The absence of segmentation may probably be accounted for by the migratory habits of the embryo after development has commenced. The fact that no sperm-morula is formed supports this view. The evidence before us does not support the view that the ovum of Millepora formerly contained much yolk and has subsequently lost it.

I am inclined to believe that the Hydrocorallinæ belong to a separate stock of the Hydrozoa, which probably never possessed medusiform gonophores. Millepora is not related to Hydractinia.

IV. "On Photometry of the Glow Lamp." By Captain Abney, R.E., F.R.S., and Major-General Festing, R.E., F.R.S. Received November 21, 1887.

In a paper which we read before the Royal Society ('Roy. Soc. Proc.,' No. 232, 1884) it was shown when a carbon filament or a platinum wire *in vacuo* was gradually raised in temperature, that the different rays in the visible and invisible regions of the spectrum followed a law governing their intensity.

In the dark region of the spectrum (below the red) if the abscissæ to a curve represented watts (current $\times$ potential), and the ordinates the intensity of the ray under consideration, the curve so formed was hyperbolic, approaching more nearly to the parabolic form as the red was approached. In the visible spectrum the parabolic curve was actually reached, the vertices of the parabolas moving along the axis of abscissæ; the shift being greater the more refrangible the rays under consideration. This implied that until a certain number of watts had been expended the ray was absent. Further, we had shown in the 'Philosophical Magazine' for September, 1883, that when measured by a thermopile,

$$\text{total radiation} \propto (\text{watts} - \text{constant}).$$

In the visible radiation of an incandescent filament in a glow lamp we are only dealing, however, with a small portion of the radiation, and therefore could not expect it to follow such a simple law as that which governs total radiation. It appeared probable, however, that as the intensity of any individual ray in this part of the spectrum increased parabolically, the sum of all the visible rays ought also to follow very closely the same form of curve, the vertex of such parabola lying at some point in the axis of abscissæ between the vertices of the parabolas of the extreme visible rays. It likewise appeared probable that when the rays of extreme refrangibility were absent or in defect, as is the case when the filament is red hot, the parabola would fail to represent the intensity of visible radiation.

In the communication we have already referred to one example of

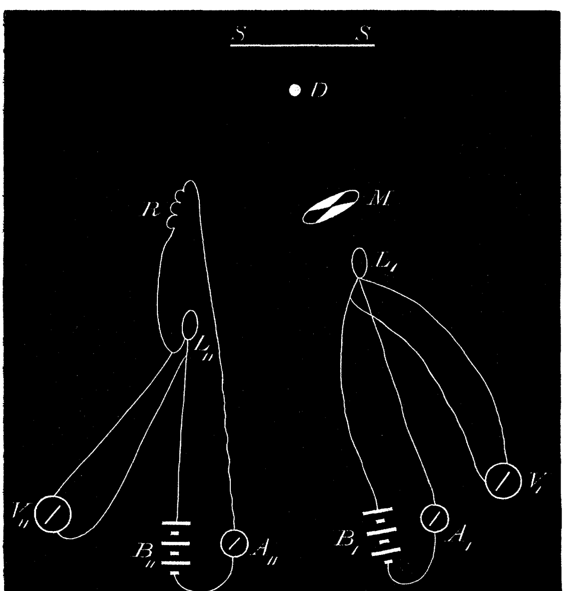
the applicability of the parabolic formula was given, for white light, but by itself it was hardly conclusive. We, therefore, conducted a series of experiments to ascertain if our anticipations were correct.

An incandescence lamp was selected as a standard lamp, through which a fixed current was maintained. This we used instead of a standard candle or other variable light. We then selected a second similar lamp, of which to measure the light when currents of various strengths were passed through it.

The shadow and grease-spot methods were both experimented with, the former being perhaps the most exact. Whichever method is, however, employed, it was inexpedient to move either lamp towards or from the source, or to vary the distance of the source from the lamp, as the carbon filaments show more or less illuminating surface to the screen according as they are close or distant from it. It therefore became necessary to adopt some other plan for altering the intensity of the light falling on the source from the comparison lamp.

In the Rumford (shadow) method, fig. 1 will give the general idea of the arrangements.

FIG. 1.



The shadows cast by the rod D from the two sources of light, L_1 and L_{11}, were made just to touch each other, on the white screen SS,

and to fall within a rectangle cut out of black paper, which deadened the light on the rest of the screen. Each lamp (L_1 and L_{11}) was in connexion with an ampère-meter and volt-meter (A_1, A_{11} and V_1, V_{11}). In front of L_1 (the comparison lamp) was placed an electromotor which caused a pair of sectors of variable aperture to rotate between it and the screen.

Evidently two methods are open to equalise the illumination of the screen from each source:—

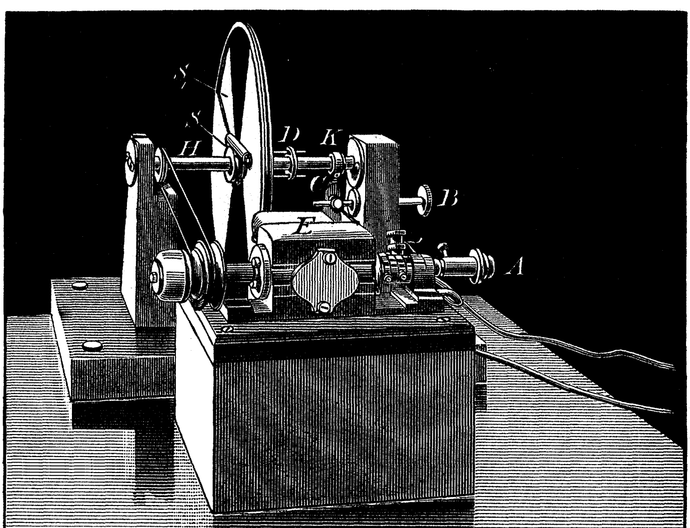
1st. Cutting off more or less light from L_1.

2nd. Varying the current in L_{11} by means of the variable resistance in the circuit.

The first plan necessitates the opening and closing of the sectors whilst rotating, and the second the alteration of the resistance, &c., at will. Whichever method was adopted the lamp L_1 was brought to a bright yellow glow, and the lamp L_{11} had a current passed through it which, when the minimum resistance was in circuit in R, produced a brilliant white light. Such intense heat the filament would not be able to stand for any considerable time.

When measurements were to be taken by the first plan the instrument shown in the annexed diagram, fig. 2, was employed. A pair of

FIG. 2.



