Phys Thesis Case

A Test on the Candle-Power of an Enclosed Arc Lamp.

Thesis by

[illegible]

May 1897.

Contents

Object.

The very rapid introduction of the enclosed arc lamp upon constant potential circuits makes it desiricable to study the efficiency and general behavior of such a lamp. The enclosed arc are supplanting the open arc and incandescent lamps very generally because they can be used anywhere that an incandescent circuit of 110 volts can be obtained, thus avoiding the introduction of high voltage wires into stores and public places where they may be dangerous to life and property. There are no sparks or flying particles of carbon, since the arc is entirely enclosed, and there is very little trouble caused by the visits of the trimmer, since the lamp burns over 100 hours with one trimming.

As compared to the incandescent lamp, the light of the enclosed arc is much whiter (nearer the color of daylight) than the incandescent. This is of advantage in stores where cloths of all kinds are sold, because colors can be matched easier than by the incandescent.

At first it was decided to make a series of tests of the lamp obtained (A. Manhattan Enclosed arc Lamp) under and determine the best and most economical conditions (as regards current and voltage) ~~under~~ under which to run it, using the apparatus as described in Part II of the Physical Laboratory Notes, except that the ammeter and voltmeter should be placed in the same room as the photometer itself. This was done and a

few preliminary readings were taken. This leads up to the difficulties met with.

The difficulties.

The arc being in an atmosphere in which there is very little oxygen, the carbons are not consumed by the ordinary combustion (except just as the arc starts) which produces the points in the open arc carbons, but, on the other hand, they burn with flat square ends. The carbons are one-half an inch in diameter and the arc burns between the two small points which happen to be nearest each other. The carbon gradually burns away at these two points until they are further apart than another pair of points. The arc then shifts to this new

place and the same thing occurs again. The arc is therefore shifting about on the carbons, sometimes burning in one place for quite a little while and then sometimes shifting quite rapidly from place to place.

Owing to the ~~square~~ flat ends of the carbon, as the arc shifts, the corners of the carbon (i.e. negative) keep most of the light from coming in a certain direction and the photometer gives a low reading. In a little while the arc may (or may not) shift so that the hot spot of the positive will no longer be hidden from the disc and the photometer will show a high candle-power, in some cases from 50 to 100 times what it was in the first case. This action is

very irregular, sometimes occuring frequently and sometimes not. From this it was seen that no results at all could be obtained (with the clear glass bulb used) by taking readings and waiting for the arc to shift unless an endless amount of time was spent. Also a certain series of nearly constant readings would not be a ~~reproti~~ representitive set, for perhaps a set taken 10 minutes afterwards would only give one-fiftieth of that candle-power.

This ~~decided~~ indulged me to make an apparatus to rotate the lamp and get the mean from a number of different horizontal directions. This will be described under Apparatus.

I was obliged to read the photometer

the ammeter and volts both at the arc and at the terminals for each set of readings. Of these the current varied quite rapidly from about 4.5 to 5.5 amperes and the volts at the arc from about 70 to about 82 volts and as the current increased the volts diminished, keeping the watts used in the arc nearly constant. Therefore to obviate the necessity of taking two fluctuating readings which could not be taken exactly at the same time I decided to measure the resistance of the solenoid and of the series resistance in the top of the lamp (by means of ammeter and voltmeter readings) and then, knowing their resistance and reading only current and volts at the terminals, the C R drop in these parts could

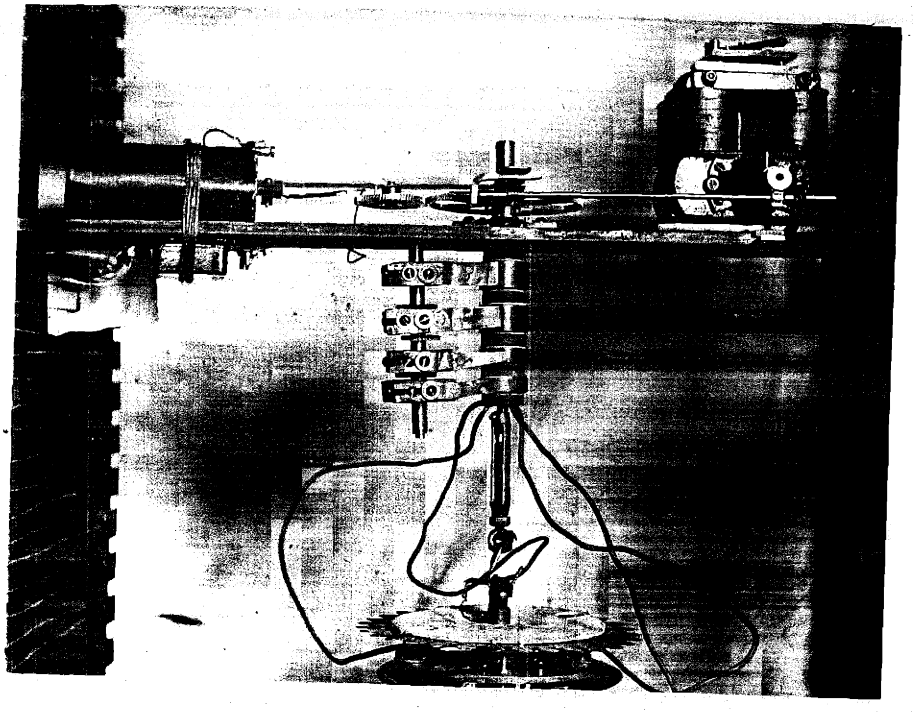
be calculated and this drop subtracted from the volts at the terminals would then give the volts across the arc itself.

