Thomson effect in any given metal are dependent mainly, if not entirely, upon the specific heat, specific resistance, and coefficient of expansion of the metal (or upon changes of these properties with changes of temperature), the Thomson coefficient is not exactly given by the expression spec. heat $\times$ spec. res. $\times 10^6 - (\text{Exp.} \div 34)^2$, even if due allowance is made for the uncertainty of the numbers in columns II, III, IV, and VI, and for the fact that some of them may vary greatly with different specimens of the same metal. But I have not succeeded in finding a better expression.*

II. "Experimental Research on the Electromotive Force from Difference of Potential during Diffusion in Tidal Streams." By Thomas Andrews, F.R.S.E., Assoc. M. Inst. C.E., Wortley Iron Works, near Sheffield. Communicated by Professor Stokes, Sec. R.S. Received April 20, 1884.

An examination of the composition of the waters throughout the length of a tidal stream during diffusion of salt and fresh water consequent on tidal action, reveals a very considerable difference in the proportion of saline constituents between the water at the surface and that at the bottom, during certain times of tide this difference amounting sometimes to near 100 per cent., and it may frequently be either much greater or less according to tidal fluctuations.

This fact constitutes the basis of the investigation which the author undertook, to obtain some approximate quantitative measurement of the resultant electromotive force, &c., arising from such difference of potential. It is known that a current is set up when a bar or plate of the same metal is immersed in two dissimilar solutions in contact, one capable of acting readily upon the metal, the other having little or no action on it, the whole forming a circuit.

The current continues until diffusion renders the composition of the solutions uniform, after which a reverse current may not

* With regard to aluminium, which in column X comes between platinum and magnesium, instead of between lead and tin, as in column II, it is possible that the specific resistance given by Matthiessen as 0·029 is too high. I do not know of any other determination professing to be exact, but it is stated in Wurtz's "Dic. de Chimie," p. 129, upon the authority of Deville, to be one-eighth that of iron, which would make it 0·012. This, however, is undoubtedly too low. If it were 0·019, the place of aluminium in column X would be the same as in column II, and if it were as high as 0·026, its place would be between magnesium and lead. I may mention that some experiments of my own show that the coefficient of the Thomson effect in aluminium comes slightly above that of lead, instead of below it. And in the diagram at p. 178 of Jenkin's "Electricity" the inclination of the aluminium line is also shown as positive.

unfrequently be observed arising from the previous unequal action of the solutions on the metal.

The series of groups of metals employed in this investigation, viz., wrought irons, various steels, and cast metals, &c., were especially selected in order to render the research of more practical value.

The two dissimilar solutions used were sea water (from Filey Bay) and distilled water.

The author devised the arrangement described below for carrying out this research.

The experiments were made on large round bars of each of the following metals, of known chemical composition and specific gravity, every bar was $2\frac{3}{3}\frac{1}{2}$ inches diameter, carefully turned and polished quite bright, the metals being each especially prepared throughout for these observations.

A careful selection was made with reference to the percentage of combined carbon, specimens containing the highest and lowest being taken, in order that extreme results in each case might be arrived at. The descriptive terms "soft" and "hard" have reference solely to percentages of combined carbon.

This large size and round form of bar were employed to ensure in the manipulation of the metals as uniform a molecular structure as practicable.

The steel and iron bars in each case were prepared from the same ingot or bloom and sawn into equal lengths when finished, so that the bars of the same metal (turned and finished) were identically of one composition, &c. The same exact care was exercised in the preparation of the cast metal bars.

The chemical composition and specific gravities of the metals are shown in Table A.

Table A.—Analyses of the Wrought Iron, various Steels, and Cast Metals employed.