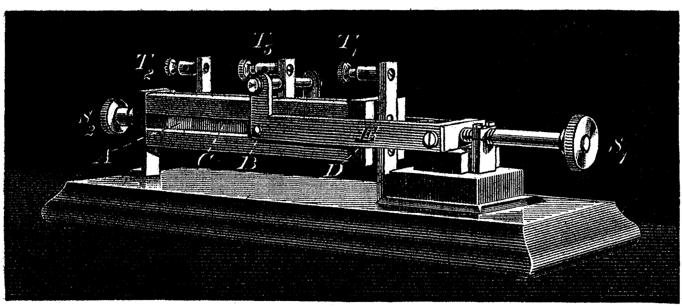
sectors, S (each of 90°), are mounted on a horizontal axis, a similar pair, S_1, are carried on a short sleeve, to which are attached two horizontal pins, passing through holes in the flange D of another

sleeve C. A stud in this last engages with a screw thread of long pitch cut on the axis. A horizontal movement of C thus causes it, as well as the sectors S_1, to rotate with reference to the axis and the other sectors (S), and therefore alters the aperture. This movement is given by means of a vertical lever engaging with the groove K on C, and which is actuated by the screw B. The aperture can thus be varied between 0° and 180°, whether the instrument be in motion or at rest. The instrument has been described at length, as it varies in some particulars from previous ones, having been made under our own supervision. The edge of S is graduated into degrees so that the amount of aperture is at once known.

A certain current is passed through L_{11}, which is noted, and the sectors opened or closed till the shadows cast by the rod appear equally luminous. The motor is stopped and the aperture read off. Three or four readings for each current passing through L_{11} are taken, and then the current is altered, and a new set of three or four readings made. The current is altered so that the light from L_{11} varies from extreme brightness to a dull red.

By the other plan the sectors shown in fig. 2 are detached from the motor, and card disks placed on A. A resistance, R, fig. 3, has now

FIG. 3.



to vary to bring the light equal to the standard light diminished by the disks rotating between the lamp L_1 and the screen with known apertures. For the resistance at first we used a non-conducting tube, in which about forty spherical pellets of hard carbon were inserted. At one end of the latter was a brass plate to which one terminal of the battery was attached, and at the other a screw was inserted, which was attached to the other terminal of the battery through the lamp. This screw pressed the pellets together to any required degree, diminishing the resistance or increasing it as occasion required. This answered fairly well, but not so well as would be desired, as the response to the screw was some-

what sluggish. Mr. Varley supplied us with one of his carbonised cloth resistances, which consists essentially of a series of square pieces of carbonised cloth more or less in contact. The figure represents the one we had made for us. The carbonised cloth is represented by C, fig. 3, which fills the whole length from A to D when loosely packed. At B is a plate to which T_3 is attached, and which can be separated more or less from a fixed metal plate to which T_1 is connected by the arm E, which is moved by the screw S_1. At A is an insulated block carrying another plate to which T_2 is attached, and A can be carried backwards or forwards by means of the screw S_2. For some purposes the main current can be brought in at T_3, and leads be taken from T_2 and T_1, thus forming part of a Wheatstone bridge. When only one resistance has to be inserted, T_1 and T_3, T_1 and T_2, or T_1 and T_3 may be used for connecting on to the leads with one pole of the battery and the ampère-meter. It was in this way the resistance was used in the case in point. The lamp L_{11} by the use of this could be raised from black heat to bright white, and a small turn of the screw altered the resistance very considerably. We used two sets of sectors; one pair enabled us to use an aperture from 135° to 90°, and the other pair from 90° to 0°. The light from L_1 was diminished by the first pair of sectors being placed on A (fig. 2), the current $\propto$ potential being noted. The resistance of the current passing through L_{11} was then altered till the illumination of the two shadows on the screen appeared equal, the screw S (fig. 3) being turned backwards and forwards, first one shadow and then the other being made to appear too dark. By diminishing the oscillations the neutral point can be very readily arrived at, even though the colours of the lights may be very different (see Bakerian Lecture, 1886, "Colour Photometry," by the authors). The readings of V_{11} and A_{11} were then read and noted. The apertures of the sectors were altered, and the same operations gone through. From observations thus made the curves were constructed, enabling the theory propounded to be tested.

The grease-spot plan of photometry was arranged in a somewhat similar manner, L_{11} being on the opposite side of the screen SS, and the rod being abolished. In this method the room has to be dark so as to admit of no reflection. At first we were not prepared for any great exactitude with it, but finally we came to the conclusion that it was very reliable, a conclusion that Mr. W. H. Preece* came to when he constructed his photometric arrangements.

Having described the arrangements for taking the measurements, it remains to give the conclusions at which we arrived after making a large number of experiments.

* 'Roy. Soc. Proc.,' vol. 36, 1884, p. 270.

Let

W be the watts,
c „ current,
p „ potential,
y „ intensity of light;

all other letters being constants.

In order for the curve of intensity to be parabolic

$$\text{(i.)} \quad W - m = n\sqrt{y},$$

m being the number of watts at which the vertex of the parabola lies.

From the equations given in the paper already referred to ('Phil. Mag.,' September, 1883), where

$$c = ap + bp^{3|2},$$

the above equation (i) may be written—

$$p^2(a + bp^{\frac{1}{2}}) - m = n\sqrt{y};$$

when p is fairly large this becomes—

$$\text{(ii)} \quad p^2 - h = k\sqrt{y} \quad \text{approximately.}$$

Similarly it may be shown that—

$$\text{(iii)} \quad c^2 - s = t\sqrt{y} \quad \text{approximately.}$$

The following tables will show the application of (i). It must be understood that the measures of current and potential are not given in ampères and volts, and that as a consequence the watts are only represented by watts × a constant. The first three tables show the exactitude of the method of measurement where the resistance is altered, and the fourth table the exactitude when the rotating sectors are altered.

Table I.—A Woodhouse and Rawson lamp, changing the resistance and reading current and potential.

C.	P.	Watts × a constant.	Aperture of disk.	Calculated aperture (shadow).	Calculated aperture (grease-spot).*
13·4	38·0	509·2	180	180·23	181·6
12·75	36·1	460·3	135	135·20	134·2
12·5	35·5	443·8	120	121·44	120·0
12·3	35·0	430·5	110	110·95	109·4
12·2	34·7	423·3	105	105·47	105·5
11·9	33·8	402·2	90	90·11	91·1
11·7	33·1	387·3	80	79·99	80·1
11·5	32·5	373·7	70	70·34	71·2
11·2	31·7	353·9	60	60·20	61·3
10·9	30·75	335·2	50	49·40	48·7
10·6	29·9	316·9	40	40·42	39·8
10·2	28·8	293·9	30	30·11	29·7
9·65	27·55	265·4	20	20·07	19·5
9·35	26·7	249·6	15	15·07	15·0
9·0	25·6	230·4	10	10·09	
8·4	24·2	203·3	5	4·75	

$m = 144$. $n = 27·2$.