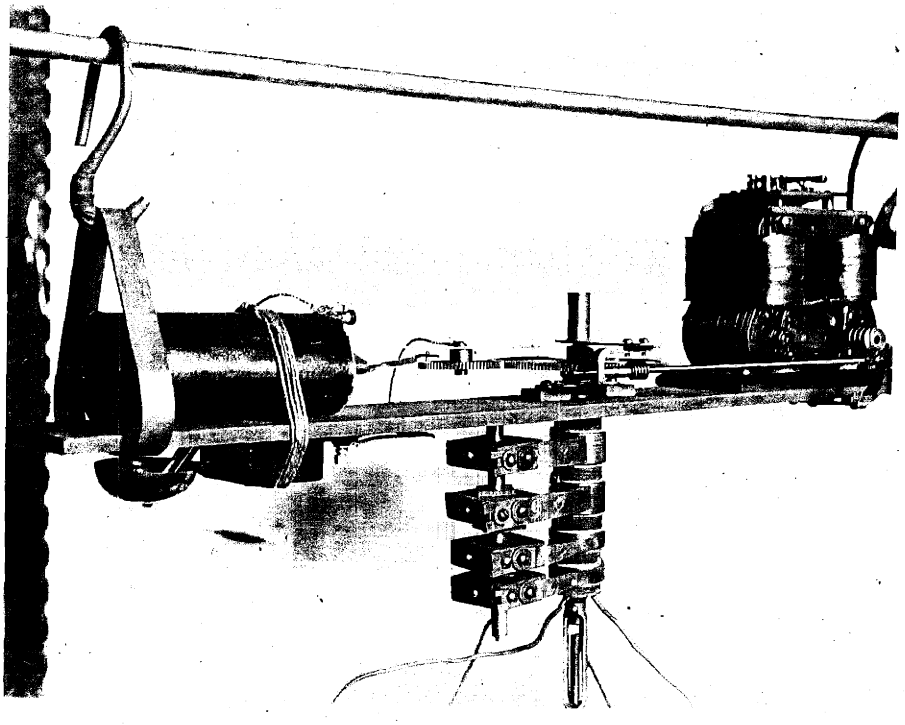
The measurement of the hot resistance was quite easy because when an external resistance was put in series with the lamp, although the current could be reduced to about 4.5 amperes before the lamp would go out, the resistance could then be cut out until the current went up to nearly 5.5 amperes before the arc would start again. Also the current and voltage reading were absolutely steady. The current used was about that used when the arc was burning so that the heating of the resistance would be the same as when the

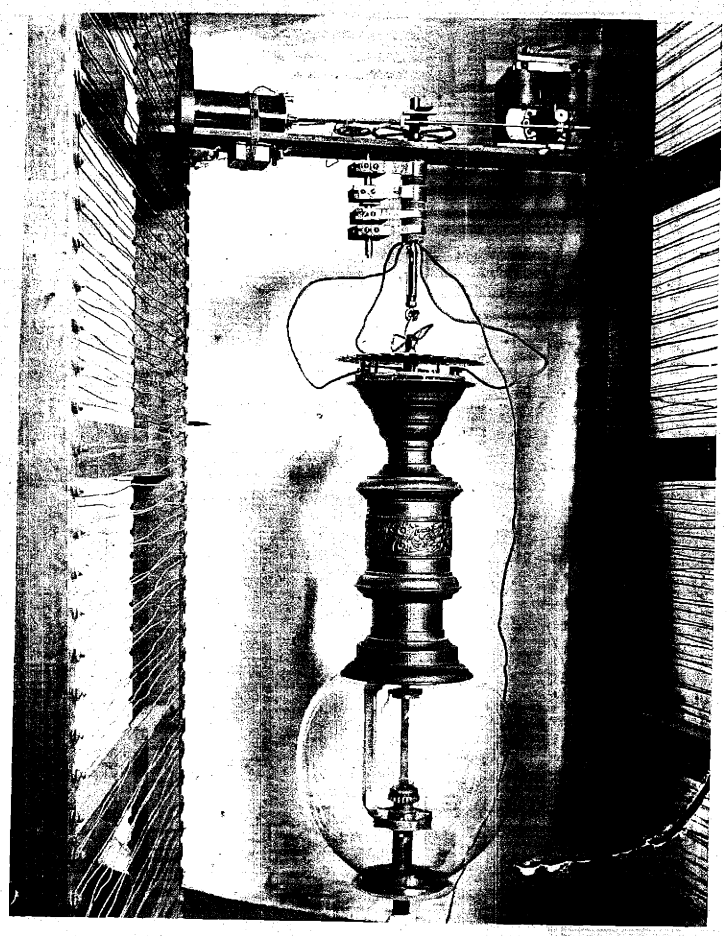
lamp was burning.

Apparatus and Methods

The apparatus for revolving the lamp is shown in the photograph and the wiring is shown in drawing. A worm on the shaft of a small 10 volt series motor (the only one available although the speed was irregular) turned an 8 tooth spur-gear which was fastened on a shaft about 12" long the other end of which carried a smaller worm. This shaft ran in loose bearings, one fastened to the iron supporting bar and the other to an arm projecting from a loose sleeve on the spindle from which the lamp was suspended. The arm followed the motions of lamp when it got to swinging and at the same







three always kept the small worm in mesh with the large gear fastened to the spindle and which revolved the lamp. The lamp revolved in ball-bearings, a collar fastened by a groove and set-screws to the spindle and turned cone-shaped like an ordinary ball-bearing cone, formed the cone. The cup was from a bicycle pedal. Driven on the spindle was a cylinder of wood on which were driven four ~~of~~ slip rings of brass. A wire was soldered to each ring and brought out at the bottom of the cylinder. Four brushes, one bearing on each ring, connected the current and voltmeter wires to the revolving lamp. The brushes were fastened to blocks of red fibre which could

be adjusted on a brass rod screwed into the supporting bar and they could each be locked in position by a set screw. A turn-buckle on the end of the spindle gave a means of adjusting the height of the lamp.

