These spicules belong to numerous species. All four orders of siliceous sponges are represented, but whilst the Monactinellid and Hexactinellid sponges form but a small proportion, the Tetractinellid and Lithistid sponges, more particularly those of the Megamorina family, are extremely abundant.

## III. "The Solar Spectrum from λ7150 to λ10,000." By Capt. Abney, R.E., F.R.S. Received May 6, 1885.

(Abstract.)

The paper deals with the method employed in taking the photographs of the solar spectrum, from which the map accompanying it was made, and indicates the degree of accuracy which has been obtained.

## IV. "On Charging Secondary Batteries." By William Henry Preece, F.R.S. Received May 6, 1885.

1. I have for the past twelve months been experimenting with secondary batteries with a view of getting an efficient, uniform, and constant source of currents for electric lighting my house, and I have succeeded beyond my expectations. Some new facts have developed themselves during my experience, which I have thought of sufficient importance to bring before the Society.

2. The cells are of the Planté type, manufactured by the Elwell Parker Company of Wolverhampton. Fourteen plates of plain sheet lead 17″ × 11″ are suspended in well insulated wood boxes filled with diluted sulphuric acid in the proportion of about 1 to 10. These plates are grouped in two groups of seven, each group being soldered to a lead strip, forming alternately the positive and negative poles of the cell. The plates of the respective poles are prevented from touching each other by ebonite grids or separators.* Each plate offers a surface of 1·3 square feet, so that the total surface of lead of each group opposed to each other is 9·1 square feet; that is, 9·1 square feet of peroxidised lead is opposed to 9·1 square feet of spongy lead. I use twenty-four such cells.

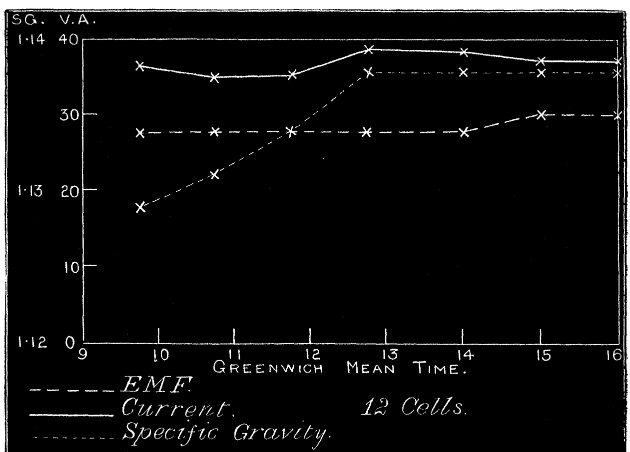
3. My charging current varies from 3 to $3\frac{1}{2}$ ampères per square foot, while the current of discharge used in lighting my house varies from 1 to $1\frac{1}{2}$ ampère per square foot. The total weight of each cell is

* These ebonite grids were introduced by Mr. Charles Moseley, and have effectually removed one incessant source of trouble in these cells, viz., short-circuiting through the buckling of the plates.

120 lbs. The plates are prepared by the Parker-Planté process before insertion in the cell, those forming the positive pole being well peroxidised, while those forming the negative pole are well coated with spongy lead.* They are thus, when put together, prepared at once to be charged. If they are not at once charged, local action sets in, and lead sulphate is injuriously formed.

4. I have cut away a small portion of the centre of the central plate of each cell to admit a hydrometer having a scale graduated from 1·050 to 1·150. The changes of the density of the liquid and of the colour of the plates give the fullest and clearest indications of the behaviour of the cell. The condition of the surface of the peroxidised plate as felt by the finger is also good evidence of its condition. If a plate is yellowish-brown and rough, it probably makes bad contact with the lead terminal; if black and hard, it wants the density of current regulated; if plum-coloured and greasy to the touch, it is in good order, and working well.