Table II.—Swan lamp-light measured by changing the resistance and reading current and potential.

C.	P.	Watts × a constant.	Aperture of disk.	Calculated aperture.
23·2	24·2	562·4	180	180·63
22·0	22·2	488·4	133†	132·71
21·6	21·6	466·6	120	119·89
21·4	21·4	458·0	115	114·91
20·6	19·9	410·0	90	89·14
20·2	19·2	387·8	79†	78·68
19·7	18·7	368·4	70	69·88
19·2	18·0	345·8	60	60·37
18·6	17·2	320·0	50	50·00
17·9	16·3	291·8	40	40·25
17·1	15·3	261·6	30	30·8
15·9	13·8	220·4	20	19·98
14·3	12·0	171·6	10	10·11
13·0	10·6	137·8	5	5·29

$m = 50·52$ $n = 38·0$.

The following shows the readings in full of one set of observations :—

* This column shows results given by the grease-spot method. The watts are not given, but merely the results, to enable a comparison to be made between the accuracy of the two methods.

† In these two the sectors were supposed to be set at 135 and 80 respectively, but after the set had been taken and the sectors stopped it was found they read as in the table.

Table III.

Current.					Potential.					Aperture.		
Readings.				Mean.	Readings.				Mean.	Watts × a constant.	Calculated.	Set on the sector.
1	2	3	4		1	2	3	4				
19·3	19·2	19·3	19·3	19·3	11·4	11·5	11·4	11·4	11·4	220	180	180
18·5	18·5	18·5	..	18·5	10·8	10·85	10·75	..	10·8	200	135·5	135
17·1	17·1	17·0	17·1	17·1	10·3	10·3	10·3	10·3	10·3	176	89·5	90
16·8	16·8	16·8	16·7	16·8	10·1	10·1	10·1	10·1	10·1	170	79·6	80
16·5	16·4	16·5	..	16·5	9·9	10	9·9	..	9·9	163	71·7	70
16·1	16·1	..	..	16·1	9·75	9·75	..	..	9·75	157	59·9	60
15·6	15·7	15·6	15·6	15·6	9·6	9·5	9·5	9·6	9·55	149	49·2	50
15·1	15·0	15·2	15	15·1	9·3	9·3	9·5	9·2	9·4	142	40·7	40
14·5	14·5	14·5	..	14·5	9·1	9·1	9·0	..	9·1	132	30·0	30
13·7	13·65	13·7	13·7	13·7	8·7	8·7	8·65	8·7	8·7	119	18·7	20
12·2	12·2	12·2	..	12·2	7·9	7·9	7·9	7·9	7·9	96·5	5·6	10
10·6	10·5	10·6	..	10·6	7·3	7·1	7·2	..	7·2	76·3	0·14	5

$m = 71 \cdot 5$. $n = 11 \cdot 04$.

The following is an example of measuring by using known currents and cutting off more or less of the comparison light by the sectors. The observations have been given in full to show the deviation of individual observations from the mean :—

Table IV.

C.	P.	Watts × constant.	Aperture of disks to balance light.	Mean observed aperture.	Calculated aperture.
7·9	28·1	222	90*	90	91·2
7·75	27·4	212	81, 81, 80	80·7	80·6
7·6	26·8	204	72·5, 72·5, 72·5	72·5	72·5
7·25	25·5	185	56·5, 56, 56·0, 55, 55·5	55·8	55·6
7·00	24·8	174	46·5, 47, 46·5, 45·5	46·4	46·6
6·7	23·8	159	37, 35, 36, 36	36·0	36·0
6·25	22·2	139	23, 24, 23·5, 24	23·8	23·6
5·85	20·6	120·5	14·15, 15, 14·5, 14	14·5	14·6
5·7	20·1	114	11·75, 11·75, 11·75	11·75	11·75
5·4	19·1	102	8, 8, 7·5, 8, 7·5	7·6	7·7
5·3	18·7	99	6·5, 6·5, 6·5, 7	6·6	6·8

$m = 53.$ $n = 17·7.$

The foregoing examples will give an idea of the accuracy with which measurements may be made by either method, and of the exactness with which the parabolic curve is followed. It seems that the photometry of incandescence lamps may be well carried out by measuring the watts. It may be objected that each observation requires readings of the galvanometers, but this is avoided by the use of the formula given in the beginning of this paper. Two observations of current and potential enable the constants to be calculated, and after that one galvanometer alone need be used; by preference that one giving comparative volts. The current is calculated from such a reading and subsequently the watts.

Mr. W. H. Preece, in his paper† already alluded to, came to the conclusion that the intensity of the light emitted from a glow lamp varied as the sixth power of the current. This formula is fairly exact within limits, but it is obviously empyric, since where the current is small enough only to cause dark radiation it must fail. The example that he gives would require some slight rectification before it can be used as in the method given above; since the small distances at which the candle he employed was placed from the screen make it necessary to apply corrections for the thickness and length of flame.

* The light was fixed so as to balance as nearly as possible when the sectors were at their full aperture.

† 'Roy. Soc. Proc.,' vol. 36, p. 270.

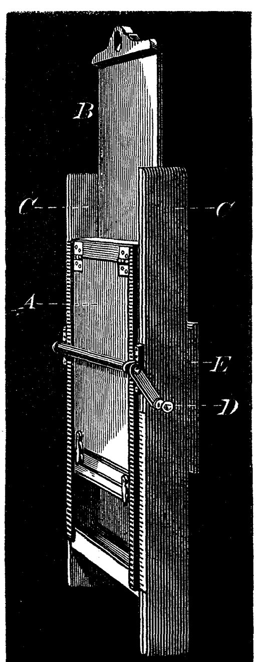
Mr. Preece's table is as follows; the last column is derived from the parabolic formula using $C^2 - s$ instead of $W - m = a\sqrt{y}$.

Table V.