A second arm on the movable sleeve carried a 72 tooth wheel which geared into the large (160 tooth) gear wheel. A pin on the small wheel struck a copper strip once in every revolution and completed a circuit through a dry battery and a bell on the supporting-bar. The bell rang therefore once in $\frac{9}{20}$ of a revolution of the lamp. The bar was hung by hooks upon the V-shaped piping in the arc-light room and lamp revolved. The photometer-carriage was moved and kept

as nearly advanced as possible (the carriage) and when the bell rang that was left where it was and the current read as soon as possible. This current varied so much that it was not practicable to estimate tenths of divisions and only whole divisions (tenths of an ampere) were recorded. read and

The volts at the mains were then read and recorded and finally the photometer ratio recorded. This was then repeated for 20 readings. The candle-power was thus obtained in 20 different directions and every ~~other~~ reading was in a direction nearly opposite from the preceding one thus tending to more or less eliminate the effect of the shifting of the position of the arc on the carbons. The method of getting the directions in

This order occurred to me from thinking of the ordinary method of winding a drum armature where each conductor (or point) is connected before the winding is closed on itself. 20 was taken as a convenient number to take and to average, it being as large a number as the time permitted me to take.

The wiring is shown in the diagram. S_m is the main switch. The current enters lamp by means of one heavy brush (4) and leaves by the other (1). It then passes through S_3, a switch that short circuits the resistance box R_1, through S_4 (and ammeter A if S_4 is moved forward), R_2 which is a carbon rheostat (generally short-circuited) and fuse F.

When S_m is closed, a current flows through c and lamp L.

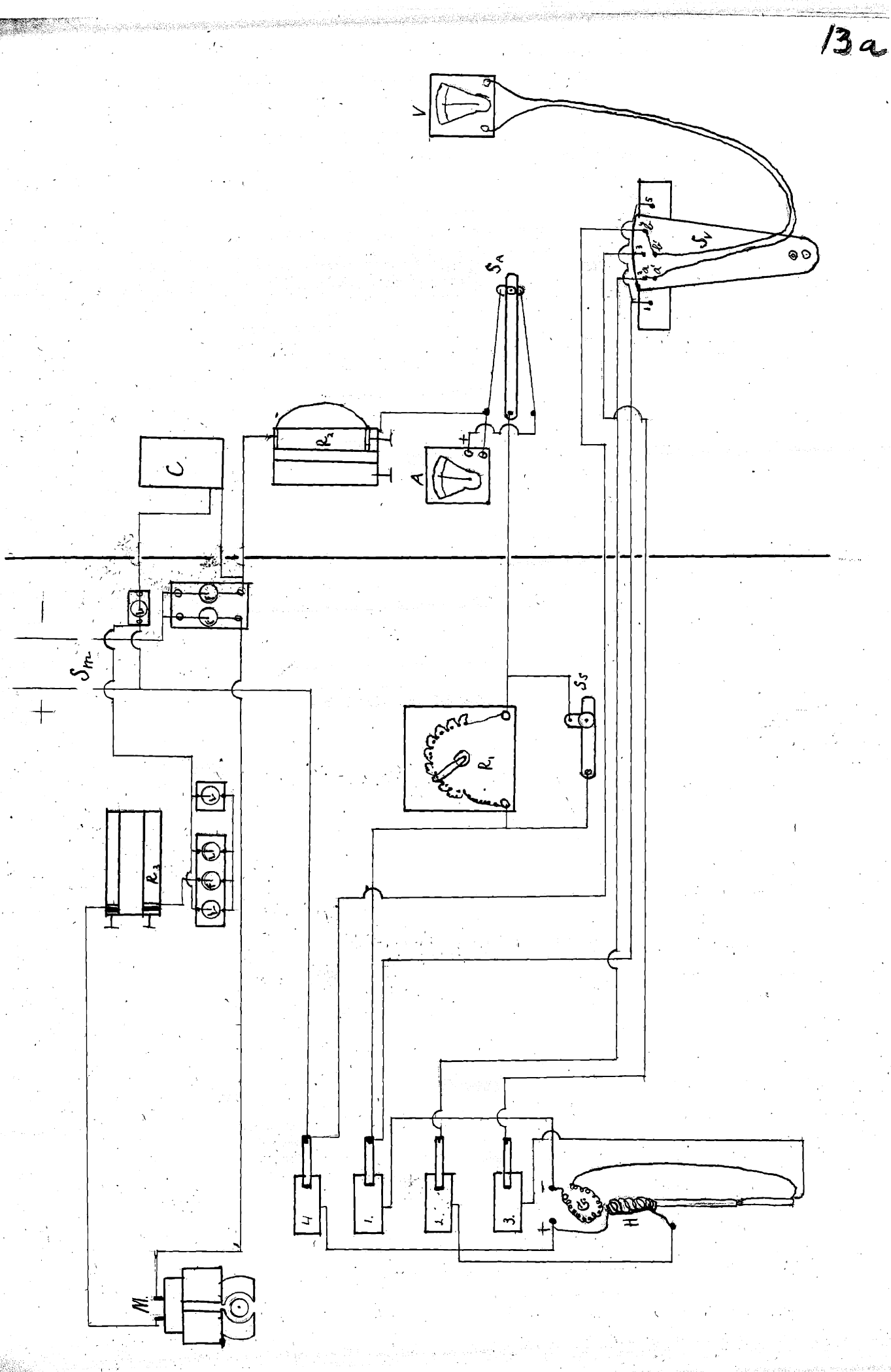
C is a clock that goes when the current flows through its electro-magnet and thus records the number of hours the lamp has burned. If fuse F is blown the clock stops.