5. At the present time I am charging my battery twice a week, putting in at each charge about 120 ampère-hours. The battery is charged in two sections. During each charge observations are made

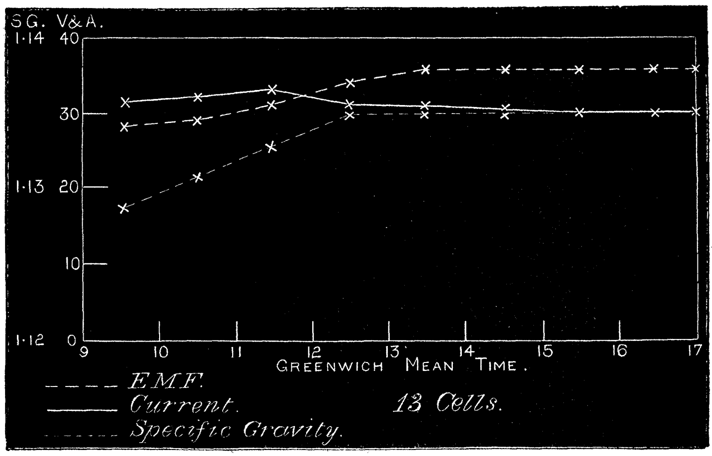


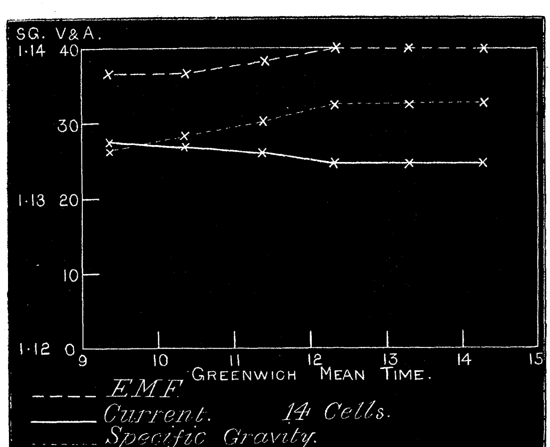

* The Parker-Planté process consists in immersing for a few hours the lead plates in a solution of nitric and sulphuric acids in these proportions—

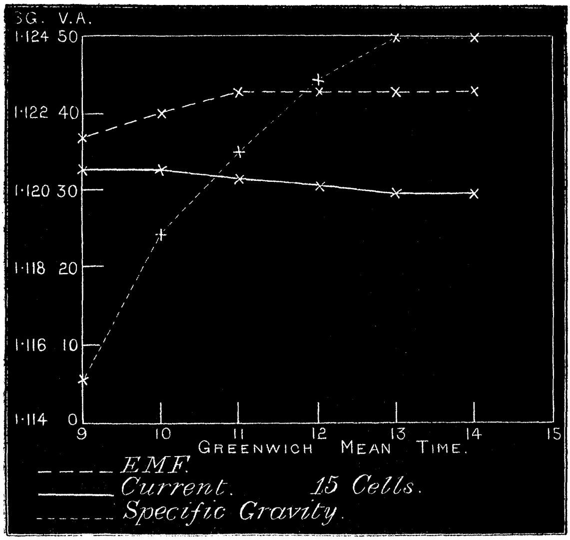
| | |
|---|---|
| Nitric acid ............ | 1 |
| Sulphuric acid ........ | 2 |
| Water ............... | 17 |

before fixing in the cells. This not only chemically cleans the lead surfaces, but it favours the formation of sulphate of lead in such a way as to be readily converted into lead peroxide and spongy lead on the passage of a strong current through the cells. The formation of the cells is thus greatly expedited.

every hour, and sometimes every half-hour, (1) of the strength of current flowing through; (2) of the electromotive force; and (3) of the density of the liquid of one or more of the cells. The relation of these three quantities tells me the condition of the charge. The accompanying diagrams are typical cases.





