. C.	Volume of water at T°.	Difference per 1°.	T°. C.	Volume of water at T°.	Difference per 1°.
4	1·000000	0·000006	37	1·006616	0·000355	69	1·022050	0·000598
5	1·000006	22	38	1·006979	363	70	1·022648	604
6	1·000028	38	39	1·007351	372	71	1·023252	609
7	1·000066	53	40	1·007730	379	72	1·023861	616
8	1·000119	69	41	1·008118	388	73	1·024477	622
9	1·000188	83	42	1·008514	396	74	1·025099	628
10	1·000271	98	43	1·008918	404	75	1·025727	634
11	1·000369	110	44	1·009331	413	76	1·026361	639
12	1·000479	125	45	1·009751	420	77	1·027000	646
13	1·000604	138	46	1·010179	428	78	1·027646	650
14	1·000742	150	47	1·010614	435	79	1·028296	657
15	1·000892	162	48	1·011059	445	80	1·028953	662
16	1·001054	173	49	1·011510	451	81	1·029615	668
17	1·001227	185	50	1·011969	459	82	1·030283	673
18	1·001412	196	51	1·012435	466	83	1·030956	678
19	1·001608	206	52	1·012909	474	84	1·031634	684
20	1·001814	215	53	1·013391	482	85	1·032318	689
21	1·002029	225	54	1·013879	488	86	1·033007	694
22	1·002254	234	55	1·014376	497	87	1·033701	699
23	1·002488	243	56	1·014879	503	88	1·034400	704
24	1·002731	251	57	1·015390	511	89	1·035104	709
25	1·002982	259	58	1·015907	517	90	1·035813	714
26	1·003241	266	59	1·016432	525	91	1·036527	718
27	1·003507	273	60	1·016964	532	92	1·037245	724
28	1·003780	279	61	1·017502	538	93	1·037969	728
29	1·004059	286	62	1·018047	545	94	1·038697	732
30	1·004345	290	63	1·018599	552	95	1·039429	737
31	1·004635	296	64	1·019158	559	96	1·040166	741
32	1·004931	318	65	1·019724	566	97	1·040907	746
33	1·005249	329	66	1·020296	572	98	1·041653	751
34	1·005578	338	67	1·020874	578	99	1·042404	0·000755
35	1·005916	0·000345	68	1·021459	585	100	1·043159	
36	1·006261				0·000591			

IV. On the redetermination of the coefficient of expansion of mercury.

The pure mercury was weighed in a bucket in the water at different temperatures. The glass bucket was made from the end of a test-tube (its length being about 20 millims. and width 15 millims.). The expansion of this sort of glass was found to be

$$V_t = V_0 (1 + 0{\cdot}00002566t).$$

Five series were made with mercury; and its expansions, deduced from the water-expansions given in Table I, were

Series I. ...... $V_t = V_0 (1 + 0{\cdot}0001815t)$,
Series II. ...... $V_t = V_0 (1 + 0{\cdot}0001813t)$,
Series III. ...... $V_t = V_0 (1 + 0{\cdot}0001808t)$,
Series IV. ...... $V_t = V_0 (1 + 0{\cdot}0001808t)$,
Series V. ...... $V_t = V_0 (1 + 0{\cdot}0001816t)$,
Mean .... $V_t = V_0 (1 + 0{\cdot}0001812t)$,

a value closely agreeing with Regnault's, namely

$$V = V_0 (1 + 0{\cdot}0001815t).$$

Calculating from the five series the coefficients of expansion of mercury, using Kopp's water-expansion (taking the volume at $4°=1$), we find as mean

$$V_t=V_0(1+0\cdot000178t).$$

In the following Table I give the values obtained by different observers for the volumes occupied by water at different temperatures, the volume at 4° being taken equal to 1.

Table II.

T.	p*.	Despretz †.	Pierre ‡.	Hagen §.	Matthiessen.
4°	1·000000	1·000000	1·000000	1·000000	1·000000
10	1·000247	1·000268	1·000271	1·000269	1·000271
15	1·000818	1·000875	1·000850	1·000849	1·000892
20	1·001690	1·001790	1·001717	1·001721	1·001814
30	1·004187	1·004330	1·004195	1·004250	1·004345
40	1·007654	1·007730	1·007636	1·007711	1·007730
50	1·011890	1·012050	1·011939	1·011994	1·011969
60	1·016715	1·016980	1·017243	1·017001	1·016964
70	1·022371	1·022550	1·023064	1·022675	1·022648
80	1·028707	1·028850	1·029486	1·028932	1·028953
90	1·035524	1·035660	1·036421	1·035715	1·035813
100	1·043114	1·043150	1·043777	1·042969	1·043159

Kopp, Despretz, and Pierre used the same method for their determinations—that of determining the expansion of water in glass vessels (dilatometers). Hagen employed the weighing process, but at high temperatures employed no special precautions to prevent the steam condensing on his fine wire ; hence his values at 90° and 100° fall below mine.

It will be seen from the foregoing Table that Kopp's values are lower than the others ; and bearing in mind that the coefficient of expansion of mercury, when deduced by means of these, falls below that obtained by Regnault, but when deduced from Despretz's or my own agrees closely with Regnault's, we are led to conclude that Kopp's values must be somewhat incorrect.

* Pogg. Ann. xcii. 42.

† Ann. de Chim. et de Phys. lxx. (1re sér.) 1.

‡ Ann. de Chim. et de Phys. xiii. (3me sér.) 325. Calculated by Frankenheim, Pogg. Ann. xcvi. 451.

§ Abhandlungen d. k. Acad. der Wissensch. zu Berlin, 1865.