Description.	Graphitic carbon.	Combined carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Iron (by difference).	Total.	Specific gravity.
Wrought iron	...	none	0·392	·034	·270	·194	99·110	100·000	7·590
"Soft" Bessemer steel....	...	0·150	0·009	·112	·088	·468	99·173	100·000	7·853
"Soft" Siemens-Martin steel	...	0·230	0·014	·100	·075	·698	98·883	100·000	7·856
"Soft" cast steel...........	...	0·450	0·016	·027	·048	·086	99·373	100·000	7·863
"Hard" Siemens-Martin steel	...	0·460	0·107	·023	·075	·972	98·363	100·000	7·845
"Hard" Bessemer steel..	...	0·480	0·121	·096	·089	·684	98·530	100·000	7·838
"Hard" cast steel.........	0·259	*1·190	0·175	·063	·019	·396	97·898	100·000	7·805
Cast metal, No. 1	2·780	*0·390	2·340	·090	·580	·450	93·370	100·000	7·206
,, No. 2...........	2·620	*0·670	1·940	·090	·950	·520	93·210	100·000	7·134

* Combined carbon in these samples was determined by combustion, and in the other samples by the colour test.

Method of Experimentation.

The experiments were conducted as follows, in precisely the same manner in each case for comparison.

For the purposes of this research the cells were constructed so that the diffusion effects, electromotive force, &c., observed should approximate to those obtaining during a tidal period of six hours.

A strong wooden box was divided into two equal compartments, A and B, the partition containing at the lower end a porous diaphragm of chamois leather to allow of a suitable diffusion between the solutions.

Two bars from the same piece of metal (of precisely the same composition), polished bright, and exactly $2\frac{3}{32}$ inches diameter, were placed in the cells exactly at equal distances apart in each case ($1\frac{9}{32}$ inch), one bar in partition A, and the other bar in partition B, the bars being attached to the galvanometer No. 1. The partitions A and B were then simultaneously carefully filled up to a depth of 12 inches, the one with sea water, the other with distilled water, and careful telescopic readings taken of the time changes in the deflections of the galvanometer No. 1, regularly during the tidal period of six hours.

The difference in level between the solutions in the cells, caused by the greater specific gravity of the sea water, assisted diffusion, thus approximating to the current pressures in rivers exerted by the tidal flow.

To render the application of these experiments as practical as possible, the observations of the electromotive force and time changes of resistance during diffusion, were taken at regular intervals of two and a half minutes (the results being summarised in Table B), over tidal periods of six hours, so as to afford an approximation to the effects produced by alternating diffusion of salt and fresh water during the tidal changes of a tidal river.

The galvanometer No. 1 with its accessories, resistance coils, &c., employed in these experiments was a delicate astatic one (by Messrs. Elliott Bros.), suspended needles, large mirrored dial, and it was also arranged to work as a mirror galvanometer (R. of galvanometer 521 ohms at 20° C.).

It was constructed as to resistance, &c., specially to suit the purpose of this research.

The galvanometer was carefully calibrated throughout, on the spot, at the commencement of the research with a Daniell's cell in circuit, and the constancy of the instrument afterwards frequently verified.

Another astatic galvanometer, No. 2 (suspended needles), of lower resistance was used for taking the time changes in the resistance of the cells, by the first fling method as described further on.

The results of the observations giving the E.M.F., &c., during diffusion are recorded in the summary of results on Table B, the E.M.F. being calculated from the ascertained resistances in circuit, in conjunction with the known calibration of the galvanometer No. 1, which was used for this part of the research.

For ascertaining the comparative behaviour of the various metals employed, the author has given the average, together with the highest E.M.F. noted during the observations in each case.

Determination of Resistance of Cells.

Difficulties were experienced in determining the resistance in the cells which was momentarily such an inconstant quantity, owing to diffusion between the two solutions, and the difficulty was further increased by polarisation when the Daniell's cell was connected.

After conferring with Professor J. V. Jones, B.Sc., B.A., recourse was had in separate experiments to the method of rapidly alternating the direction of the current sent through the cells (it being first sent in the direction of the current from those cells, then reversed), and reading from the first fling of the galvanometer No. 2 by the aid of a reading telescope.