The motor is connected in series with R_3 (a carbon rheostat with both branches in series) and with 3 lamps in parallel ~~(a 5 C.P. a 50 or 16~~ (2 - 50 C.P.s and 1 - 16 C.P.)

S_V is a voltmeter switch of 5 mercury cups and a red-fibre arm with two points "a" and "b" on one side and two others "a'" and "b'" on the other. The arm can be turned over so that a + b are in 2 and 4 giving volts reversed (H)

a + b " " " 1 " 3 " " " resistance (S)
or
a' + b' " " 3 " 2 " " " arc
a' + b' " " 5 " 4 " " " terminals.

and voltmeter terminals need not be reversed.


V
S_V
S_A
A
R_2
C
S_m
S_S
R_1
R_3
M.
4
1.
2.
3.
H

Note.

When A.C. current is shut off a bluish flame burns in the bulb near the top for a few seconds. Probably air from outer globe enters (due to cooling of air in inner bulb) and burns the CO in the bulb to CO_2 (i.e. the oxygen burned in the CO)

With clear globe the light above the horizontal is very blue (i.e. it is from the arc itself) except on the side towards the arc itself when the light from the carbons is seen. Horizontal lines of white and blue alternately are seen on the wall (due to the lense effect of the outer globe.)

When lamp is first turned on the volts at arc = 84. but as it gets hot the resistance of carbons increases and voltage is from 72 to 78. Arc flames at 84 volts.

Clear Bulbs gets smoky after an hour's burn and the deposit thickens as the lamp continues to burn.

I made some determinations of the light reflected from the wall back of mirror and found that it was negligible as the screens are ordinarily used.

Apr. 16. 1897.

Retrimmed lamp with ½" Electra carbons.

Negative $3\frac{15}{16}$" above socket
Positive 12" long
Clock R'dg 1814.0

May 29, 1897.

Negative $2\frac{13}{16}$" above socket
Positive $9\frac{3}{4}$" long
Clock R'dg 1924.2

In 30.2 hours
Positive burned $2\frac{1}{4}$"
Negative " $1\frac{1}{8}$"
∴ Positive burns twice as fast as the negative.

Apr. 20, 1911.

Preliminary Runs, Test at 5.0 Watts.

6.0 Watts Photometer Rdg. Ratio 16 C.P.	5.0 Watts Photometer Rdg. Ratio 16 C.P.
51.	32.0
48	47.0
47	16.75
40	22.97
43	1.14
41	22.00
47	33.00
60	38.00
56	47.00
64	51.00
1.14	1.39
.90	1.23
.76	1.10
.93	
37.00	

Shows effect of shifting of arc on carbons when clear bulb is used (as noted under title of difficulties.)

Apr. 15, 1898.

Calibration of Voltmeter No 342

R_v = 11 + 99 Ω. zero = 0.00

Temp Bath = 21.2

E.M.F. at 21.2 = 1.437

V	R	Vcal	cor
109.5	221	109.7	+.2
34.9	720	34.9	.0
104.4	240	104.7	+.3
4.9	5037	5.0	+.1

Calibration of Ammeter No. 995.

No 995 +.2	cor. for zero	Stan. +.07	cor. for zero
4.10	3.90	4.00	3.93
4.61	4.41	4.50	4.43
5.11	4.91	5.00	4.93

cor after apply zero cor.

	cor
at 4.10	+.03
" 4.61	+.02
" 5.11	+.02

May 16, 1891.

Standardizing of 16 C.P. Incandescent Lamp.

Photometer Rdg in inches.

	91.3
	91.7
	92.5
	92.2
	92.2
	92.0
	91.6
	92.0
	91.5
	92.0
Total	919.0
Mean	91.9 = 11.86 C.P.

May 18, 1921.

Clear 15 miles 1 1/2 hour.

Obs. No.	Current	V. Std. Length	Chart Ratio	Work Ring
1.	5.4	108.5	8.5	9913.2
2.	5.0	108.2	37.0	
3.	5.0	108.2	7.5	
4.	4.8	108.2	53.0	
5.	5.0	109.5	2.2	
6.	5.3	108.5	7.5	
7.	4.8	108.2	51.0	
8.	5.2	108.0	8.5	
9.	5.4	108.0	44.0	
10.	5.2	108.5	0.0	
11.	5.2	108.0	14.0	
12.	5.3	107.2	49.0	
13.	5.6	108.0	1.8	
14	5.4	108.5	49.0	
15.	5.6	108.0	0.0	
16.	5.5	108.0	10.5	
17.	5.6	108.0	17.2	
18.	5.2	108.0	3.4	
19.	5.0	107.5	49.0	
20.	5.0	108.0	1.0	
Tot.	104.5	2162.8	401.1	
Mean.	5.23	108.14	20.05	

May 18, 1891.

Clear Bulb. 0° Below

Obs. No.	Current	Volts at Lamp	Centre Ratio
1.	4.6	108.5	61.0
2	5.3	108.0	52.0
3.	5.0	109.1	7.0
4.	5.2	108.0	58.0
5.	5.0	107.5	1.8
6	5.7	108.0	56.0
7.	5.0	108.0	52.0
8.	4.9	108.0	18.0
9.	5.0	107.5	52.0
10.	5.1	108.5	29.0
11.	5.0	108.5	21.5
12.	4.7	108.0	60.0
13.	5.5	108.0	1.0
14	5.5	108.0	20.0
15.	5.5	107.8	64.0
16.	5.2	108.0	1.0
17.	5.3	107.5	41.0
18.	5.2	108.1	1.1
19.	5.0	108.0	48.0
20.	5.6	108.5	7.0
Total	103.3	2161.5	647.4
Mean	5.17	108.08	32.37

May 18, 1891.