Distance of source of light from illuminated surface.	Equivalent degree of illumination.	Current in lamp.	$C^6 \times 15{\cdot}994$.	Parabolic formula.
0·50 feet	64·000	1·260	64·000	64·00
0·75 "	28·445	1·100	28·335	32·83
1·00 "	16·000	0·959	12·442	16·00
2·00 "	4·000	0·790	3·888	4·41
3·00 "	1·778	0·690	1·726	1·78
4·00 "	1·000	0·651	1·217	1·00

It having been shown that the parabolic formula applies to visual measures of an incandescence light, it appeared that the same ought to hold good for the total light which is photographically active. These rays may be taken to lie between the blue and the extreme ultra-

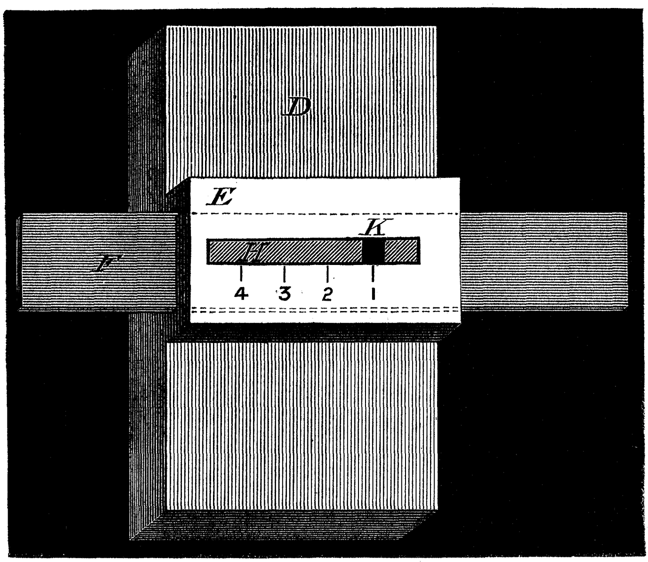
FIG. 4.



violet of the spectrum, and consequently the vertex of the parabola should lie further towards the blue of the spectrum than it does with the visual rays. The method of testing was as follows.

An ordinary dark slide, A, carrying a sensitive plate, was placed in grooves, CC, attached to a board, D, against which the slide (when its front B was drawn out) could be raised or lowered as occasion required by means of a rack and pinion motion working by the handle D.

FIG. 5.



E is a projection in which a slot, H, is cut, and through which a card having a square aperture, K, can slide. K can be covered by means of a cardboard screen. The bottom of the plate in A is first brought opposite the aperture K, which is placed opposite the number marked 1 on E. The lamp is placed 4 feet away, the volts and ampères noted, and exposure is given to the small square of the plate seen through the square in K for any time which may be fixed upon. The slide A is lowered, so that a fresh portion of the plate is brought opposite to K (K being covered up) a different current passed through the lamp, and another exposure given, and so on. When the top of the plate has been arrived at by the motion of A, the card F is moved till K is opposite 2, and the same procedure repeated. Six to ten exposures can be made in the same row.

When the second row is exhausted, K is placed opposite 3, and

such a current is passed through the lamp that it emits a medium light. A time scale is then made by giving different lengths of exposure at each movement of the plate in its last half. The plate is then taken out of the slide, and the images developed. By this means both a time scale and a measure of intensity for different temperatures are on the same plate in the shape of squares of different density of deposit. When the negative is dry it is placed in an apparatus which works on the principle of the optical lantern, and is described in the paper written by one of us, "Atmospheric Absorption of Sunlight" ('Phil. Trans.,' 1887), and the density of each square measured. The "intensity" measures are then compared with the time scale, and the value of the intensity calculated. From these values can be determined if the curve of intensity and watts increases parabolically. It might be objected that increase in intensity is not convertible into "time of exposure." Careful experiments have been made as to this, and for the range of time which is comprised in the seconds of exposure given no appreciable error ensues.

The following is an example of an experiment conducted in the above manner:—

Table VI.

Time Scale.

No. of aperture.	Exposure given to portion of plate.	Light transmitted through developed plate.
	secs.	
1	5	55·0
2	10	47·5
3	15	39·5
4	20	33·0
5	25	27·5
6	30	23·2
7	35	20·0
8	40	18·1
9	45	16·0
10	50	14·1
11	55	13·2
12	60	12·4

Bare glass = 56.

Table VII.

No. of exposure.	Lamp.			Exposure in seconds of small squares.	Light transmitted.	Equivalent time exposure.	Mean.	Reduction to one minute's exposure.	Calculated intensity.	By least squares.
	Current.	Potential.	Watts × constant.							
1......	15·0	37·5	562	15	21·5	66	66	264	264	264·8
2......	,,	,,	,,	,,	21·5	66				
3......	14·1	35·3	498	30	16·25	88	88·5	177	185	176·2
4......	,,	,,	,,	,,	16·00	89				
5......	13·2	33·3	440	30	25	56	56·5	113	114·5	111·1
6......	,,	,,	,,	,,	24·5	57				
7......	12·6	32·1	404	30	32·5	40	41	82	79·2	78·3
8......	,,	,,	,,	,,	31·5	42				
9......	11·6	29·8	346	60	35	36	35	35	36·0	37·4
10......	,,	,,	,,	,,	37	34				
11......	11·1	28·6	317	120	31·5	42	42	21	21	22·1
12......	,,	,,	,,	,,	31·5	42				
13......	10 3	26·9	277	180	33	40	38·5	12·8	6·8	8·4
14......	,,	,,	,,	,,	34·5	37				
15......	9·4	24·8	231	240	42·5	25	25	6·2	0·9	
16......	,,	,,	,,	,,	42·5	25				
17......	9·2	24·4	224	360	39	31	31	5·2	0	
18......	,,	,,	,,	,,	39	31				
19......	8·6	22·9	197	480	48	17	18	2·25	0	
20......	,,	,,	,,	,,	$47\frac{1}{2}$	19				

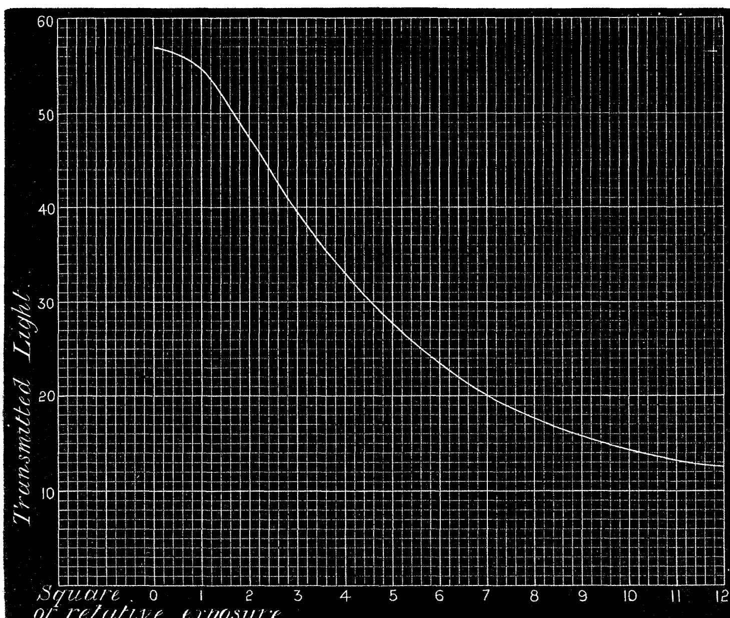
$m = 225.$ $n = 20·08.$

It may be well to point out exactly how the above table was devised. From the time scale (Table VI) the diagram, fig. 6 (on large

dimensions) was constructed. Take Nos. 1 and 2, Table VII, the exposures given to each were the same, viz., 15 seconds. The light transmitted through each square was read off, and found to be identical, viz., 21·5. In the scale diagram the abscissa of the curve having the ordinate 21·5 is 66, which is the equivalent time exposure, which is also a measure of the intensity. If the exposure had been prolonged to 1 minute it would be equivalent to an intensity of 264 (since the measured exposure was only 15 seconds). The other intensities were calculated in a similar manner. The intensities 21 and 264 were taken as points on the parabola, and the intermediate intensities calculated using the formula $W - m = n\sqrt{y}$.

