

views given out in that paper of the manner in which the various elements most common in steel exert their influence in so materially modifying the properties of the metal.

The following are the elements the action of which is considered, viz., silicon, sulphur, phosphorus, manganese, chromium, tungsten, and titanium.

PRIVATE BUSINESS.

Mr. Sang's motion of January 16th, that Law XIV. be amended by the addition of the words, "Excepting when there are five Mondays in January, in which case the meetings shall be held on the third and fifth Mondays of that month," was adopted by the Society, with a verbal emendation. The following words were accordingly added to Law XIV.: "Excepting when there are five Mondays in January, in which case the meetings for that month shall be held on the third and fifth Mondays."

Monday, 6th March 1882.

PROFESSOR H. C. FLEEMING JENKIN, F.R.S.,
Vice-President, in the Chair.

The Chairman intimated that a letter had been received from the Imperial Society of Naturalists of Moscow, inviting the Society to be represented on the 14/2 May 1882, at the celebration of the fiftieth anniversary of the graduation of its Vice-President, Dr. Charles Renard.

The following Communications were read:—

1. The Effect of Flame on the Electric Discharge. By Dr. A. Macfarlane and Mr. D. Rintoul. (Plate IV. *a*).

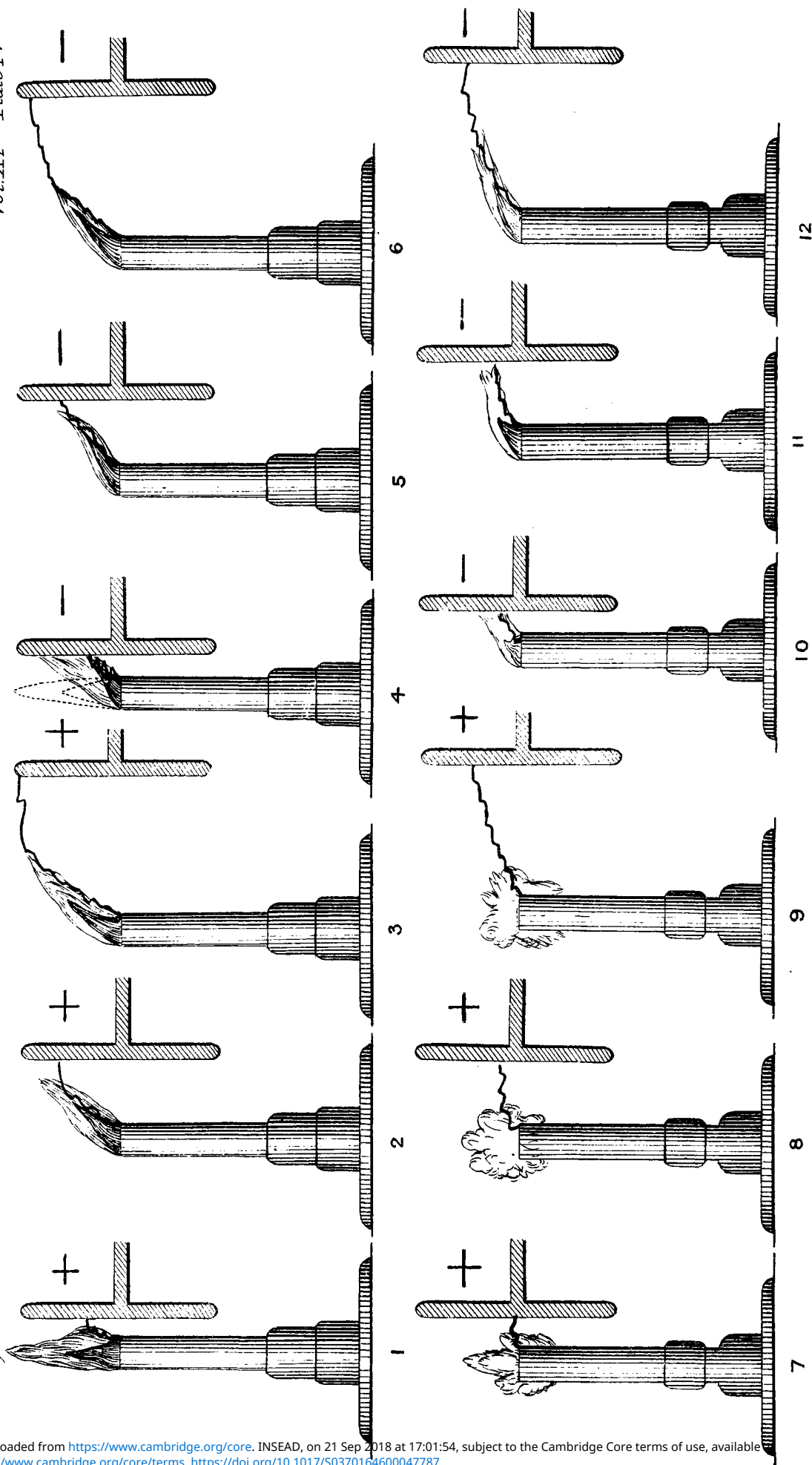
The properties of flames of various kinds as generating electricity and as serving to conduct a voltaic current, as also their behaviour under the influence of a charge of electricity, have been investigated