Clear Cold. 5.1° Below

Obs. No.	Current.	Volts & Temp.	Platin. Ratio.	Calorie Rej.
1.	5.1	108.0	47.0	3913.8
2.	5.2	107.8	48.0	
3.	5.7	108.0	62.0	
4.	5.3	108.5	43.0	
5.	5.0	108.5	48.0	
6.	5.5	109.0	37.0	
7.	4.8	108.8	30.0	
8.	4.8	108.0	44.0	
9.	5.2	108.0	47.0	
10.	5.3	108.0	40.0	
11.	4.7	108.0	40.0	
12.	5.0	108.0	56.0	
13.	5.2	108.0	1.2	
14	4.9	107.1	58.0	
15.	5.6	108.5	1.3	
16.	5.3	107.2	70.0	
17.	5.4	108.5	6.0	
18.	4.8	108.2	5.5	
19.	5.3	109.0	54.0	
20.	5.6	109.0	1.4	
Total	108.7	2166.6	742.4	
Mean	5.19	108.33	37.12	

May 18, 1891.

Clear Bulb. 40° Below.

Obs. No.	Current	Volts	Photometer Reading
1.	5.5	108.0	28.0
2.	5.4	107.8	60.0
3.	5.7	108.0	31.0
4.	5.4	108.0	48.0
5.	5.2	108.2	32.0
6.	4.8	108.3	31.0
7.	4.8	107.5	52.0
8.	5.1	108.0	19.5
9.	5.1	108.0	49.0
10.	5.0	108.0	37.0
11.	5.0	109.0	60.0
12	5.5	107.8	22.5
13	5.1	108.0	45.0
14.	5.4	107.8	38.0
15.	5.4	108.0	46.0
16.	5.3	107.5	44.0
17.	5.7	108.0	42.0
18.	5.5	108.0	52.0
19.	5.3	108.0	37.0
20.	4.7	108.2	43.0
Total	104.9	2160.1	820.0
Mean	5.25	108.0	41.00

May 18, 1911.

Clear Bottle 30' Below.

Obs. No.	Current.	Voltage Temp.	Photic Ratio	Blue Ray
1.	5.1	107.6	24.0	1917.6
2.	5.2	108.5	35.0	
3.	5.0	109.0	24.0	
4.	5.1	108.8	39.0	
5.	5.1	108.8	32.0	
6.	5.6	109.0	33.0	
7.	5.0	108.0	26.5	
8.	5.1	109.0	38.0	
9.	5.8	108.0	36.0	
10.	5.7	108.0	43.0	
11.	5.5	107.8	43.0	
12.	5.2	108.0	37.0	
13	5.2	108.5	38.0	
14.	5.4	108.2	43.0	
15.	5.1	108.5	35.0	
16.	5.3	107.5	40.0	
17.	4.9	108.0	31.0	
18	5.5	108.0	28.5	
19.	5.1	108.0	44.0	
20	5.5	107.4	15.0	
Total	105.4	2164.8	675.0	
Mean	5.27	108.24	33.75	

Clear Bulb. 20° Below. May 18, 1891.

Obs. No.	Current	Voltage	Photic Ratio
1.	5.6	108.0	24.0
2.	5.4	108.0	21.5
3.	4.8	108.1	29.0
4.	4.5	108.0	38.0
5.	5.4	108.0	20.0
6.	5.3	107.5	27.0
7.	5.3	108.0	16.5
8.	5.2	107.5	28.5
9.	5.4	108.0	29.0
10.	5.7	108.0	16.0
11.	5.2	108.0	15.75
12.	5.1	108.0	220
13.	4.8	108.0	15.75
14.	5.2	108.1	40.08
15.	5.4	108.0	7.02
16.	5.5	108.0	39.02
17.	5.5	108.0	6.02
18.	5.8	108.0	33.02
19.	5.4	108.1	16.02
20.	5.1	108.0	22.0
Total	105.6	2159.3	469.0
Mean	5.28	107.97	23.45

May 18, 1891.

Klear Bulbs, 10' Below.

Obs. No.	Current	Volts & Emf.	Plant's Rate
1.	4.6	105.5	4.5
2.	5.1	107.0	24.5
3.	5.2	105.5	24.5
4.	5.6	105.5	15.0
5.	5.3	105.5	15.5
6.	5.1	105.5	4.2
7.	5.1	105.6	19.0
8.	5.4	105.5	5.0
9.	5.0	105.6	20.3
10.	4.9	107.0	3.5
11.	5.0	105.0	23.5
12.	5.1	105.0	7.4
13.	5.1	105.9	22.0
14.	5.6	107.5	10.25
15.	5.1	107.5	11.75
16.	5.2	105.0	19.5
17.	5.4	105.0	2.7
18.	5.6	105.8	25.0
19.	5.4	107.5	3.0
20.	5.5	107.5	26.0
Total	104.8	2165.6	287.10
Mean	5.24	108.28	14.35

May 18, 1891.