The time changes in the resistance of the diffusing solutions ascertained by this first fling method, are shown in the curve of resistance, fig. No. 1, which is constructed from the average of a series of six carefully repeated experiments, each extending over the tidal period of six hours. The highest resistance of the cells at the commencement was found to be 243 ohms, gradually reducing with a steady curve to 12 ohms at the termination of each experiment. This resistance curve, fig. No. 1, is the result of above 4,300 observations. This first fling method with a Daniell's element in circuit was used only for taking the rapidly changing resistance of the cells.

General Remarks.

A circumstance of interest in connexion with this research is the change of electro-chemical position which not unfrequently happened.

Another noticeable feature was the electro-chemical position maintained by the wrought iron bar (covered with its blue magnetic oxide) immersed in the sea water, this bar being in the negative position throughout; repeated experiments confirmed this.

Also when the bars were removed from the solutions at the close of an experiment, the different manner in which the metals had been acted upon in the respective cells was decidedly noticeable.

From an examination of the results (taking the highest and the average E.M.F.), it will be seen in what comparative manner the metals arranged themselves under the conditions of the experiment.

Table B.—The Electromotive Force, &c., during Diffusion of Sea Water and Distilled Water acting on the same Metal over Tidal Periods of Six Hours.

Time from commencement of experiment.	Time changes of resistance in the cells in ohms.	Wrought iron rolled bars (bright).		Wrought iron hammered bars (bright).		"Soft" Bessemer steel (bright).		"Hard" Bessemer steel (bright).		"Soft" Siemens-Martin steel (bright).		"Hard" Siemens-Martin steel (bright).	
		Electro-chemical position of the wrought iron rolled bar in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the wrought iron hammered bar in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the "soft" Bessemer steel in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the "hard" Bessemer steel in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the "soft" Siemens-Martin steel in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the "hard" Siemens-Martin steel in the sea water compartment.	Electro-motive force in volts.
hr. min.													
0 0	243	P	0·015	N	0·016	P	0·040	P	0·080	P	0·059	P	0·003
0 15	102	P	0·095	P	0·021	P	0·064	P	0·114	P	0·115	P	0·130
0 30	51	P	0·092	P	0·036	P	0·049	P	0·119	P	0·075	P	0·121
0 45	32	P	0·085	P	0·035	P	0·043	P	0·132	P	0·064	P	0·109
1 0	25	P	0·078	P	0·030	P	0·037	P	0·135	P	0·052	P	0·098
1 15	20	P	0·069	P	0·027	P	0·030	P	0·133	P	0·046	P	0·085
1 30	17	P	0·063	P	0·023	P	0·026	P	0·130	P	0·040	P	0·074
1 45	17	P	0·058	P	0·019	P	0·021	P	0·127	P	0·034	P	0·068
2 0	16	P	0·054	P	0·016	P	0·016	P	0·122	P	0·029	P	0·061
2 15	15	P	0·050	P	0·013	P	0·014	P	0·117	P	0·026	P	0·055
2 30	14	P	0·045	P	0·010	P	0·012	P	0·111	P	0·020	P	0·051
2 45	13	P	0·041	P	0·009	P	0·009	P	0·106	P	0·017	P	0·046
3 0	13	P	0·036	P	0·007	P	0·006	P	0·100	P	0·014	P	0·040
3 30	13	P	0·029	P	0·005	P	0·002	P	0·089	P	0·012	P	0·032
4 0	12	P	0·023	P	0·004	N	0·002	P	0·079	P	0·010	P	0·027
4 30	12	P	0·018	P	0·004	N	0·004	P	0·068	P	0·009	P	0·019
5 0	12	P	0·014	P	0·004	N	0·006	P	0·060	P	0·004	P	0·016
5 30	12	P	0·011	P	0·004	N	0·009	P	0·051	P	0·002	P	0·014
6 0	12	P	0·009	P	0·006	N	0·011	P	0·045	Zero	no E.M.F.	P	0·013
		Highest E.M.F. attained, 0·095 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·054 of a volt.		Highest E.M.F. attained, 0·036 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·017 of a volt.		Highest E.M.F. attained, 0·064 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·024 of a volt.		Highest E.M.F. attained, 0·135 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·110 of a volt.		Highest E.M.F. attained, 0·115 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·038 of a volt.		Highest E.M.F. attained, 0·130 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·066 of a volt.	