by several philosophers.* But, so far as we know, the effect of flame on the electric spark has not been methodically observed, or at all events has not been methodically measured. This was the problem which at the opening of the College session presented itself to us, and the results now attained by a course of experimenting appear capable of throwing some light on the solution.

We first made a number of tentative experiments, for the purpose of finding out the general aspect of the phenomena, and the conditions most favourable for exact measurement. An ordinary Bunsen burner served to supply a flame luminous or non-luminous. It was always connected with the earth, and the charged body was in general a disc of 4 inches diameter, connected along with a large Leyden jar to the insulated conductor of a Holtz machine. We tried the disc in a position above the flames, but found that the disturbing conditions introduced were, as was to be expected, rather numerous, namely, the heating of the disc and the covering of it with soot, and the melting of the gutta-percha covering of the connecting wire. Hence for a series of measurements we preferred the disc placed in a position at the side, as represented in the accompanying figures. (See Plate IV. *a*).

The series of observations finally attained are recorded in Tables I. and II.; they are supported by the more preliminary observations. The charged disc was throughout placed at the side of the Bunsen tube in a vertical plane, and so as to have its centre on the same level with the mouth of the tube. The conditions varied were—*first*, the nature of the flame; *second*, the sign of the charge on the disc; *third*, the height of the flame; *fourth*, the distance of the disc from the tube. As regards the first variation two states were observed, the one being the clear flame without any luminosity, the other being the flame as luminous as possible. The height of the flame was varied through a range from 1 cm. to 8 cm., but sometimes the range was extended to the maximum height of the flame (about 20 cm.). In the case of the non-luminous flame, it was the height of the apex of the cone that was measured off; while in the case of the luminous, it was the extreme tip. The total height of the former flame may be taken as double that of the cone. The

