

COMPARISON OF CLARK AND WESTON CELLS. BY S. N. TAYLOR.

A great deal of work of very excellent character has been done upon the Latimer Clark Standard Cell by Prof. Glazebrook, Prof. Carhart, Prof. Kahle, Lord Rayleigh and others, and by them the merit of the cell has been well established.

It has been shown by them that the cell can be made so that, under favorable conditions, it will vary in E. M. F. less than one part in a thousand, even when made by different persons and of materials obtained from various sources. It has also been shown that with proper care the cell maintains its potential indefinitely, and forms a very excellent standard of electro-motive force, which is both moderately portable and cheap.

It is well known, however, that this standard of potential has at least one very serious drawback, namely, it has a very large temperature coefficient, and the E. M. F. of the cell varies considerably for slight changes in temperature. Moreover the coefficient may not be the same for different cells, or may be different at different temperatures even in the same cell, if the temperatures considered are not near together. Therefore the coefficient for any cell can be exactly determined only by experiment on that particular cell, and must be ascertained for all ranges of temperature to which the cell is likely to be exposed. It is also true that changes in temperature in the cell can not be detected easily and accurately, and hence arises some doubt as to the actual E. M. F. of a Clark cell at any particular instant.

Methods have been proposed for obviating this difficulty, but for want of space we must omit them here. It goes without saying, however, that if we could find another cell having the same excellencies as the Clark in all respects, and not having this defect in temperature coefficient, it would be a decided advantage.

The Cadmium cell, recently invented by Mr. Edward Weston, has attracted considerable attention, and so far as our observations go, it possesses these very qualifications. For the past three years we have spent considerable time in testing the merits of this cell as compared with the Clark Standard Cell.

To do this we made a number of Clark cells according to the latest instructions given by the English Board of Trade, as found in the Philosophical Transactions for 1892. We also made a number of Weston cells similar to the Clark, except that in the Cadmium or Weston cells Cadmium and Cadmium-Sulphate took the place of the Zinc and Zinc-Sulphate of the Clark.

Groups of cells were made at various times, and tests made upon them. We mention the group set up during March, 1895, as typical of all the Cadmium cells. They were of the H form (see Fig. 1) and constructed as follows:

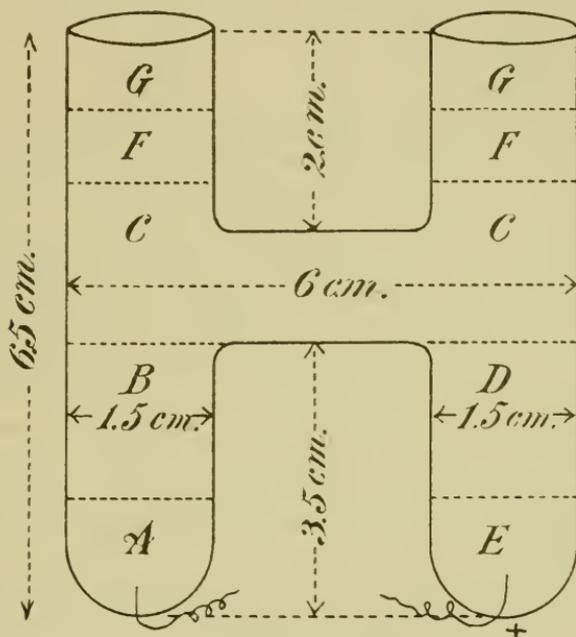


Fig. 1.

At *A* there is a quantity of Cadmium Amalgam about one centimeter deep, and covering the platinum wire, the negative terminal. Above this, at *B*, there is a concentrated solution of Cadmium Sulphate (CdSO_4) containing crystals of Cadmium Sulphate. At *E* there is pure mercury covering the platinum wire which serves as a positive terminal. Above the mercury, at *D*, there is a thick paste of Mercurous Sulphate (Hg_2SO_4), reaching as high as the cross tube. The remainder of the space, *CC* up to the corks *FF*, is filled with a solution of Cadmium Sulphate. The tubes are then sealed above the corks in the usual manner by marine glue or some other form of cement. I can not describe here the manner in which these materials were prepared, but can only refer those interested in the subject to a dissertation which I am about to publish concerning my investigations at Clark University. Suffice it to say that the mercury used was some which I had purified a short time before by means of chemicals and distillation in vacuo;

and the other materials were bought of Eimer & Amend as being chemically pure. The cells are easily made, and can be set up by anyone without much trouble.