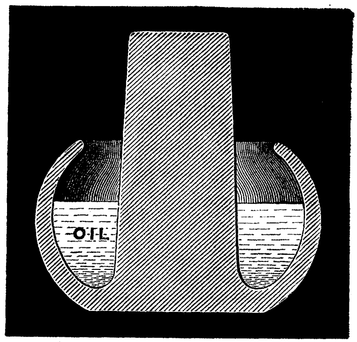

Take No. 4, which is the diagram of this morning's (April 28) charge of 15 cells. The following are the particulars:—

| | E. | C. | D. |
|---|---|---|---|
| 9.0 A.M. | 37·7 | 32·24 | 1·115 |
| 10.0 „ | 40·2 | 32·24 | 1·119 |
| 11.0 „ | 42·5 | 31·50 | 1·121 |
| 12.0 noon | 42·5 | 30·74 | 1·123 |
| 1.0 P.M. | 42·5 | 29·95 | 1·124 |
| 2.0 „ | 42·5 | 29·95 | 1·124 |

6. It is evident that after four hours' continuous charging the battery was full, for the density, the electromotive force, and the strength of current became constant. The same scale of ordinates is used for volts and ampères. When each magnitude reaches its constant bubbles of gas are freely given forth, and energy is being wasted. The variation of the electromotive force and current strength is clearly due to the counter-electromotive force of the cells, which becomes a maximum only when the plates are fully formed. The counter-electromotive force partakes of the character of a higher resistance opposing the charging current, and increasing the proportion of the current through the shunt of the dynamo. Hence the changes of electromotive force are more marked than those of the current. Indeed, the changes in the electromotive force, as given by the voltmeter, are sufficient alone to indicate the progress and completion of the charge. They are more reliable than the evolution of gas. My dynamo is a shunt-wound Gramme, my voltmeter is Cardew's,

a most reliable, simple, and valuable instrument, and my current meter a Siemens' electrodynamometer.

7. I was at first much troubled with electrical leakage. The current escaped over the edges of the box through creeping by capillary action, and the formation of moisture from the spray of the solution when bubbles of gas arose in the liquid and burst on the surface. This was quite cured by standing each box on three white porcelain supports of the form shown in the following figure, the




cups being half filled with resin oil on Messrs. Johnson and Phillips' plan. It is now quite impossible to measure the leakage except with a delicate galvanometer, and the insulation may be said to be practically perfect.

8. The E.M.F. of the battery at its terminals:—

| | |
|---|---|
| When charging .......... | 2·25 per cell. |
| When idle .............. | 2·05 ,, |
| When discharging ........ | 1·90 ,, |

The internal resistance* is, per cell:—

| | |
|---|---|
| When charging .......... | ·0060$^{\omega}$ |
| When discharging ........ | ·0017$^{\omega}$ |

9. But the latter varies very markedly with the strength of current of discharge. This is shown by the following experiment made with 23 cells of a smaller type than those described above, which are used in the Post Office.

| Current of discharge in ampères. | Internal resistance in ohms. |
|---|---|
| 4·39 | 0·7608 |
| 7·25 | 0·4607 |
| 15·84 | 0·2816 |
| 25·07 | 0·1969 |

* The term "internal resistance" means the effect of counter-electromotive force as well as of resistance to conduction.

10. Thinking that this remarkable diminution of internal resistance might be due to the evolution of heat, I measured the temperature with a delicate thermometer.