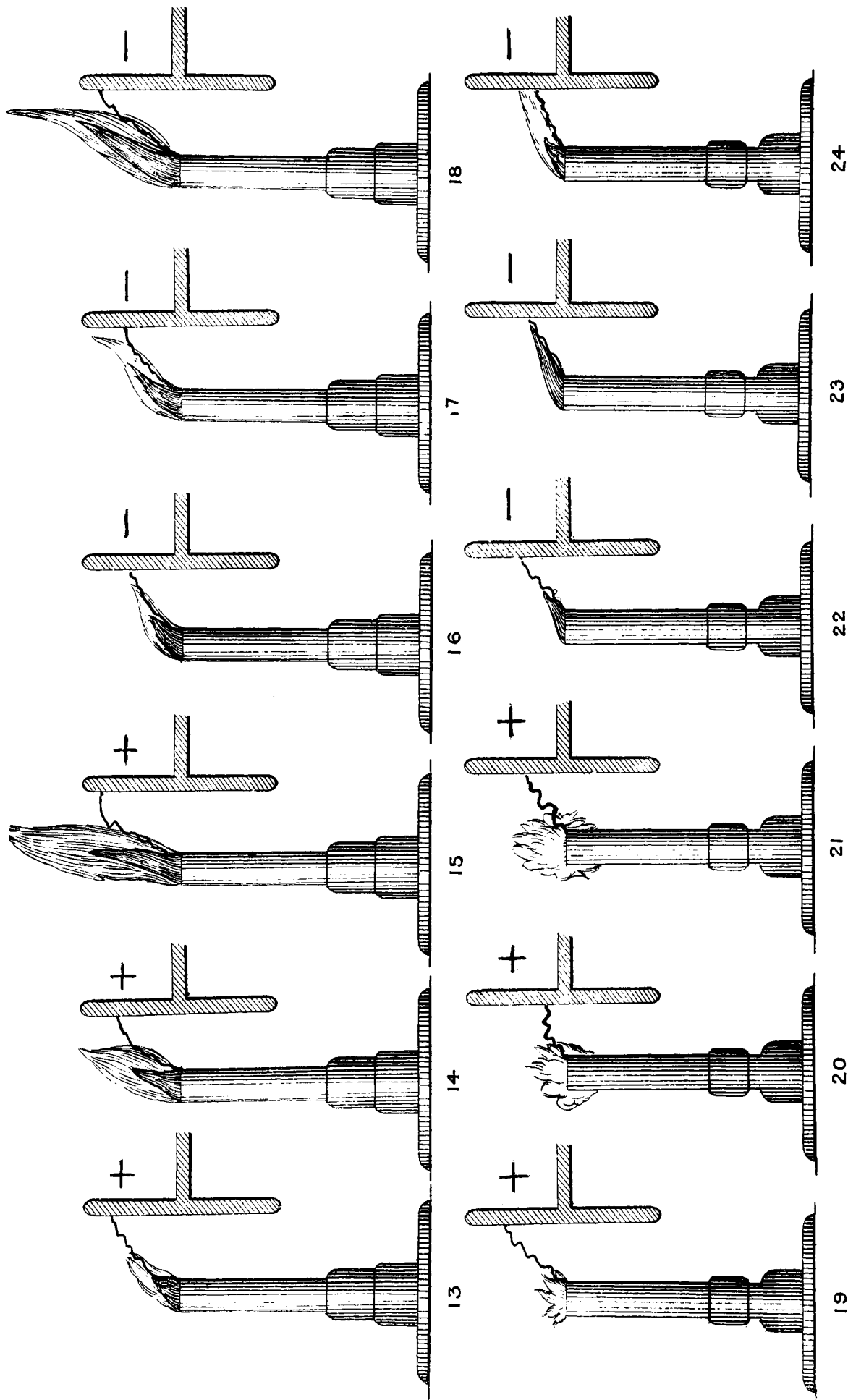
* A summary of what has been done is given in a recent paper by Holtz, *Carl's Repertorium*, vol. xvii. p. 269.



Figs. 1-3. Flame non-luminous, electricity on disc positive.
Figs. 4-6. " " " negative.

Figs. 7-9. Flame luminous, electricity on disc positive.
Figs. 10-12. " " " negative.

Figs. 1-12. Height of flame constant.