The method adopted for comparing these cells one with another was a modification of the potentiometer method used by Professor Kahle, and was as follows:

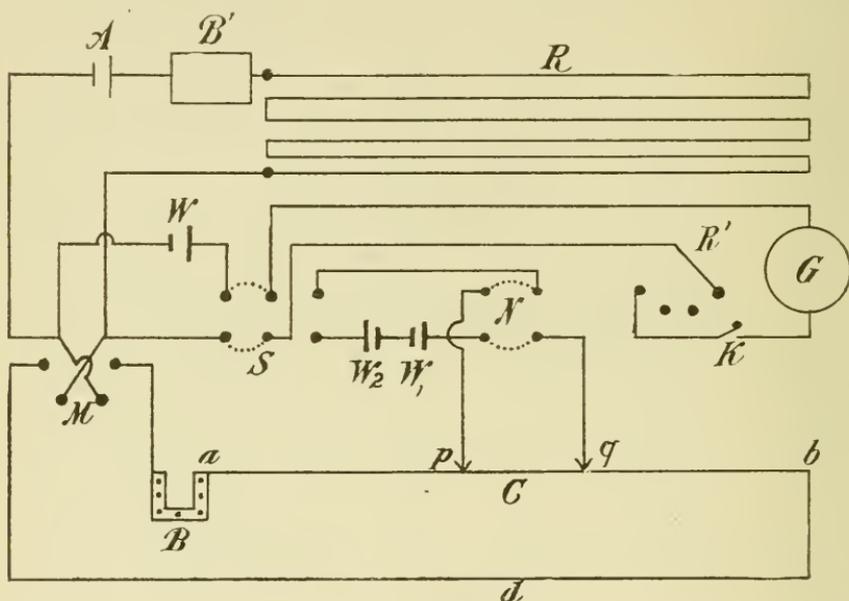


Fig. 2.

The current from a single storage cell A (Fig. 2) passes through an ordinary resistance box B^1 and through a wire resistance R made of German silver, with sliding contact capable of continuous variation for fine adjustment. At the mercury commutator M the circuit is divided. The first branch passes through B , then through the wire c back through d and M to the storage cell A . The second branch of the circuit passes successively from M through the transfer switch S , the variable resistance R^1 , the sensitive galvanometer G , back again to S , and thence through W to M . The resistance box B was made especially for this purpose and consists of seven coils of wire, having the resistances of 10, 15, 50, 100, 300 and 500 ohms approximately. These dip into a dish of kerosene, so that their temperature can be measured more readily. C is a German silver wire 1,122 mms. long, stretched tightly over a boxwood meter bar. The resistances of both

B and c have been very accurately measured in international ohms and their temperature coefficients determined. W is a standard cell, either a Clark or a Weston, and is connected in opposition to the storage cell A . As the current then passes from A , if the resistance in B is properly adjusted, the E. M. F. of W will just counterbalance the potential around the B -branch and there will be no deflection of the galvanometer G when the key K is closed. But increasing the resistance in B , if A is constant, has the same effect upon the potential around the B -branch as decreasing the resistance in R would have. Hence we may choose any resistance in the B branch that we may wish, and yet regulate the potential about that branch by properly adjusting the resistance in R . This being true, let B denote the total resistance of the B -branch, including c and d ; let c denote the resistance of the wire $a b$; let E_w denote the E. M. F. of the standard cell W and E_c the potential about the wire a, b or c . Then, when the resistance in B and R are so adjusted that we get no deflection of the galvanometer G when K is closed, we have the proportion:

$$B : C :: E_w : E_c$$

Knowing the resistance c of $a b$ and that of the total B -branch, of course we know the potential about c . Again, since the potential between any two points $p q$ between $a b$ increases directly as the resistance included between them, and since the resistance increases directly as the distance between the points, we can find any portion of the potential E_c by measuring off on the meter bar the appropriate length along the wire $a b$.

Another portion of the potentiometer consists of a third branch circuit including two standard cells W_1 and W_2 which are to be compared. For short we shall call this branch the N -branch. It starts from a movable contact p on the wire $a b$ and leads to the reversing commutator X , thence through W_1 and W_2 to S through the galvanometer G back again through X to q , another movable contact on $a b$. p and q are knife-edged contacts and can be placed at any position along the wire $a b$ and the distance between them measured by means of the meter rod.