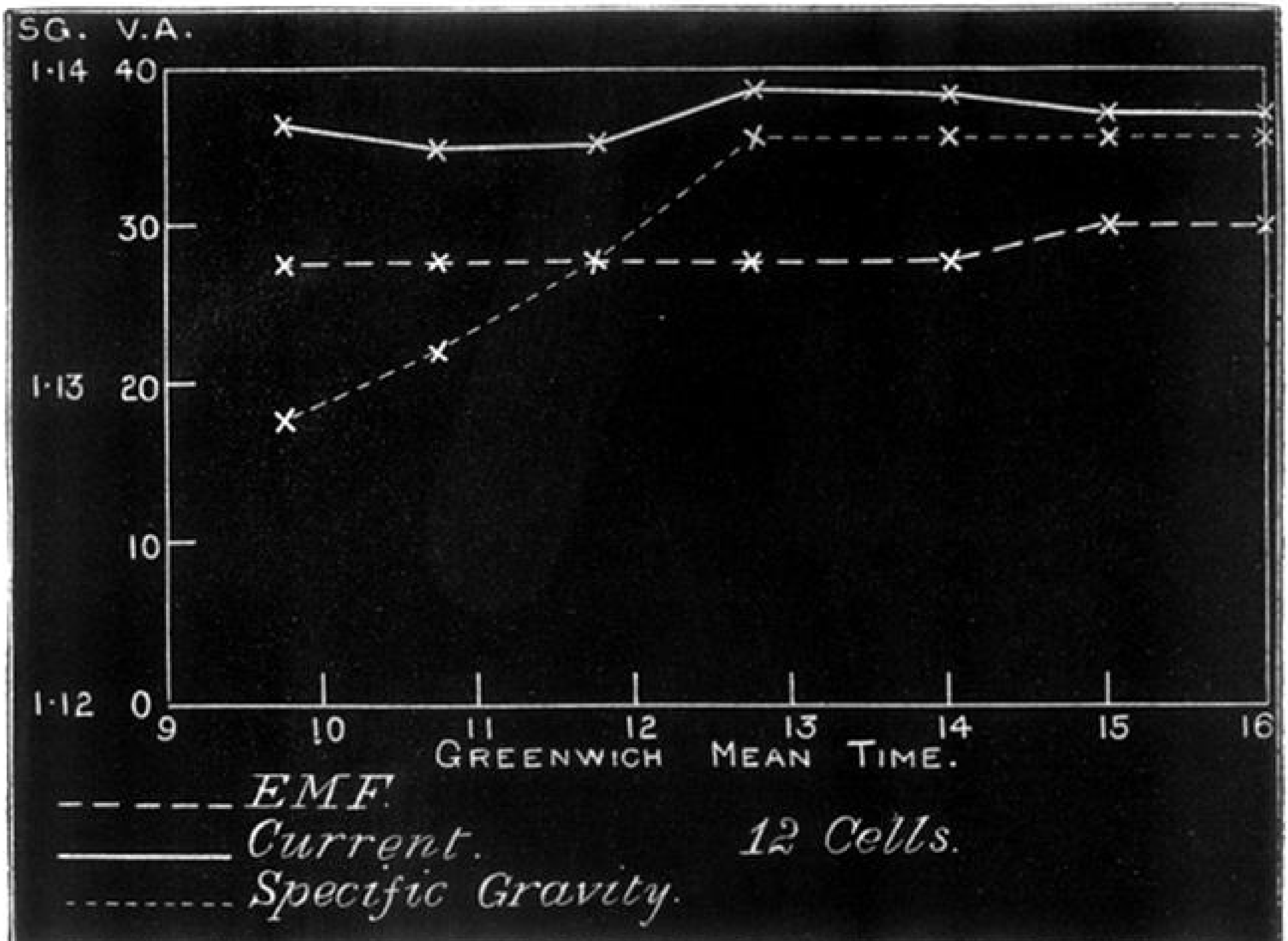
Normal temperature of cell $12\frac{1}{2}°$ C. Current of discharge:—