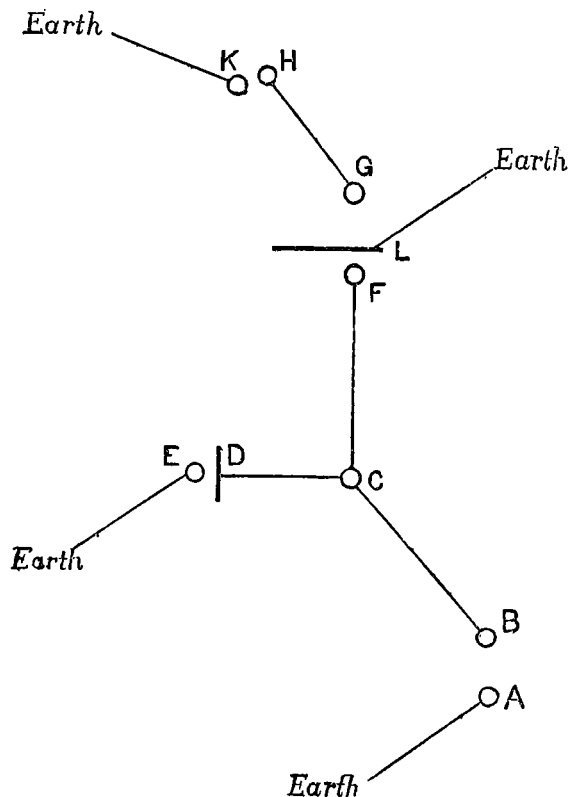
Figs. 13-15. Flame non-luminous, electricity on disc positive.
Figs. 16-18. " " " negative.

Figs. 19-21. Flame luminous, electricity on disc positive.
Figs. 22-24. " " " negative.

Figs. 13-24. Distance of tube from disc constant.

distance of the tube was varied through a range extending from 1 cm. to 7 cm.

The method of measuring the potential required to produce the spark was that employed in Macfarlane's previous experiments.* The special arrangement of the apparatus is indicated by the accompanying plan.



A and B are the two electrodes of a Holtz machine, of which one, say A, was connected with the earth. An insulated wire joined B to the knob of a large Leyden jar C, and C was similarly connected with the disc D and with the insulated ball F. G, the other insulated ball, was connected with one of the electrodes H, of a Thomson quadrant electrometer, the other electrode K being earthed. An uninsulated metallic plate L, with a hole in the middle of it, was placed between F and G, for the purpose of diminishing the influence of F on G. This is a modification of an idea introduced by Professor Chrystal, namely, the placing of F inside a metallic cube having a hole in the side next G.

* *Trans. Roy. Soc. Edin.*, vol. xxviii. p. 633, or *Phil. Mag.*, s. 5, vol. x. p. 389.