The two cells W_1 and W_2 , which are to be compared, are now placed in this branch in opposition to each other. If, then, the E. M. F. of W_1 is exactly equal to that of W_2 , that is if $E_1 = E_2$, and if p and q are placed close together upon C , then there will be no deflection of the galvanometer G when K is closed. If, however, E_1 is greater than E_2 we can find two points upon C such that the difference in potential between p and q shall exactly equal the difference between E_1 and E_2 and in opposite directions. The potentials in the N -branch will then be at equilibrium, and there will be no deflection of the galvanometer. In other

words, we thus measure the difference between E_1 and E_2 in terms of the standard cell W . This is expressed by the formula

$$E_1 - E_2 = n \frac{E_w C}{l B} = n k$$

Where E_w = E. M. F. of the cell W ; E_1 = E. M. F. of the cell W_1 ;

E_2 = the E. M. F. of the cell W_2

n = number of millimeters between p and q

l = total length of the wire ab in millimeters

c = resistance of the wire ab

B = total resistance of the B-branch

$k = \frac{E_w C}{l B}$ or the constant of the wire ab .

The resistance of R^1 consists of a few coils of wire varying in resistance from zero to fifty thousand ohms, but their actual resistance need not be known. Neither is it necessary to know the resistance at B^1 and R , nor that of the galvanometer G , since the method of no deflection is used. Care was always taken, however, never to close the circuit through the galvanometer without including a high resistance at R^1 , unless it was first known that the system was almost exactly at equilibrium. For it is important that as little current as possible shall be allowed to pass through the cells. But when the system has been carefully adjusted, the resistance of R^1 can be gradually cut out, so as to utilize the full sensitiveness of the galvanometer. Measurements made by means of this apparatus were limited in accuracy only by the galvanometer's sensitiveness. For by taking the resistance in B large enough we can make k as small as we please. Thus we found that we were able to detect differences in E. M. F. as small as three one-millionths ($\frac{3}{1000000}$) of a volt with a considerable degree of certainty.

One difficulty which we had to overcome was the change in position of the galvanometer's zero, caused by the passing of electric street cars some four hundred feet distant. It was found necessary to make the final measurements between 12:30 and 5:30 A. M., when the cars were not running.

Measurements made at various times upon a number of Clark and Weston cells are given in the following table:

TABLE No. 1.

VARIATIONS OF E. M. F. OF CLARK AND WESTON CELLS IN $\frac{1}{100000}$ VOLTS.

