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NOTES ON THE CALIBRATION OF A FUEL CALORIMETER.

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THE instrument to be calibrated was on the well-known Thomson principle, of Mr. Rosenhain's design, manufactured by the Cambridge Scientific Instrument Company, Limited. The sample is burned in a combustion chamber under water, through which the products escape, and the oxygen is supplied (from a cylinder) warmed to atmospheric temperature by being passed through a coil of metallic tube in water, and a wash-bottle. The weight of water employed is 2200 grammes; the whole system is brought to atmospheric temperature before the commencement of each experiment, this being much more convenient than bringing the system to atmospheric temperature minus half the expected rise; and draughts are carefully excluded. On the conclusion of a combustion, the combustion chamber is flooded and emptied so as to bring the whole system to a uniform temperature. The rise in temperature of the system in degrees Centigrade, multiplied by the water equivalent in grammes, divided by the weight of the sample in grammes, is the calorific value of the fuel in C.G.S. calories per gramme, or in pound degrees Centigrade per pound, which must be multiplied by $\frac{9}{5}$ to reduce to British thermal units per pound. The expression "water equivalent" is not strictly accurate in this connection, since the quantity so called makes allowance for radiation losses, &c.; but it will serve.

The method of calculating the water equivalent from the specific heats and weights of the materials constituting a calorimeter is impracticable, as the whole instrument would have to be dismantled to ascertain the weight of each material used in it, and, in the absence of special experiments, their specific heats would not be exactly known. No allowance would be so made for radiation losses, &c.

The method of burning in the instrument a known weight of carbon, naphthalene, or some such substance, was considered unsatisfactory on account of possible impurity, or imperfect combustion.

An electrical method of supplying a known amount of heat was adopted; a heating coil was arranged in the place that a sample of fuel would normally occupy, connection with it being effected by means of a special insulated terminal, and another on the body of the instrument, potential leads being connected just above those for the current. The electrical quantities measured were current and potential, the former by a Weston ammeter which was calibrated immediately before and after each experiment, and the latter by Poggendorff's method of direct comparison with a Standard Clark Cell. Oxygen was supplied at about the same average rate as during a combustion.

The following figures are the results of experiments to determine the water equivalent of the system:—

Temperature Rise. Deg. Cent.	Average Watts.	Water Equivalent. Grammes.		
5.75	102.9	2564	2566	2571
5.92	106.1	2568		
4.64	83.72	2585	2574	
4.91	87.76	2561		
4.36	78.37	2576		
2.75	49.35	2572	2572	
3.08	55.15	2566		
3.26	58.62	2577		

Duration of experiment = T = 600 seconds in all cases.

When W = watts.

$$\text{Therms } (= \text{gramme-degrees C.}) = \frac{W\,T}{4.187} = 143.3\text{ W.}$$

(J being 4.187×10^7 (Griffiths adopted) at 15 deg. C. which was the average temperature of the experiments.)

$$\text{Water equivalent} = \frac{\text{therms.}}{\text{temp. rise deg. C.}} = \frac{143.3\text{ W.}}{\text{deg. C.}}$$

grammes.

It will be observed that the water equivalent is constant (within the limits of experimental error) whether the rise in temperature is 6, $4\frac{1}{2}$, or 3 deg.

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Cent.; thus showing the radiation losses, &c., to be practically constant; the average value obtained is therefore adopted.

No further allowance is necessary for radiation losses, &c., as these are the same during calibration and combustion, heat being supplied electrically at the same average rate as by a sample of burning fuel.

The body terminal and heating coil are discarded during a combustion, and their water equivalent is calculated as follows :—

	Grammes.
Weight of body terminal, 16.7 grammes; specific heat = 0.086; water equivalent ... =	1.4
Weight of heating coil, 17.7 grammes; specific heat = 0.094; water equivalent ... =	1.7
Total	3.1

which, subtracted from the above result, gives a net water equivalent of 2568 grammes.

Should a new part—*e.g.*, a glass cylinder or thermometer have to be employed, any difference in such a part can be allowed for as follows :—

Weight of glass cylinder, 56.6 grammes; specific heat, 0.198; water equivalent = 11.2 grammes.

Immersed volume of thermometer, 3.5 cubic centimetres; capacity per cubic centimetre, 0.46; water equivalent = 1.6 grammes. ("Ostwald. . . remarks that glass and mercury have practically the same capacity per cubic centimetre—namely, 0.46." Everett's C. G. S. System, page 132, fifth edition.)

These corrections are not very important in this instrument, but in instruments in which the weight of the parts is larger in proportion to the water equivalent, they would be more—in some cases much more—important.

The thermometer used was an ordinary mercury-in-glass instrument, having a scale of about 1 in. per degree Centigrade; it was read to 0.01 deg. Cent., and corrections were made according to a N. P. L. certificate.

The heat supplied to the system by the electric ignition is allowed for as follows :—

Watts dissipated in platinum ignition wire = 11.8.

Watt-seconds required to raise the whole system 5.92 deg. Cent. = 600 × 106.1 = 63,660.

Watt-seconds required to raise the whole system

$$0.01 \text{ deg. Cent} = \frac{63,660}{5.92 \times 100} = 107.5.$$

Ignition-seconds required to raise the whole system

$$0.01 \text{ deg. Cent.} = \frac{107.5}{11.8} = 9.$$

The ignition therefore causes a rise of 0.01 deg. Cent. in the whole system for every 9 seconds it is used, and a corresponding amount is consequently deducted from the observed rise in temperature during a combustion. Nine or eighteen seconds is long enough to ignite a sample of steam coal.

An experiment made with a pair of opposed thermopiles, one over the exit of the combustion-chamber, and another at the top near the bulb of the thermometer, showed a maximum difference in temperature between these points during combustion of two or three tenths of a degree Centigrade.

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