Clear Bulb. 0.°

Obs. No.	Current	Volts at Lamp	Photo Ratio
1.	5.3	108.5	15.5
2.	5.5	106.0	4.8
3.	5.4	108.0	12.5
4.	5.4	109.0	3.1
5.	4.6	107.5	5.0
6.	5.4	109.0	3.1
7.	5.3	108.0	3.5
8.	5.0	108.2	8.4
9.	4.8	107.8	2.8
10.	5.1	107.5	10.0
11.	4.8	108.0	3.2
12.	4.9	105.0	10.5
13.	5.1	108.5	3.5
14.	5.6	109.0	3.4
15.	5.6	108.2	8.2
16.	5.7	108.1	3.0
17.	4.6	107.8	22.5
18.	5.4	108.0	7.0
19.	5.4	108.0	14.0
20.	5.1	105.1	5.3
Total	103.7	2163.2	149.3
Mean	5.19	108.16	7.47

May 10, 1911.

Clear. Bulb 10° Above.

Obs. No.	Current	Volts	Lamp	Photometer Reading	Black Deg
1.	4.6	108.5		3.0	1915.7
2.	5.4	108.0		10.0	
3.	5.5	108.0		3.0	
4.	5.3	105.5		13.0	
5.	5.3	108.0		3.6	
6.	5.0	108.5		19.0	
7.	4.9	108.5		2.7	
8.	4.8	108.9		8.5	
9.	4.9	109.0		6.0	
10.	5.4	109.0		4.5	
11.	5.4	109.0		7.3	
12.	4.8	109.0		1.9	
13.	4.8	108.0		12.0	
14.	5.4	108.0		5.9	
15.	5.3	108.0		9.0	
16	5.4	108.0		3.6	
17.	5.5	108.0		6.4	
18.	5.5	107.8		3.1	
19.	5.6	108.0		7.4	
20.	5.4	108.0		5.5	
Total	104.2	2166.7		135.4	
Mean	5.21	108.34		6.77	

May 18, 1911.

Clear Bulb. 20° Above

Obs. No.	Current	Volts at Lamp	Photo. Ratio
1.	4.8	107.7	4.8
2.	5.2	108.1	5.4
3.	4.9	108.1	4.3
4.	5.1	108.0	6.4
5.	4.7	108.0	3.5
6.	4.9	109.0	7.3
7.	5.4	108.0	3.2
8.	4.8	108.1	11.0
9.	5.1	108.0	4.0
10.	5.6	108.0	6.9
11.	5.6	108.1	6.0
12.	5.0	108.1	5.1
13.	4.8	108.0	5.9
14.	5.1	108.0	4.5
15.	5.0	107.7	5.0
16.	5.5	108.8	5.8
17.	5.4	108.8	5.7
18.	5.6	108.8	7.7
19.	5.7	109.0	4.7
20.	5.0	107.5	5.8
Total	103.2	2164.8	113.0
Mean	5.16	108.24	5.65

May 18, 1891.

Clear Bulb. 30° above.

Obs. No.	Current	Volts & Temp.	Platin Resis.	Blank Rly
1.	4.8	109.0	12.0	0916.6
2.	4.8	108.5	2.2	
3.	5.6	108.5	3.4	
4.	5.3	108.3	4.3	
5.	5.3	108.0	5.6	
6.	4.8	108.0	6.0	
7.	5.1	108.5	3.5	
8.	5.4	108.0	9.5	
9.	5.2	108.0	4.0	
10.	5.5	108.2	7.5	
11.	5.2	108.0	5.9	
12.	5.6	108.0	4.1	
13.	4.6	108.0	6.7	
14.	5.4	107.5	4.6	
15.	5.1	108.0	5.8	
16.	5.0	108.2	4.5	
17.	5.1	108.2	6.7	
18.	5.1	108.0	4.1	
19.	5.0	107.2	8.2	
20.	5.0	108.0	3.2	0916.7
Total	103.1	2162.1	111.8	
Mean	5.16	108.11	5.59	

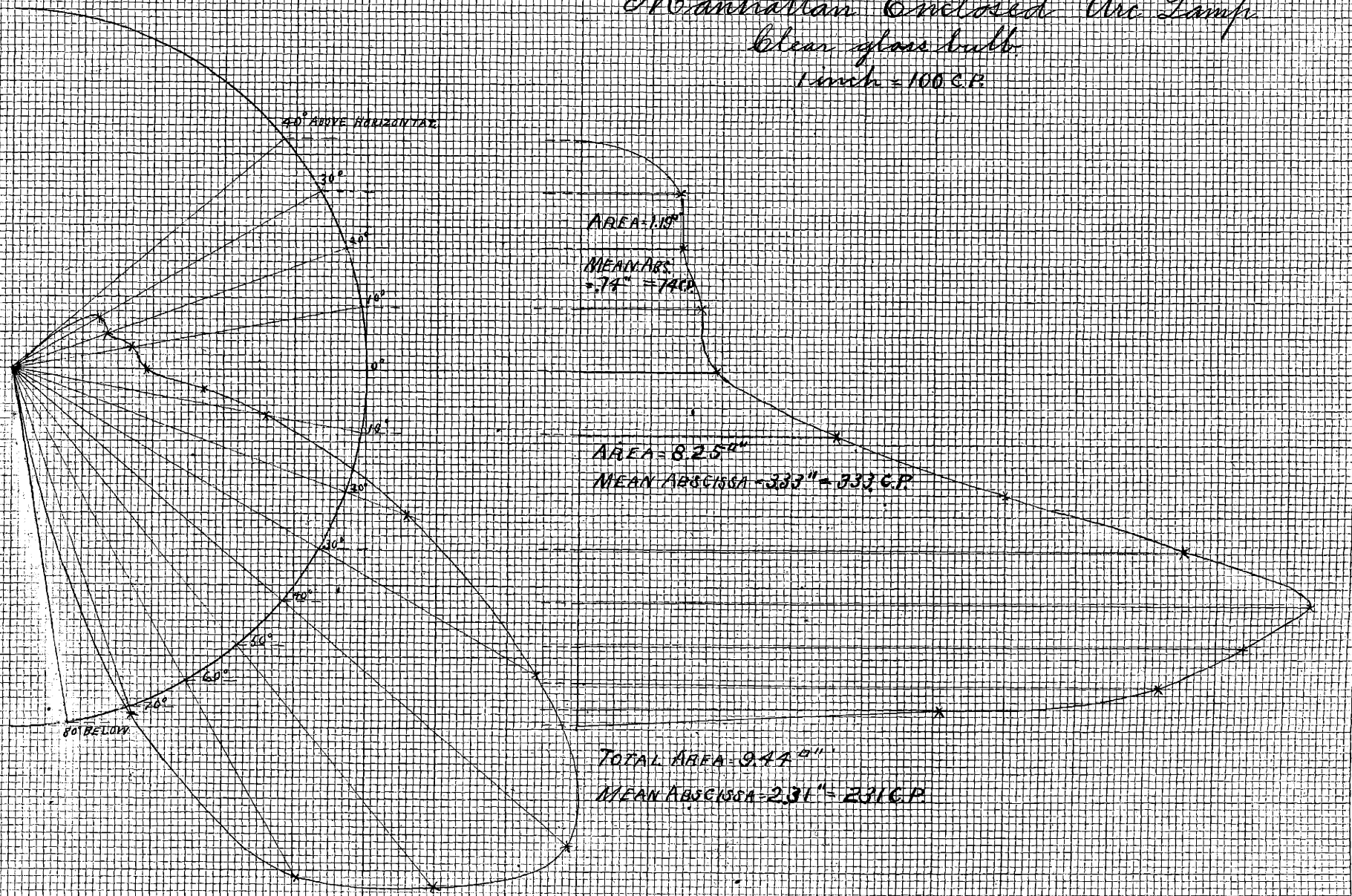
Summary of Vertical Distribution with clear bulb.