	DATE OF MEASUREMENT.	Mar. 16, 1895.	Mar. 18, 1895.	Mar. 22, 1895.	Apr. 15, 1895.	Apr. 17, 1895.	Apr. 18, 1895.	June 17, 1895.	Oct. 25, 1895.	May 29, 1896.
	TEMP.	18.°8C.	19. 8.	20. 0.	19.°0.	20.°2.	20.°0.	23.°2.	19.°6.	20.°0.
Cells made October, 1894.....	C ₁	.....	.....	.....	C ₅ + 13.0	C ₆ + 20.3	C ₈ + 17.8	C ₉ + 37.6	.....	.....
	C ₅	.....	.....	.....	.....	.....	.....	C ₉ + 60.2	C ₆ + 49.6	.....
	C ₇	.....	.....	.....	C ₆ + 16.5	C ₈ + 74.3	C ₉ + 86.7	C ₅ + 42.8	C ₇ + 74.9	.....
	C ₈	.....	.....	.....	C ₇ - 10.9	C ₉ - 15.1	C ₅ - 15.1	C ₇ - 64.1	C ₈ - 49.6	.....
	C ₉	.....	.....	.....	C ₅ - 11.5	C ₇ - 14.2	C ₉ - 4.5	C ₈ - 45.9	C ₉ - 49.6	.....
Cells made March, 1895	W ₇	W ₈ - 15.1	W ₈ + 16.3	W ₈ - 21.1	W ₈ + 8.8	W ₈ + 10.3	W ₈ + 9.1	W ₈ + 13.8	W ₈ + 7.2	W ₈ + 3.0
	W ₉	W ₈ + 21.1	W ₈ + 24.6	W ₈ + 12.1	W ₈ - 5.1	W ₈ - 4.5	W ₈ - 4.8	W ₈ + 4.8	W ₈ - 7.8	W ₈ + 1.9
	W ₁₀	W ₈ - 24.5	W ₈ - 23.9	W ₈ - 39.2	W ₈ - 23.6	W ₈ - 22.3	W ₈ - 23.6	W ₈ + 4.2	W ₈ - 3.0	W ₈ + 1.9
	W ₁₁	W ₈ - 8.2	W ₈ + 14.2	W ₈ + 12.1	W ₈ + 3.9	W ₈ + 3.6	W ₈ + 4.5	W ₈ + 1.2	W ₈ - 2.4	W ₈ + 7.6
	W ₁₂	W ₈ + 64.3	W ₈ + 74.0	W ₈ + 10.8	W ₈ + 19.3	W ₈ + 13.9	W ₈ + 16.0	W ₈ + 12.6	W ₈ + 11.1	W ₈ + 14.1
	W ₁₃	W ₈ + 72.5	W ₈ + 5.5	W ₈ - 3.0	W ₈ - 2.7	W ₈ - 3.0	W ₈ - 3.0	W ₈ + 3.0	W ₈ - 5.7	W ₈ + 1.9
	W ₁₄	W ₈ + 7.6	W ₈ - 3.0	W ₈ - 13.8	W ₈ - 8.5	W ₈ - 7.0	W ₈ - 9.1	W ₈ - 7.2	W ₈ - 3.0	W ₈ - 1.2
Cells made May 31, 1895.....	W ₁₅	.....	.....	.....	.....	.....	.....	W ₈ + 27.1	W ₈ + 22.3	W ₈ + 7.6
	W ₁₆	.....	.....	.....	.....	.....	.....	W ₈ + 18.4	W ₈ + 7.5	W ₈ + 2.7
	W ₁₇	.....	.....	.....	.....	.....	.....	W ₈ + 25.5	W ₈ + 9.6	W ₈ + 5.7
	W ₁₈	.....	.....	.....	.....	.....	.....	W ₈ + 30.7	W ₈ + 15.1	W ₈ + 4.6
	W ₁₉	.....	.....	.....	.....	.....	.....	W ₈ + 18.4	W ₈ + 5.1	W ₈ + 5.6

From this table it will be noticed that when the Cadmium cells are first set up they differ somewhat in E. M. F. But after about a month they come to have a normal value which is common to all. Moreover, this value is not affected by any moderate change in temperature, and so far as our experience goes, these cells are more easily made, and there is less variation in E. M. F. between them than there is between the Clark cells.

It will be noticed that the values given in Table No. 1 are simply relative, but we have made absolute determination of their E. M. F., and find for the Weston cell the value 1.01851 volts when the resistance is measured in Legal ohms; or 1.015633 volts when the resistance is measured in International ohms.

The result of our investigations lead to the following conclusions:

First. That the Cadmium cell is more easily constructed than the Clark cell.

Second. That it has practically no temperature coefficient.

Third. That the E. M. F. of the Cadmium cell is even less variable than that of the Latimer Clark.

SOIL SOLVENTS FOR AVAILABLE POTASH AND PHOSPHORIC ACID. BY H. A. HUSTON AND J. M. BARRETT.

It seems to be accepted that in the case of worn soils solution in strong mineral acid gives little insight into the availability of their potash and phosphoric acid. More recently the use of dilute organic acids, such as the one per cent. citric acid used by Dr. Bernard Dyer¹ and the acid ammonium oxalate used by Dr. A. M. Peter², has been tried with more promising results. The theory of the use of dilute organic acid solutions seems to rest on the idea that plant roots give off fluids containing organic acids which act on the soil in a degree comparable with the effect of the dilute acids employed in the laboratory experiments.

While I do not question that plant roots in contact with polished marble, or even granite, may make appreciable markings on the carbonate of lime and on the feldspar of the granite, the conditions of the experiment, as usually conducted, differ radically from those found in the field, for in the experiment the plants are not supplied with normal soil water. So far as I have observed, normal soil waters give an alkaline reaction. No inconsiderable part of the food of the plants comes to it dissolved in the soil waters. The work of Dr. H. J. Wheeler³ shows what marked difficulty is encountered in growing plants on a well-drained soil having an acid reaction.