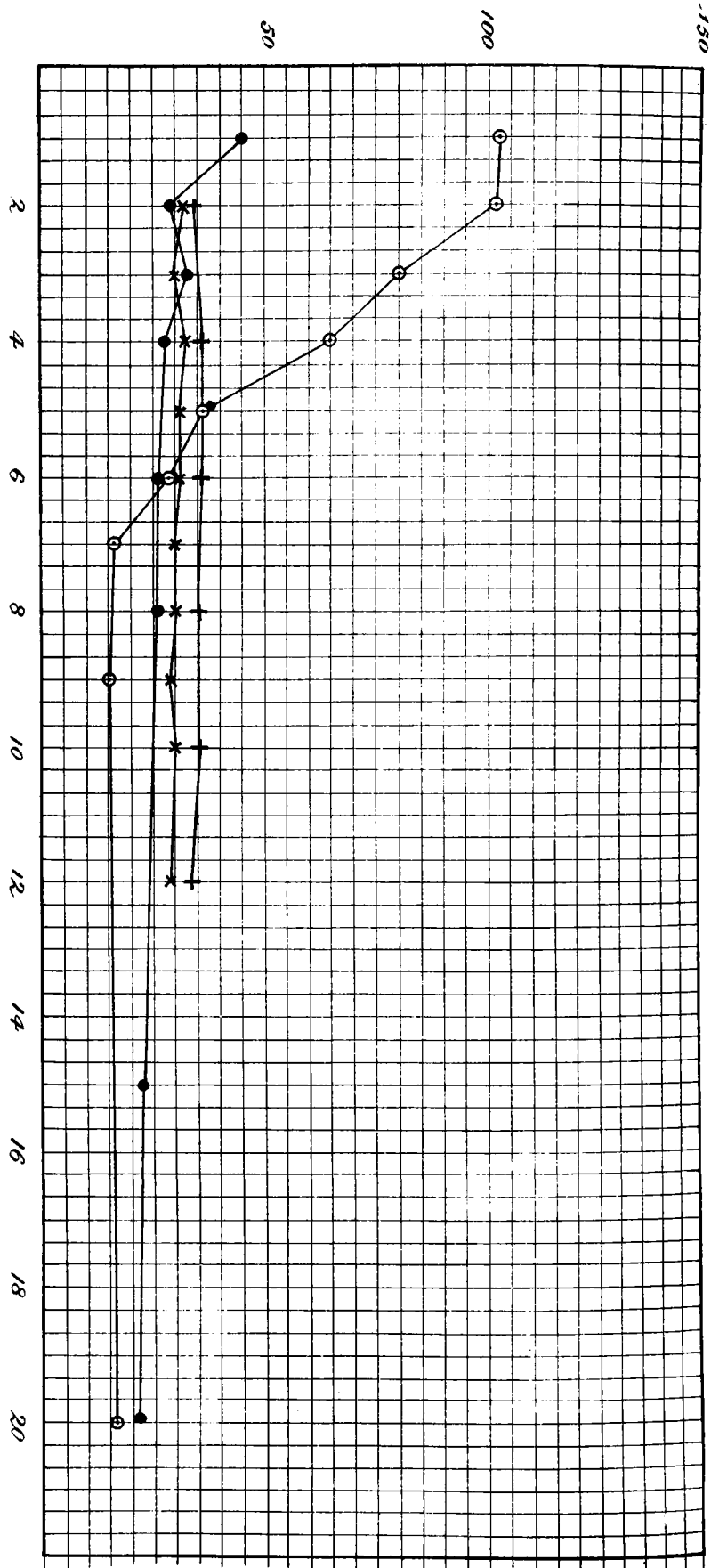
Having decided upon our variables, we drew out the logical plan exhibited in the Tables, and proceeded to fill in the observations systematically. We first observed the behaviour of the flame under the influence of the charge, and also the mode of passing of the spark, and then proceeded to note the readings of the electrometer for three separate discharges. It will be observed, that where the flame was in a steady state the three readings differ only by small quantities, but that where the flame was in what may be called a critical condition, the differences are relatively larger. The sign of the electricity was changed by interchanging the connections at A and B, and that was always accompanied by a simultaneous interchange of the connections at H and K, in order that any bias due to the electrometer might be eliminated. The mean differences of potential obtained were reduced to absolute measure by taking the mean of the differences of potential required to produce several sparks between two parallel plates at a distance of 6 mm. apart. For such a spark the absolute value of the difference of potential is 46.52 C.G.S. units.*

The figures sketched (Plate IV. *a*) indicate the behaviour of the flame, and the path of the spark in 24 representative cases. They are drawn in proportion to the exact dimensions.

The results for a flame of constant height (Table I.) are represented on diagram 1. The first conclusion that may be drawn is, that the difference of potential is greater when the disc is negatively electrified, excepting that for small distances there may be an equality or even a small difference the other way. The next conclusion is, that it is greater for the non-luminous flame at the smaller distances, but very much the opposite at the greater distances, particularly in the case of the negative luminous. If we look at the notes or at the sketches, we shall find decided differences of behaviour coexisting with these differences in electromotive force. In the case of the negative electrification, the flame in general assumes a pointed form, becomes diminished, and loses its luminosity partially or wholly, or if already clear, becomes more bluish. But at the smaller distances, the flame being able to form a bridge over to the disc, remains with its tip in contact, and there are none of the above changes. On the other hand, in the case of the positive

* *Trans. Roy. Soc. Edin.*, vol. xxviii. p. 652.

Difference of Potential in C.G.S. Units.



Height of Flame in Centimetres.

(Distance of Tube from Disc constant, = 3 cm.)

x non-luminous flame, disc being positively electrified

+ " " " negatively

• luminous " " positively

◊ " " " negatively

DIAGRAM 2.

electrification, the non-luminous flame is not attracted powerfully, and it retains its original size and character, while the luminous one is thrown down into and over the mouth of the tube, and retains its luminosity. If there are convection currents they must be such as to throw oxygen into the flame in the former case, but not in the latter.