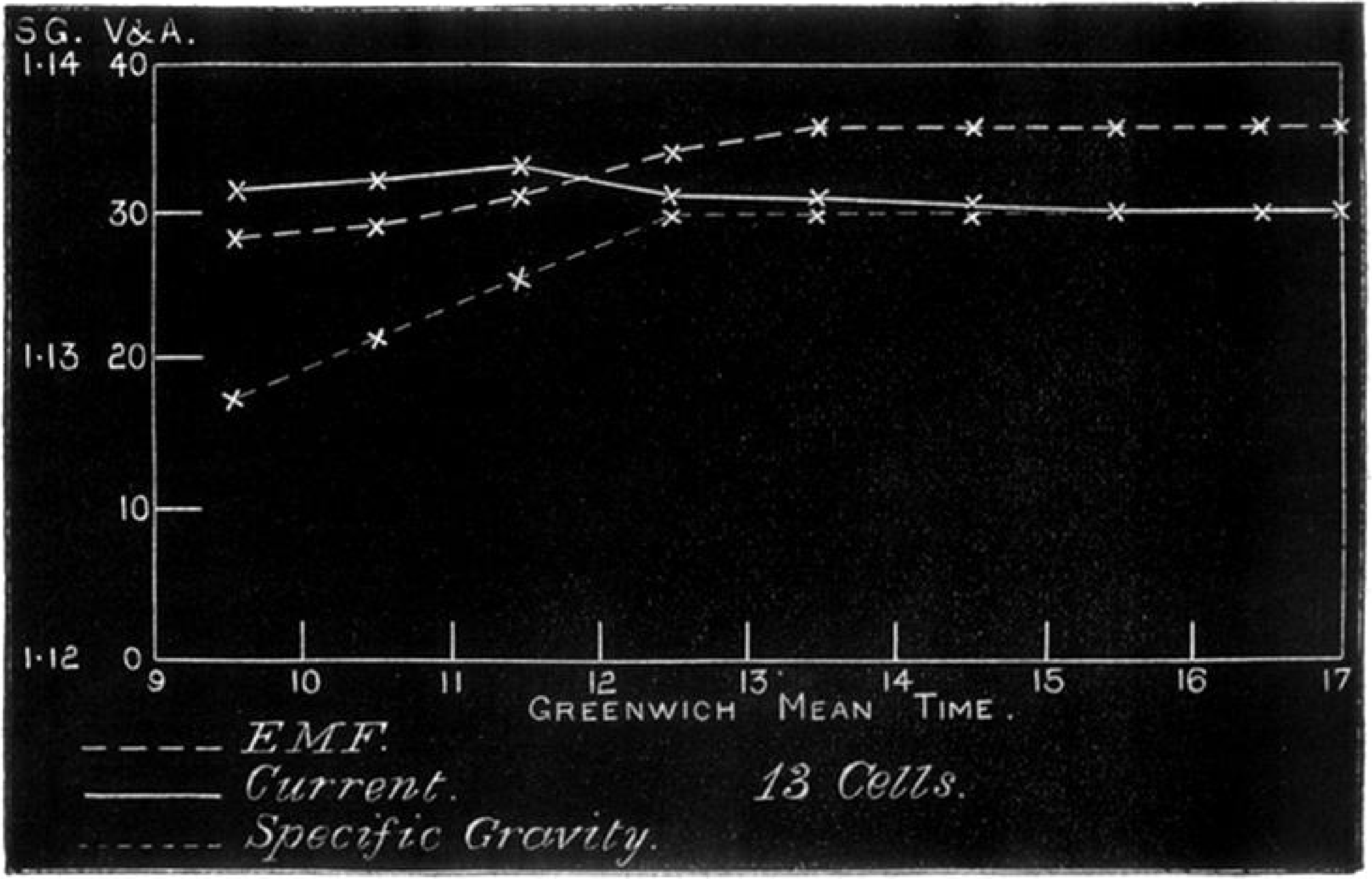
| | | |
|---|---|---|
| 5 ampères | .... | No alteration of temperature perceived. |
| 10 ,, | .... | An exceedingly slight change. |
| 16 ,, | .... | About $12\frac{3}{4}°$. |
| 20 ,, | .... | Barely 13°. |

The current in each case was kept on for 20 minutes, hence the diminution is not due to heat. Since the internal resistance varies in this way, I now always take the internal resistance with the same current, viz., 10 ampères.

11. The capacity of these batteries certainly improves with age, and up to the present time I have seen no sign of decay or deterioration. M. Planté informed me that, though in course of time the peroxidised plate becomes very brittle, it is impossible to peroxidise it completely through; there always remains a metallic core to give it strength. My experience of these plates confirms this. Up to the present moment I have made no careful measurements of the efficiency of my battery. I cannot do so without deranging the lighting of my house, and I regard observations on single cells as illusory. I put in about 240, and I take out about 200 ampère-hours weekly, and I do not observe any change or fall in the electromotive force. When the electromotive force of these cells falls, it falls rapidly, indeed, almost suddenly. Occasionally one plate of a group becomes inactive from undue local action, or from bad connexion (shown by the colour). I remove this plate and put it in what I call a "hospital" cell, where it is brought into order either by a greater density of current or by reversal. Now that my plates have been in use for some time they seem far less inclined to local action. In the oldest cells there is no trace of local action.