FIG. 6.

Time Scale Diagram.



N.B.—It will be noticed that in the above diagram the abscissæ are marked as square or relative exposure. A reference to the time scale table will show that the exposure = number of square × 5. For simplicity's sake the number of the square has been taken as the unit of time.

The following is another example of the photographic measurement.

Table VIII.

Time Scale.

No. of exposure.	Time.	Readings of density.
15	180	7·5
16	160	8·5
17	140	9·5
18	120	12·0
19	100	17·0
20	90	20·7
21	80	25·1
22	70	30·0
23	60	37·5
24	50	46·5

Table IX.

No. of exposure.	Lamp.			Exposure in seconds.	Light transmitted through negative.	Equivalent exposure.	Mean.	Reduced to one minute's exposure.	Calculated intensity.
	Current.	Potential.	Watts × constant.						
1........	8·6	32·7	281	15	7	184			
2........	,,	,,	,,	7	21·5	88	(for 15 sec.) 186	744	736
3........	8·0	30·2	242	30	not readable				
4........	,,	,,	,,	15	10	134	(for 15 sec.) 134	536	529
5........	7·7	29·0	223	40	not readable				
6........	,,	,,	,,	20	9	144	(for 20 sec.) 144	432	432
7........	6·6	24·9	186	60	8	168			
8........	,,	,,	,,	40	12·5	118	(for 60 sec.) 172	172	176
9........	6·1	22·9	139	60	10·5	130			
10........	,,	,,	,,	30	33·5	65	(for 60 sec.) 130	130	130
11........	5·4	20·0	102	120	9·75	138			
12........	,,	,,	,,	60	31	70	(for 120 sec.) 139	69·5	69·2
13........	4·4	16·2	71	600	9·5	140			
14........	,,	,,	,,	300	29·5	71	(for 600 sec.) 141	14·1	15·2

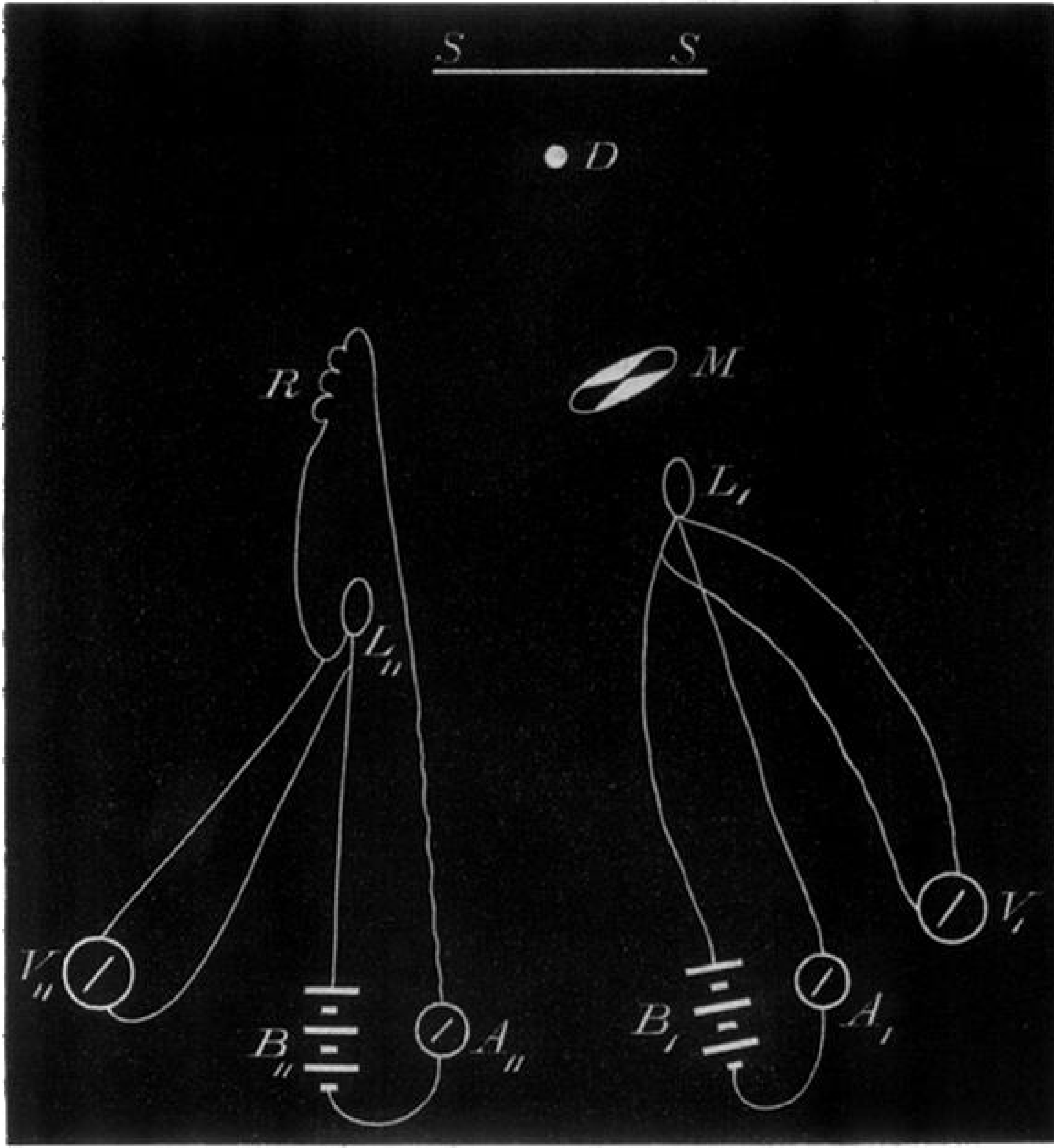
The above show that the parabolic form seems to be followed, but owing to the want of *absolute* uniformity in all parts of a photographic plate, and that errors may arise from want of exact exposure, and, again, from reading the densities, the values obtained are not so accordant as those taken by the visual method.