The observations recorded in Table II. were undertaken to test whether the difference of potential required for the spark depended largely upon the height of the flame. Where the conditions are in common with cases in the former series, the observations serve as a test of consistency; the agreement is satisfactory. Diagram 2, representing the results, in addition to confirming the conclusions drawn from the preceding diagram, shows that the variation of the height of the flame produces little change in the electromotive force, when the flame is non-luminous; also when the flame is luminous and the electrification positive, but that it produces a great difference in the remaining case, when the flame is luminous and the electrification negative, so long as the flame is not sufficiently high to reach the disc. Though the flame is attracted so as to be in contact with the disc, the discharge still passes in the form of a spark.

This investigation was made in one of the fine suite of rooms recently added to the Physical Laboratory, and in conducting it we had every facility given us by Professor Tait.

TABLE I.

TABLE I.—DISTANCE OF TUBE FROM DISC VARIED.

Height of flame = radius of disc, *i.e.*, 5.5 cm.

Date.	Nature of Flame.†	Sign of Change on Disc.	Distance of Tube from Disc.	Deflection.	Zero.	Difference.	Mean Diff. of Potential.	Abs. Value of Diff. of Potential.	Remarks on Appearance of the Flame.
30th Jan.	non-luminous.	+	.5 cm.	510	435	75	82	14.57	No sensible attraction; spark passes between the disc and the top of the tube.
				520	435	85			
				520	435	85			
				540	440	100	103	18.30	Flame has only a slight protuberance towards the disc, not diminished, nor made more bluish; spark passes to protuberance.
				550	440	110			
			2 "	540	440	100	130	23.09	Flame much more attracted; spark passes through a considerable portion of the flame.
				575	440	135			
				565	440	125			
				560	430	130			
				620	435	185	182	32.33	Flame bent still more towards the disc, not diminished, nor made more bluish; spark more through the flame, and obtained readily.
			4 "	610	430	180			
				610	430	180			
				675	435	240	240	42.63	
				670	430	240			
				675	435	240			
			5 "	750	420	330	322	57.20	
				740	430	310			
				755	430	325			
				800	440	360	377	66.96	
				810	430	380			
			7 "	830	440	390			
				849	425	415	423	76.02	Flame bent very powerfully, but not diminished or changed in colour; path of spark as much as possible through it.
				850	430	420			
				880	430	450			
		-	.5 "	510	430	80	78	13.85	
				515	435	80			
				510	435	75			
				530	425	105	97	17.23	Flame attracted so as to be in contact, diminished and made more bluish; spark passes through the flame.
				520	420	100			
			2 "	515	430	85	173	30.73	
				613	455	158			
				605	430	175			
				600	415	185			
				695	440	255	258	45.83	Flame attracted, but not in contact, assumes a toothed form broadened out across the disc, diminished, and more bluish; spark through the flame.
				700	440	260			
			4 "	700	440	260	350	62.17	
				810	450	360			
				780	445	335			
				790	435	355			
				865	450	415	408	72.47	
				880	460	420			
				890	500	390			