N.B.—The averages in the above Table B, were obtained from the 91 observations previously alluded to.

Time from commencement of experiment.	Time changes of resistance in the cells in ohms.	"Soft" cast steel (bright).		"Hard" cast steel (bright).		Cast metal, No. 1 (bright).		Cast metal, No. 2 (bright).		Cast metal, No. 1 (in the rough).		Wrought iron (covered with its own blue magnetic oxide).	
		Electro-chemical position of the "soft" cast steel in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the "hard" cast steel in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the cast metal No. 1 in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the cast metal No. 2 in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the cast metal No. 1 in the sea water compartment.	Electro-motive force in volts.	Electro-chemical position of the wrought iron in the sea water compartment.	Electro-motive force in volts.
hr. min.													
0 0	243	P	0·073	P	0·020	Zero	no E.M.F.	Zero	no E.M.F.	P	0·075	N	0·059
0 15	102	P	0·120	P	0·083	P	0·076	P	0·043	P	0·076	N	0·043
0 30	51	P	0·057	P	0·087	P	0·058	P	0·025	P	0·045	N	0·038
0 45	32	P	0·043	P	0·081	P	0·047	P	0·016	P	0·042	N	0·035
1 0	25	P	0·032	P	0·072	P	0·040	P	0·013	P	0·039	N	0·034
1 15	20	P	0·026	P	0·065	P	0·034	P	0·011	P	0·036	N	0·031
1 30	17	P	0·021	P	0·058	P	0·030	P	0·008	P	0·034	N	0·028
1 45	17	P	0·016	P	0·052	P	0·027	P	0·005	P	0·033	N	0·027
2 0	16	P	0·013	P	0·047	P	0·022	P	0·003	P	0·030	N	0·026
2 15	15	P	0·011	P	0·041	P	0·016	P	0·003	P	0·030	N	0·025
2 30	14	P	0·009	P	0·037	P	0·014	P	0·002	P	0·029	N	0·023
2 45	13	P	0·005	P	0·031	P	0·012	P	0·001	P	0·028	N	0·021
3 0	13	P	0·004	P	0·027	P	0·010	P	0·001	P	0·027	N	0·020
3 30	13	N	0·001	P	0·020	P	0·005	N	0·001	P	0·026	N	0·017
4 0	12	N	0·003	P	0·012	P	0·003	N	0·001	P	0·023	N	0·018
4 30	12	N	0·004	P	0·010	Zero	no E.M.F.	N	0·002	P	0·022	N	0·018
5 0	12	N	0·004	P	0·007	N	0·002	N	0·003	P	0·019	N	0·017
5 30	12	N	0·003	P	0·004	N	0·004	N	0·001	P	0·018	N	0·017
6 0	12	N	0·002	P	0·002	N	0·004	N	0·0004	P	0·018	N	0·017
		Highest E.M.F. attained, 0·120 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·026 of a volt.		Highest E.M.F. attained 0·087 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·047 of a volt.		Highest E.M.F. attained, 0·076 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·027 of a volt.		Highest E.M.F. attained, 0·043 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·009 of a volt.		Highest E.M.F. attained, 0·076 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·035 of a volt.		Highest E.M.F. attained, 0·059 of a volt. Average E.M.F. for the whole tidal period of six hours, 0·028 of a volt.	

N.B.—The averages in the above Table were obtained from the 91 observations previously alluded to.

Twelve accurate curves of the electromotive force (each the result of ninety-one observations) were obtained, showing the effect of this tidal action on the various groups of metals under observation. The general contour and character of these affords interesting information respecting such action on the different metals employed. For brevity, however, the results are abridged and summarised in one Table, B.