V. "On the Detonating Bolide of November 20th, 1887." By G. J. SYMONS, F.R.S. Received December 8, 1887.

Shortly after November 20th it was generally reported that an earthquake shock had been felt in the South Midland counties of England, and the author began to collect and examine the facts. It appeared that the records from Oxfordshire, and the western stations generally, indicated that much louder sounds were heard there than at the eastern stations, *e.g.*, Essex and Cambridge. The author thought that, although the phenomenon had been almost universally ascribed to an earthquake, it was more probably due to an explosive bolide, and on receiving from one of the local scientific societies a request for assistance in tracing the shock, the author suggested the alternative explanation. Mr. Fordham has subsequently written to say that he has already found one person who saw the meteor from Hertford, which he describes as "a brilliantly luminous body travelling across the sky from N.E. to W." It is further stated that a portion of the meteor was seen to fall from the main body.

Considering that the morning, as shown by the records of the Royal Meteorological Society, was both misty and cloudy, and that at the hour at which it appeared, Sunday morning, 8.20 A.M., there would be broad daylight, it is improbable that many persons saw it. Judging by the descriptions of the noise, as well as by the path roughly indicated by the Hertford observation, it seems likely that it ex-

FIG. 1.


S
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$A_{\prime\prime}$
$B_{\prime}$
$A_{\prime}$

FIG. 2.

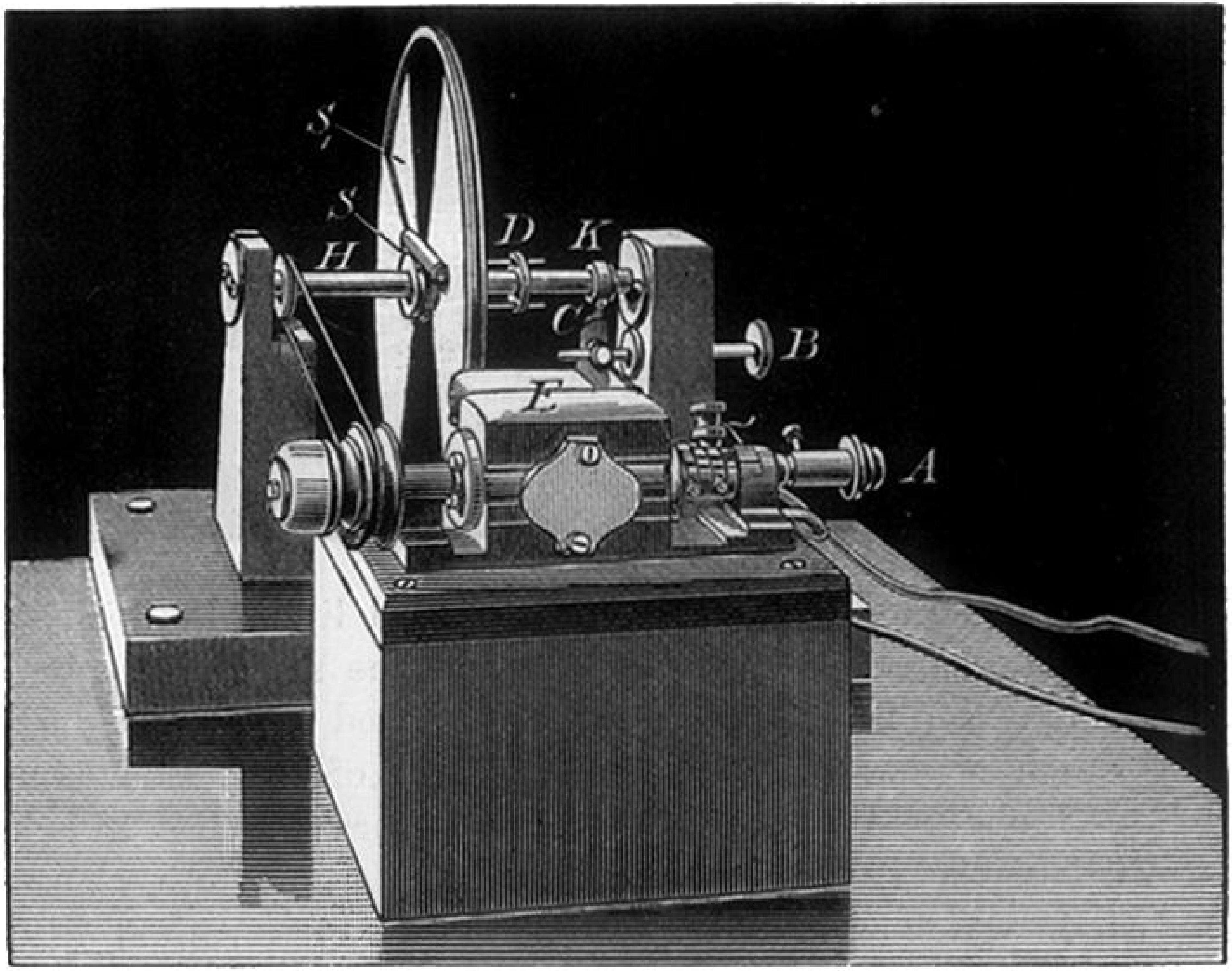


FIG. 3.