12. Reversing has a great beneficial action on a cell; it not only improves its capacity, but it removes any cause of irregular working. It is advisable to do this periodically. I have two extra cells, which enables me to have two cells always under reversal by means of the charging current. It takes from 1,000 to 1,200 ampère-hours to reverse a cell in its present condition, so that at this time of year it takes a month or more to complete the operation, and it will take a year to reverse the whole battery. I have thus, up to the present time, reversed 16 cells.


SG. V.A.
1·14 40
30
1·13 20
10
1·12 0
9
10
11
12
13
14
15
16
GREENWICH MEAN TIME.
EMF.
Current.
Specific Gravity.
12 Cells.



SG. V&A.
1·14 40
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1·13 20
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1·12 0
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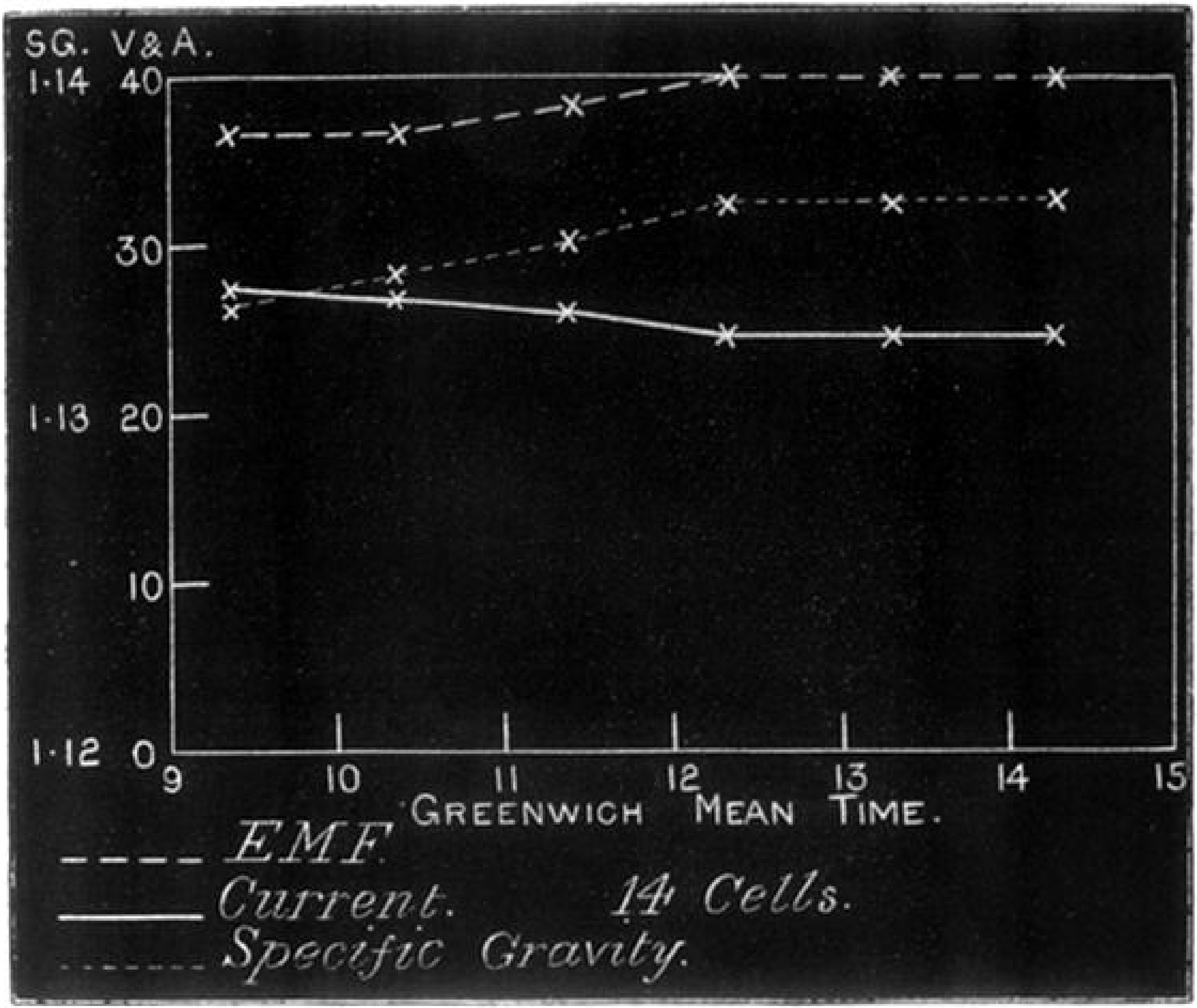
17
GREENWICH MEAN TIME.
EMF.
Current.
Specific Gravity.
13 Cells.