Feb. luminous.	+	6 "	760 745 650 760 800 820	190 200 190 200 210 200	570 545 460 560 599 620	525	93-25	Attracted, toothed form now lost; diminished, and made more bluish; spark through the flame. Sometimes diminished so much as to put out the flame. Flame repelled down; spark passes from about the centre of the disc to the edge of the tube. Flame repelled as before; spark passes more through the flames. Ditto. Flame repelled very much; spark evidently greater and from the higher part of the disc. Sputtering sound at the flame heard before the passing of the spark Great repulsion with increased sputtering at the flame; index gave no sign of discharge previous to the spark. Scintillations in the direction of the disc; spark very large; index steady some time before the passing of the spark. Flame attracted before being repelled down; index steady a considerable time before the passing of the spark. Flame attracted so as to be in contact; spark goes through the flame. Ditto. Flame attracted, but scarcely reaching to the disc; spark passes through the flame. Flame attracted first, then repelled, becoming horned and less luminous. Spark does not pass to tip, but about half way down. Flame repelled, losing luminosity; spark does not go through the flame. A large spark after some time; spark goes below the flame, not through it.
			507 485 485 479 481 481 472 466 466 435 430 440 360 400 403 300 280 260 290 285 310 350 335	528 510 510 517 517 517 520 516 520 517 505 505 470 500 500 485 490 490 485 495 490 495 500 500	21 25 25 38 36 36 48 50 54 82 75 65 110 100 97 185 210 200 225 205 205 185 150 165	24 583 37 51 74 102 198 212 167	12-06 103-6 18-60 25-62 37-18 51-25 99-49 106-5 83-91	
			485 480 468 465 468 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	
			485 480 480 468 465 390 465 370 240 360 260 155 70 about 0	505 505 502 502 505 480 500 506 480 470 475 475 470 470 640	20 25 25 34 37 90 45 41 110 230 115 215 315 400 640	23 36 59 223 372 640	11-56 18-09 29-65 112-0 186-9 321-6	

TABLE II.—HEIGHT OF FLAME VARIED.

Distance of tube from disc=3 cm.	Date.	Nature of Flame.	Sign of Charge on Disc.	Height of Flame.	Deflection.	Zero.	Difference.	Mean Diff. of Potential.	Abs. Value of Diff. of Potential.	Remarks on Appearance of the Flame.
	24th Jan.	non-luminous.	+	(cone.) 1 cm.	780 760 795 760 775 780 820 780 790 750 820 805	395 385 385 380 395 385 390 380 390 360 410 400	385 375 410 380 380 395 430 390 410 360 410 405	390	31·73	Slightly attracted, scintillations; spark passes through the flame.
				1·5				385	31·32	
				2				410	33·35	
				2·5				392	31·89	
				3				378	30·75	Has a protuberance towards the disc which is greatest about half-way up radius of disc; spark passes to protuberance.
				3·5				369	30·02	
				4				375	30·51	
				4·5				357	29·04	
				5				365	29·70	
				6				352	28·63	Protuberance opposite middle, upper part parallel to disc; scintillations pass in streams to the top; spark passes to protuberance.
			—	1	790 810 (off scale.)	380 390	410 420	415	33·76	Flame thrown down below, when the spark passes.
				2	840 805 860	380 400 430	460 405 430	432	35·14	No spark in the case of these three readings.
				3	710 745 800 840 880	390 400 360 400 460	320 345 440 420 450	368	29·94	
				5	900 860 845 850	430 415 410 410	445 435 440 440	437	35·55	Index generally steady for some time before the spark took place
								440	35·80	