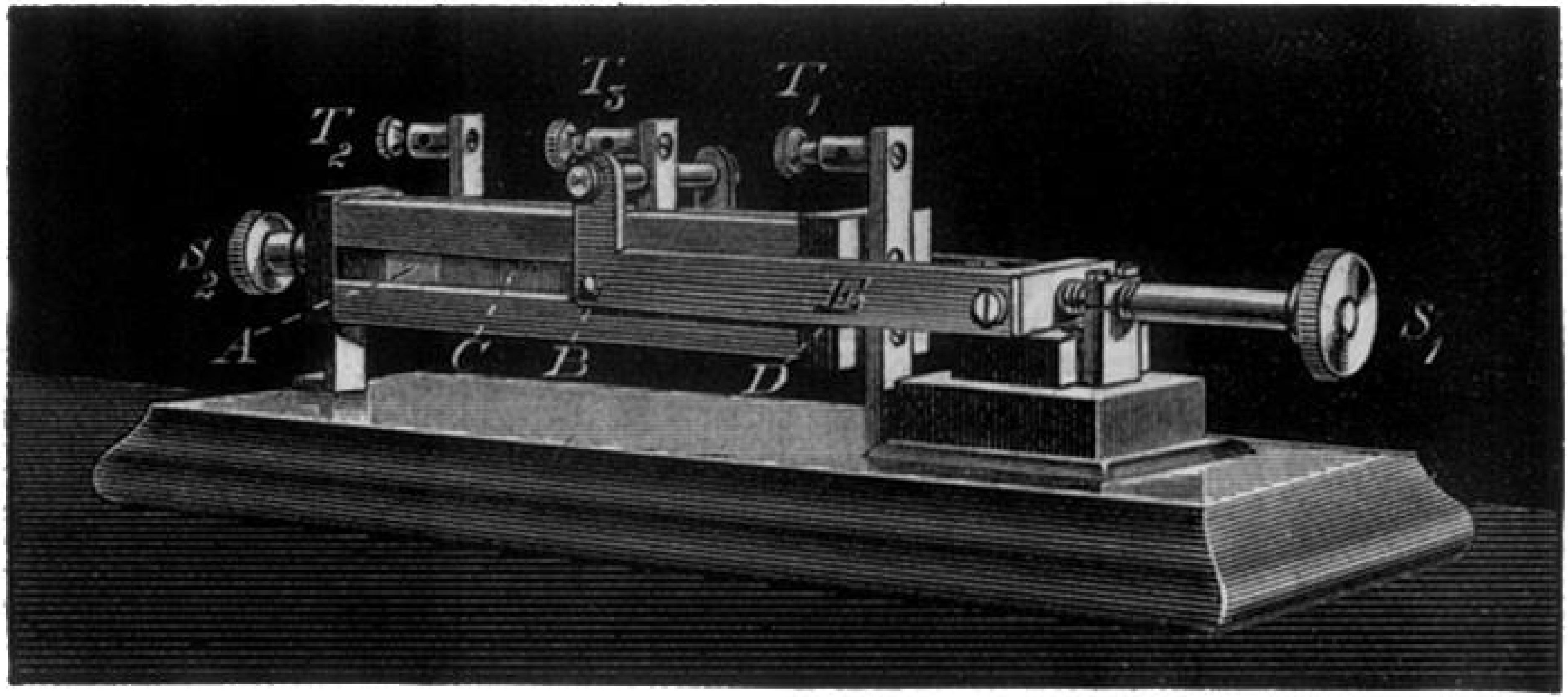


Fig. 4.

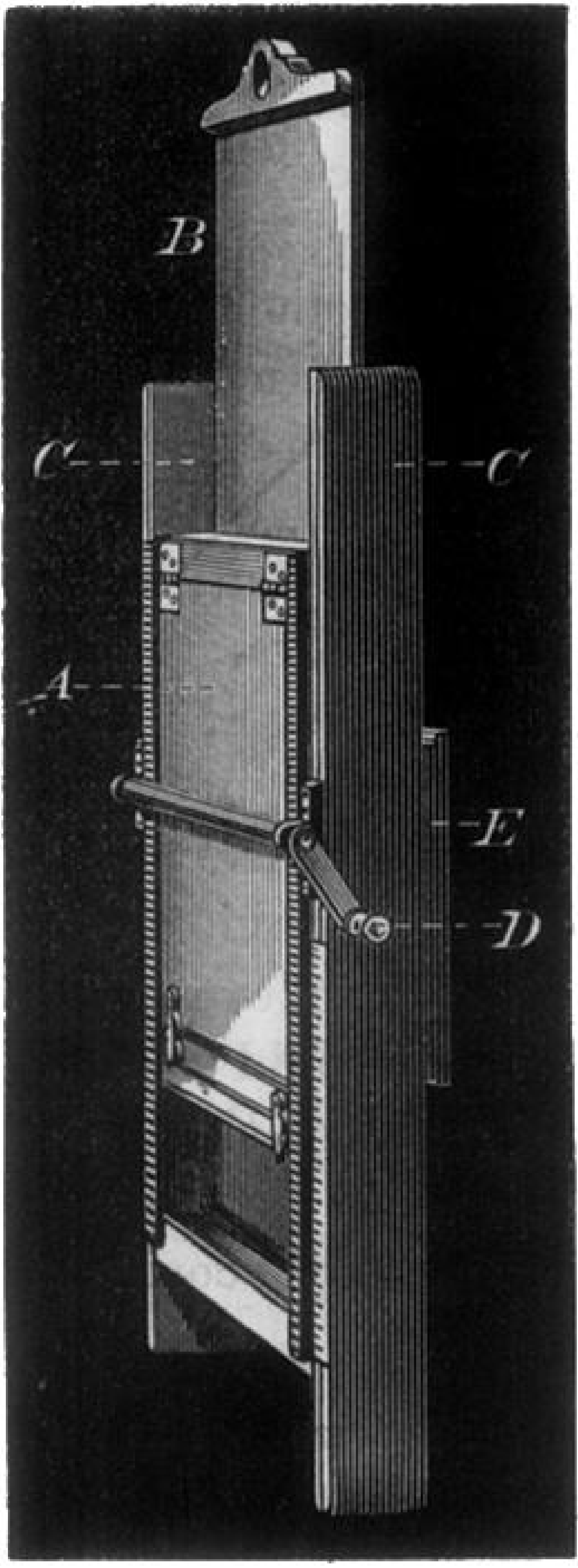


FIG. 5.