SG. V&A.
1·14 40
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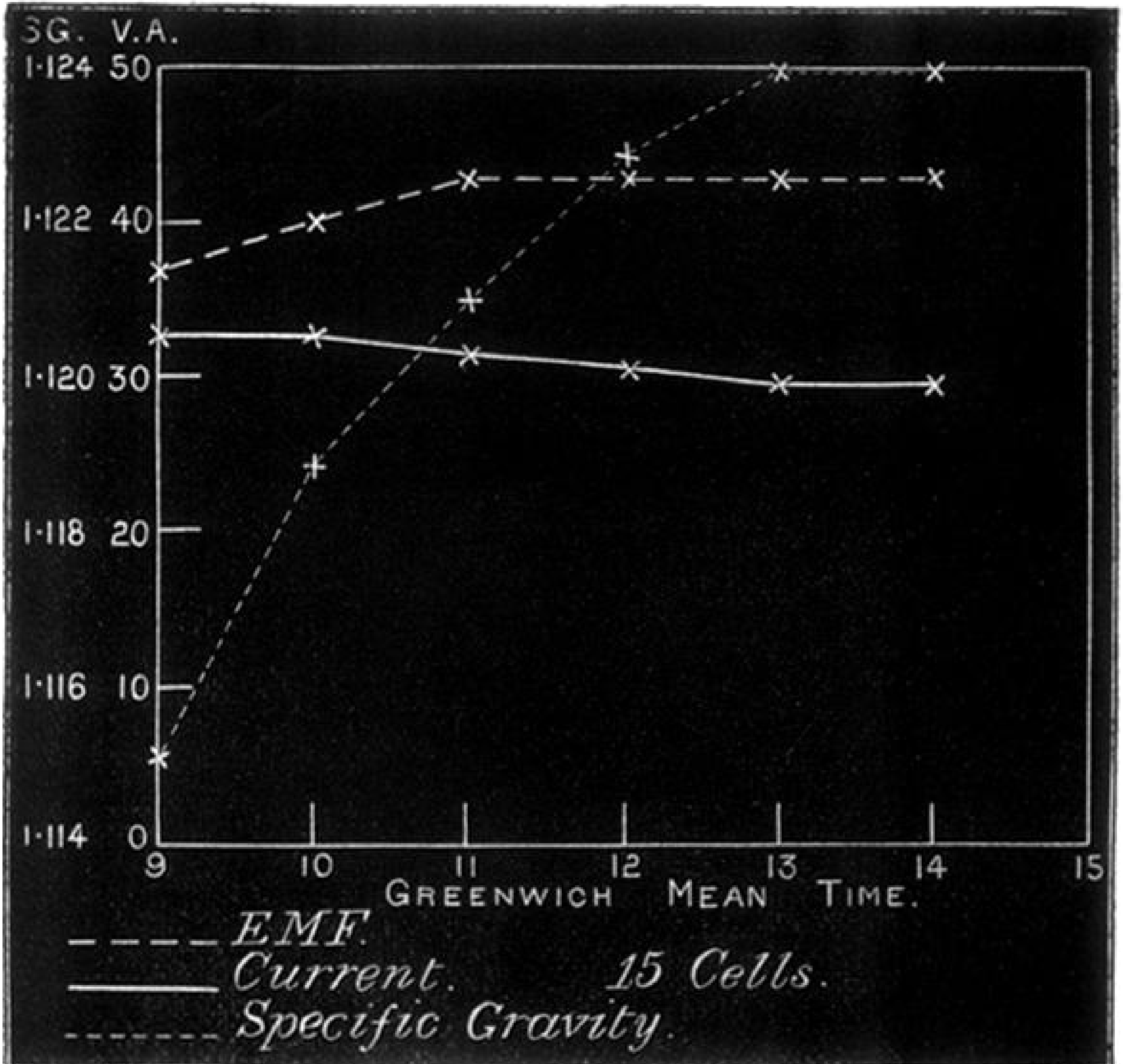
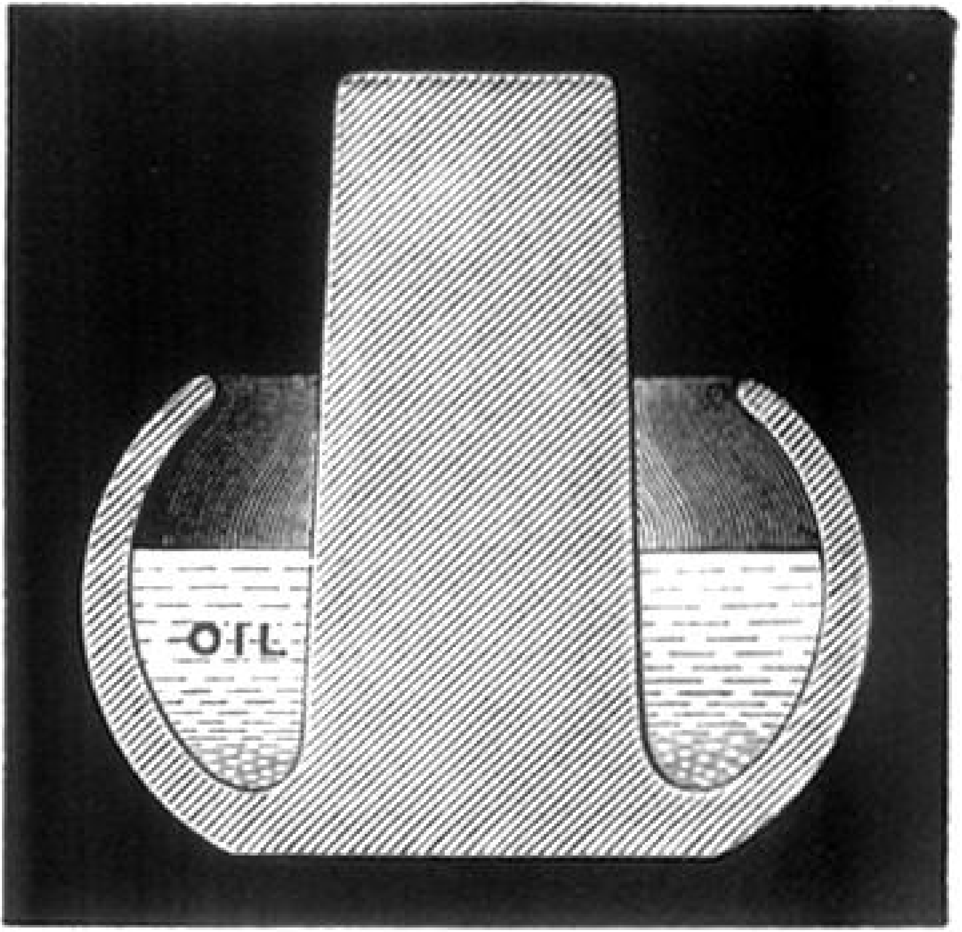
GREENWICH MEAN TIME.
EMF.
Current.
14 Cells.
Specific Gravity.


SG. V.A.
1·124 50
1·122 40
1·120 30
1·118 20
1·116 10
1·114 0
9
10
11
12
13
14
15
GREENWICH MEAN TIME.
EMF.
Current.
15 Cells.
Specific Gravity.


OIL