Direction	Mean Current	Mean Volts at Lamp	Mean Photric Reading	Candle-Power (uncorrected)	Candle Power corrected for Meter Factor.
30° above	5.16	108.11	5.59	66.30	70.78
20° "	5.16	108.24	5.65	67.00	71.53
10° "	5.21	108.34	6.77	80.30	85.72
0°	5.19	108.16	7.47	88.60	94.58
10° below	5.24	108.28	14.35	170.2	181.7
20° "	5.28	107.97	23.45	278.6	297.4
30° "	5.27	108.24	33.75	400.3	427.4
40° "	5.25	108.01	41.00	486.3	519.2
50° "	5.19	108.33	37.12	440.3	470.0
60° "	5.17	108.08	32.37	383.9	409.8
70° "	5.23	108.14	20.05	237.9	253.9
Total	57.35	1189.90			
Mean	5.21	108.2			
Cor. "	5.03	108.3			

Plot of the Distribution of Light on a Manhattan Enclosed Arc Lamp.

Clear glass bulb.

1 inch = 100 C.P.



May 17, 1897.

Standardizing of 16 C.P. Incandescent Lamp.

Photometer Bdg in inches
90.5
91.0
90.9
91.7
91.0
91.0
90.9
90.4
91.0
91.4
Total 909.8
Mean 90.98 = 10.99 C.P.

May 19, 1897.

Alabaster Bulb 70° Below.

Obs. No.	Current	Volts & Temp	Motor Ratio	Blower Rig
1.	5.6	108.0	5.7	0717.2
2.	5.6	108.5	9.4	
3.	5.2	107.9	11.75	
4.	5.5	107.8	6.0	
5.	5.4	108.0	15.25	
6.	5.3	108.4	7.5	
7.	5.2	108.2	9.3	
8.	5.6	108.0	20.0	
9.	5.1	108.5	8.5	
10.	4.9	109.2	16.5	
11.	4.8	108.0	7.6	
12.	5.4	108.0	8.1	
13.	4.7	108.1	11.75	
14.	5.3	108.0	7.1	
15.	4.9	108.2	6.90	
16.	5.3	108.5	10.00	
17.	5.1	108.6	6.1	
18.	5.1	108.5	10.25	
19.	4.8	108.2	9.0	
20.	4.9	108.5	14.0	
Total	103.7	2165.1	200.70	
Mean	5.19	108.26	10.04	

May 19, 1897.

Alabaster Bulb 61° Below.

Obs. No.	Current	Volts at Lamp	Photo. Ratio
1.	5.5	108.0	14.75
2.	5.7	108.0	16.75
3.	5.6	108.2	17.75
4.	5.4	108.2	11.5
5.	5.4	108.3	17.5
6.	5.1	107.8	9.2
7.	4.9	107.8	25.5
8.	4.6	108.0	7.7
9.	4.7	108.2	28.5
10.	4.7	108.0	6.3
11.	4.6	107.8	28.5
12.	5.2	107.5	6.9
13.	4.6	108.0	26.0
14.	5.3	108.0	9.9
15	5.6	107.8	14.0
16	5.7	107.5	16.5
17.	5.6	107.9	8.8
18.	5.3	108.0	22.0
19.	5.4	107.8	17.0
20.	5.2	108.2	21.0
Total	104.1	2159.9	326.05
Mean	5.21	108.00	16.30

May 19, 1897

Alabaster Bldg. 5° Below.