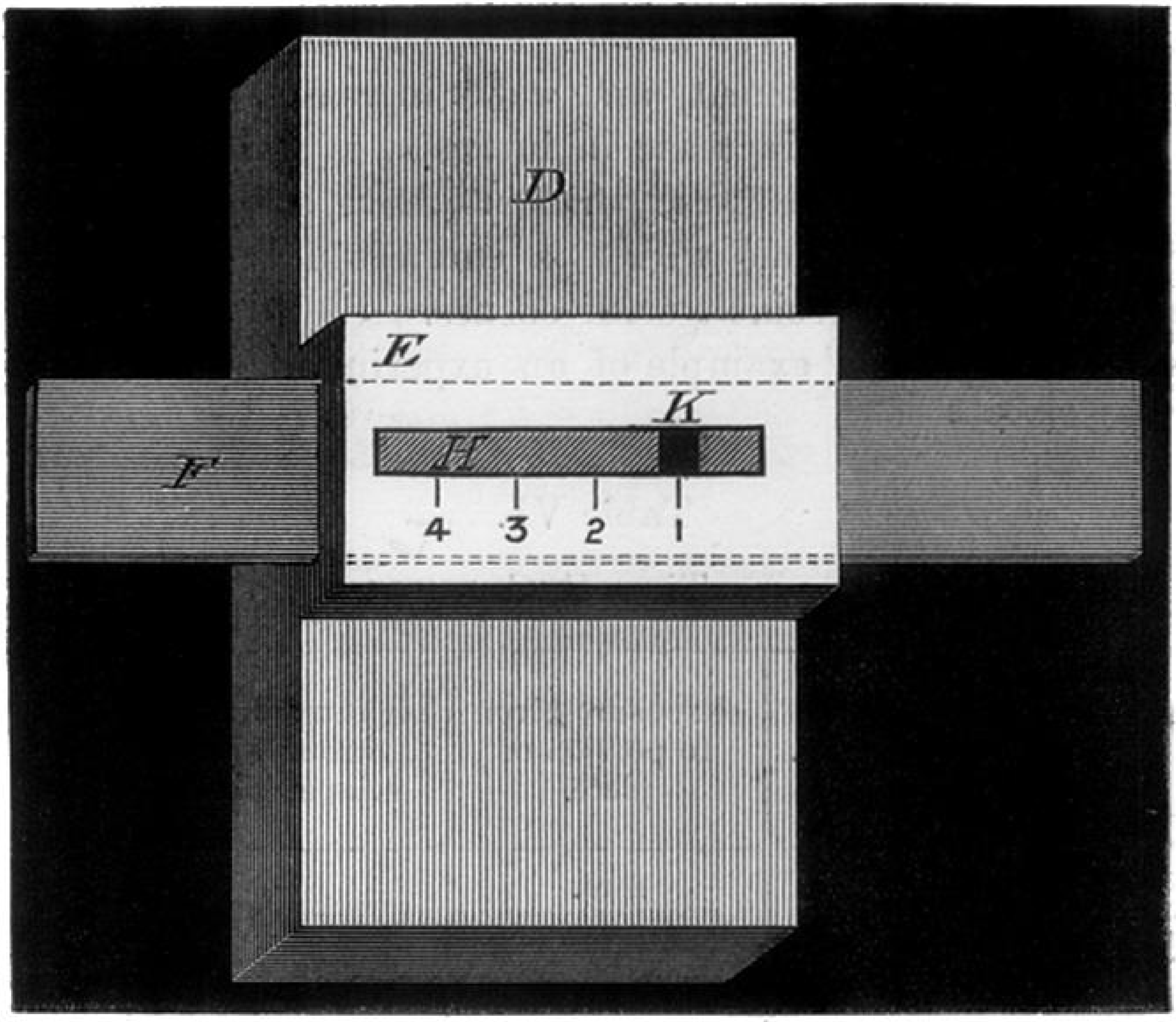
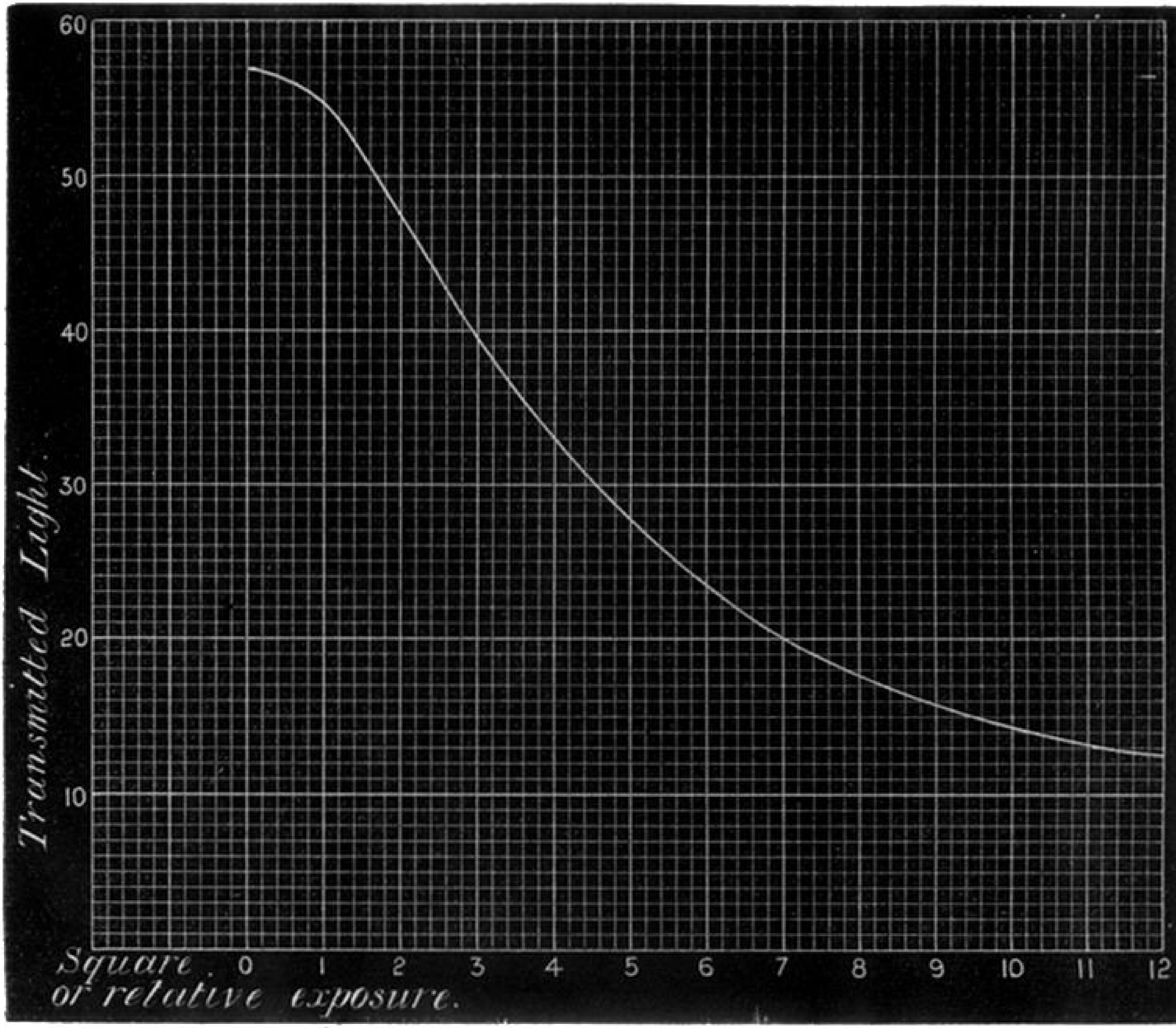


FIG. 6.

Time Scale Diagram.



N.B.—It will be noticed that in the above diagram the abscissæ are marked as square or relative exposure. A reference to the time scale table will show that the exposure = number of square × 5. For simplicity's sake the number of the square has been taken as the unit of time.