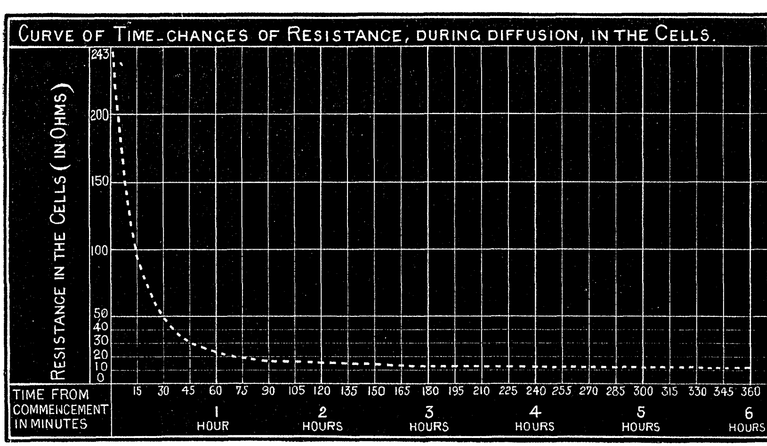
The highest E.M.F. was rapidly reached, and generally from this point to the end of a tidal period of six hours, a regular reduction of E.M.F. ensued. In every instance the greatest electromotive force was observed from the tidal action on the "hard" steels.

The "soft" steels affording on the averages less E.M.F. than the rolled wrought iron, but this group of steels generally gave a higher E.M.F. near the commencement of each experiment.

The rolled wrought iron gave more E.M.F. than the hammered wrought iron, which latter, together with cast metal No. 2, gave the least E.M.F. in these observations.

The preceding results give a quantitative measurement of the electromotive force under the conditions stated, and hence afford an indication of the extent of similar action on structural ironwork in tidal rivers during diffusion between the surface and lower waters, the electromotive force observed being not only appreciable, but in many instances very considerable, reaching not unfrequently *the one-tenth to the one-seventh of a volt.*

Fig. 1.



This destructive action would appear to be exerted most extensively on the lower portion of iron or steel vessels, metallic structures, &c.,

because such portion is shown by this research to be in the electro-positive position during certain conditions of a tidal stream.

It should be pointed out that similar conditions of galvanic action obtain in all our iron structures in tidal estuaries or rivers, the action of the salt and fresh water in course of diffusion constituting a source of galvanic disintegration independent of any difference in composition of the metals. It should also be observed that in circumstances where the electromotive force arising from causes here pointed out acts in concert with any E.M.F. from differences of composition of the metals employed in structures, a very considerable total electrolytic disintegration is likely to ensue. From data kindly furnished to the author by Dr. H. Clifton Sorby, F.R.S., an indication is afforded of the nature of the changing composition of the waters of tidal estuaries at various places and depths. The Table B of electromotive force, &c., together with the diffusion resistance curve (fig. No. 1), afford some index of the changing E.M.F. arising from such tidal difference of potential.