	6	810 760 880 832 740 880 810 880 820 765 880 885	410 380 380 390 380 380 380 380 380 355 410 385 350	400 380 442 360 430 440 445 485	407	38-11 33-35 36-36	Spark obtained only after a considerable time.
luminous	(tip.) 1	360 363 362 368 385 370 380 380 381 390 388 380 389 385 403 408 405 405 395 396	440 439 439 428 425 420 436 436 433 440 434 435 438 435 452 451 452 450 435 430	80 76 77 60 40 50 56 56 52 50 46 55 49 50 43 47 45 40 34	78	44-90	Flame slightly attracted; scintillations after the passage of the spark.
	2	368 385 370 380 380 381 390 388 380 389 385 403 408 405 405 395 396	428 425 420 436 436 433 440 434 435 438 435 452 451 452 450 435 430	60 40 50 56 56 52 50 46 55 49 50 43 47 45 40 34	50	28-78	Top of flame repelled down into the body of the flame.
	3	368 385 370 380 380 381 390 388 380 389 385 403 408 405 405 395 396	428 425 420 436 436 433 440 434 435 438 435 452 451 452 450 435 430	60 40 50 56 56 52 50 46 55 49 50 43 47 45 40 34	55	31-66	Ditto.
	4	368 385 370 380 380 381 390 388 380 389 385 403 408 405 405 395 396	428 425 420 436 436 433 440 434 435 438 435 452 451 452 450 435 430	60 40 50 56 56 52 50 46 55 49 50 43 47 45 40 34	50	28-78	Scintillations after the spark; spark does not pass through any considerable portion of the flame.
	6	368 385 370 380 380 381 390 388 380 389 385 403 408 405 405 395 396	428 425 420 436 436 433 440 434 435 438 435 452 451 452 450 435 430	60 40 50 56 56 52 50 46 55 49 50 43 47 45 40 34	50	28-78	Repelled down so as to overlap the top of the tube.
	8	368 385 370 380 380 381 390 388 380 389 385 403 408 405 405 395 396	428 425 420 436 436 433 440 434 435 438 435 452 451 452 450 435 430	60 40 50 56 56 52 50 46 55 49 50 43 47 45 40 34	46	26-48	Ditto.
	15	368 385 370 380 380 381 390 388 380 389 385 403 408 405 405 395 396	428 425 420 436 436 433 440 434 435 438 435 452 451 452 450 435 430	60 40 50 56 56 52 50 46 55 49 50 43 47 45 40 34	40	23-02	Lower part of flame most affected; flame thrown down into and over tube; index very shaky before the passing of the spark.
	1	450 460 480 460 465 240 270 260 300 300 310 290 372 371 380 390 392 392	640 640 646 620 650 425 408 405 430 410 430 400 433 437 442 442 442 442	190 180 166 160 185 185 138 145 130 110 120 110 61 66 62 52 50	179	103-0	Tip attracted towards the disc, the yellowness disappears; no sign of any discharge before the passing of a large spark.
	2	450 460 480 460 465 240 270 260 300 300 310 290 372 371 380 390 392 392	640 640 646 620 650 425 408 405 430 410 430 400 433 437 442 442 442 442	190 180 166 160 185 185 138 145 130 110 120 110 61 66 62 52 50	177	101-9	First attracted, then yellowness disappears, then repelled and becomes like a blow-pipe flame; large spark finally.
	3	450 460 480 460 465 240 270 260 300 300 310 290 372 371 380 390 392 392	640 640 646 620 650 425 408 405 430 410 430 400 433 437 442 442 442 442	190 180 166 160 185 185 138 145 130 110 120 110 61 66 62 52 50	138	79-44	Ditto.
	4	450 460 480 460 465 240 270 260 300 300 310 290 372 371 380 390 392 392	640 640 646 620 650 425 408 405 430 410 430 400 433 437 442 442 442 442	190 180 166 160 185 185 138 145 130 110 120 110 61 66 62 52 50	113	65-04	Flame attracted so as almost to touch, then becomes blue, and becomes diminished as before, taking the form of a twisted fang pointing to the disc; large spark.
	5	450 460 480 460 465 240 270 260 300 300 310 290 372 371 380 390 392 392	640 640 646 620 650 425 408 405 430 410 430 400 433 437 442 442 442 442	190 180 166 160 185 185 138 145 130 110 120 110 61 66 62 52 50	63	36-26	Very nearly touching; good deal of yellow remains, not diminished much; horns at extremity of flame stretching out to disc.
	6	450 460 480 460 465 240 270 260 300 300 310 290 372 371 380 390 392 392	640 640 646 620 650 425 408 405 430 410 430 400 433 437 442 442 442 442	190 180 166 160 185 185 138 145 130 110 120 110 61 66 62 52 50	50	28-78	Touching, remains in contact, carbon deposited on disc for the first time; spark through the flame.
	20	450 460 480 460 465 240 270 260 300 300 310 290 372 371 380 390 392 392	640 640 646 620 650 425 408 405 430 410 430 400 433 437 442 442 442 442	190 180 166 160 185 185 138 145 130 110 120 110 61 66 62 52 50		17-16	A still higher flame was tried; contact permanent, with carbon deposited on the disc.