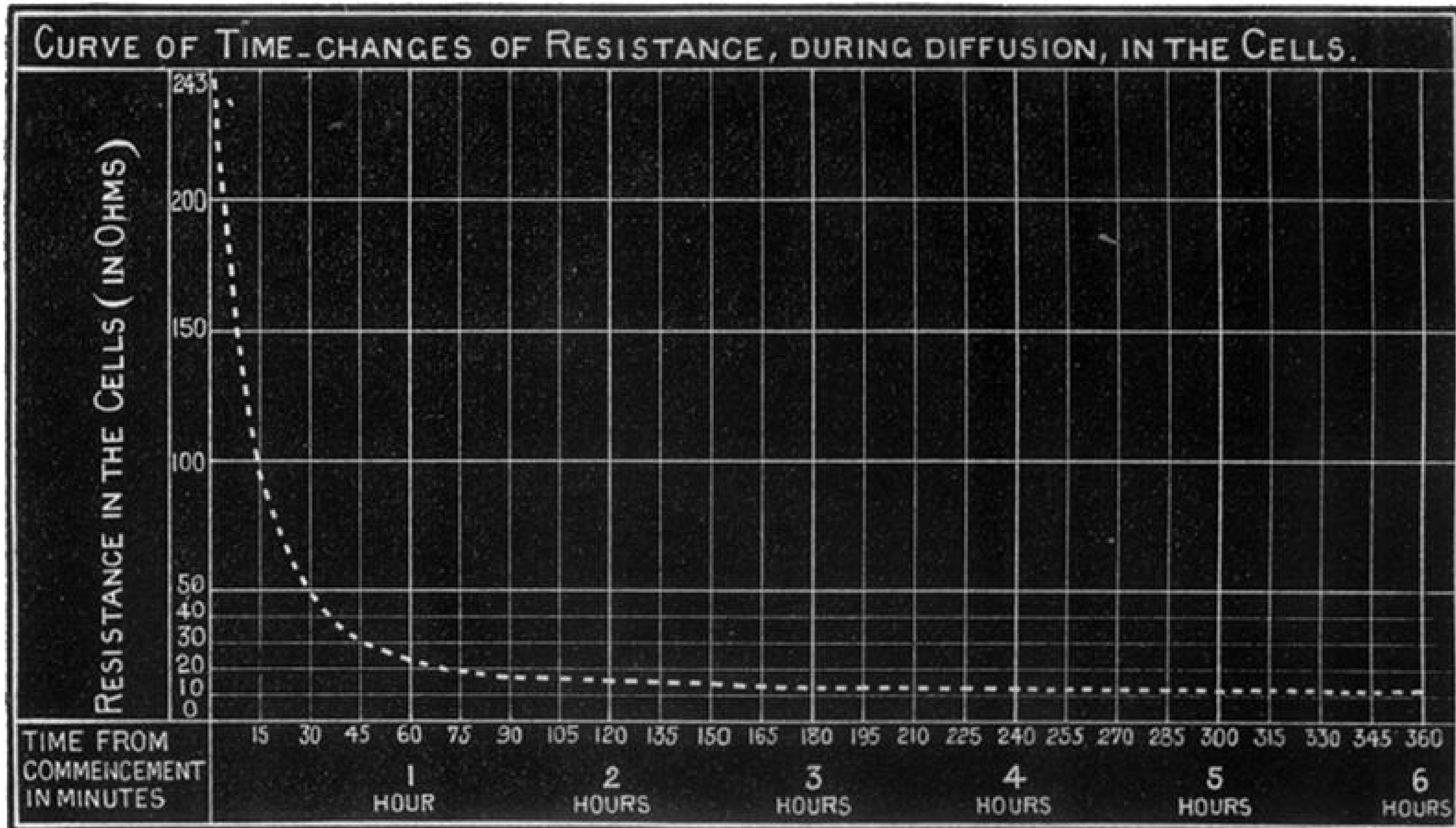
In approaching the subject in the manner stated in this memoir, the author trusts he has been able to afford some indication of the extent of the electromotive force from the action of tidal streams on the various metals experimented upon.

III. "On Unequal Electric Conduction-Resistance at Cathodes." By G. Gore, F.R.S., LL.D. Received April 30, 1884.

During some experiments which I have been making on the unequal resistance to the deposition of a metal upon cathodes of different metals in the same solution by the same current (see "Some New Phenomena of Electrolysis"), I have been led to investigate the resistance of cathodes of different metals to the passage of the current into them.

I have found that by taking a good conducting electrolyte, immersing in it a positive sheet of zinc, and a smaller negative one of another metal, connecting the plates with a galvanometer of low resistance, reducing all the other resistances in the circuit to the minimum except that of the negative plate; then making a series of measurements of strengths of current of different couples formed by the zinc and about twelve other metals, during removal of polarisation by stirring the liquid; also making another series of measurements of the electromotive forces of the same couples during stirring; calculating from these data the total resistance in each case, then deducting the portion of resistance due to the galvanometer, also that due to the liquid itself, and to opposing contact-potential, and

Fig. 1.



CURVE OF TIME-CHANGES OF RESISTANCE, DURING DIFFUSION, IN THE CELLS.
RESISTANCE IN THE CELLS (IN OHMS)
243
200
150
100
50
40
30
20
10
0
TIME FROM COMMENCEMENT IN MINUTES
15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
1 HOUR
2 HOURS
3 HOURS
4 HOURS
5 HOURS
6 HOURS