Obs. No.	Current	Volts & Temp.	Watts Ratio	Block Rej.
1.	4.4	105.8	38.0	0917.8
2.	4.1	109.0	7.6	
3.	4.1	108.2	33.0	
4.	5.2	108.1	21.0	
5.	5.2	108.0	6.9	
6.	5.5	106.5	47.0	
7.	5.4	109.0	10.0	
8.	5.5	109.0	28.0	
9.	5.3	107.5	20.5	
10.	4.8	109.0	24.5	
11.	5.0	107.8	16.25	
12.	5.7	105.0	12.25	
13.	5.6	107.2	33.0	
14.	5.7	108.8	15.0	
15.	5.6	108.5	18.75	
16.	4.8	108.0	17.50	
17.	4.6	107.6	24.0	
18.	5.5	107.5	17.25	
19.	4.6	105.5	32.0	
20.	5.0	108.5	7.0	
Total	103.2	2163.5	429.50	
Mean.	5.16	108.18	21.48	

May 19, 1897.

Manchester Bulb 40° Below.

Obs. No.	Current.	Voltage Comp.	Photo Ratio.
1.	5.6	108.0	18.25
2.	5.2	108.0	29.5
3.	5.4	108.0	21.0
4.	5.2	108.5	40.0
5.	4.9	108.1	22.0
6.	4.9	108.0	19.25
7.	5.0	108.1	29.5
8.	5.2	108.2	11.75
9.	4.8	108.0	30.1
10.	5.2	107.8	11.0
11.	4.6	108.0	27.0
12.	4.6	108.0	22.0
13.	5.4	108.0	19.25
14.	5.3	108.1	39.0
15.	5.7	107.8	29.0
16.	5.4	108.1	31.0
17.	5.7	107.2	34.0
18.	5.3	108.0	31.0
19.	4.9	107.9	16.75
20.	5.6	108.1	34.0
Total	103.9	2157.9	577.35
Mean	5.20	108.00	25.87

May 19, 1897.

Alabaster Bulb. 30° Below.

Obs. No.	Current	Volts at Lamp.	Photo's Rt.	Glare Rig
1.	5.5	108.0	33.0	0718.5
2.	5.5	108.0	12.5	
3.	4.6	108.8	35.0	
4	5.2	108.0	13.5	
5.	5.0	101.5	34.0	
6.	5.6	107.8	28.0	
7.	5.4	108.0	27.5	
8.	5.7	108.8	26.0	
9.	5.3	108.0	15.75	
10.	4.9	108.0	27.0	
11.	5.7	107.8	23.0	
12.	5.7	108.5	29.0	
13.	5.7	108.0	36.0	
14.	5.5	108.0	21.5	
15.	5.6	108.0	33.0	
16	5.4	108.0	33.0	
17.	4.8	108.0	17.5	
18.	5.1	108.0	27.0	
19.	4.6	105.2	17.0	
20	5.2	108.2	18.5	
Total	106.0	2161.6	510.75	
Mean	5.30	108.08	25.54	

May 19, 1917.

Alabaster Bulb. 20° Below.

Obs. No.	Current	Volts at Lamp	Photo Ratio
1.	5.6	108.2	26.5
2.	5.7	108.2	33.0
3.	5.5	108.2	26.0
4.	5.5	108.5	33.0
5.	5.3	108.0	21.0
6.	5.5	108.2	19.25
7.	5.3	108.2	34.0
8.	5.1	108.3	12.25
9.	4.7	108.2	29.0
10.	5.0	108.1	16.25
11.	4.9	107.5	23.0
12.	5.0	108.2	21.0
13.	5.0	108.8	16.25
14.	5.4	108.5	37.0
15.	5.4	108.3	8.4
16.	5.1	108.2	36.0
17.	4.6	108.5	13.75
18.	5.0	108.9	27.5
19.	5.2	108.0	28.0
20.	5.2	108.0	13.0
Total	104.0	2165.0	474.15
Mean	5.20	108.25	23.71

May 17, 1897.

Alabaster Bulb. 10° Below.

Obs. No.	Current	Volts at Lamp	Photo Ratio	Block Rdg.
1.	4.8	108.2	12.25	0919.0
2	5.2	108.2	19.25	
3.	5.5	108.1	22.0	
4.	5.6	108.5	12.5	
5.	4.7	108.4	30.0	
6.	5.3	107.5	8.7	
7.	5.3	108.2	25.5	
8.	5.0	108.0	15.75	
9.	5.4	108.0	17.5	
10.	5.0	108.0	21.0	
11.	5.6	108.2	11.0	
12.	5.5	108.2	22.0	
13.	5.4	108.0	17.5	
14.	5.1	108.5	25.5	
15.	5.3	108.1	23.0	
16.	5.2	108.5	21.5	
17.	5.4	108.0	30.0	
18.	5.3	108.5	18.0	
19.	5.4	108.2	24.0	
20.	5.3	108.2	15.75	
Total	106.1	2163.5	395.70	
Mean	5.31	108.18	19.78	

May 17, 1897.

Alabaster Bldg. Co.

Obs. No.	Current.	Volts at Comp.	Photo. Rate.
1.	5.1	108.2	13.75
2.	5.1	108.5	10.75
3.	5.3	108.2	19.25
4.	5.6	108.0	12.0
5.	5.3	108.0	13.75
6.	5.3	108.0	12.5
7.	5.0	108.2	16.25
8.	5.3	108.2	21.0
9.	5.6	109.0	13.5
10.	5.3	107.5	16.25
11.	5.2	108.2	12.0
12.	5.3	108.8	14.75
13.	5.3	109.0	12.5
14.	5.2	109.0	15.5
15.	5.6	108.2	16.75
16.	5.0	108.5	17.0
17.	5.4	108.0	11.0
18.	5.5	107.8	14.0
19.	5.2	107.5	11.0
20.	4.8	108.5	20.0
Total	106.0	2165.3	293.50
Mean	5.30	108.27	14.68

May 19, 1891.

Moderator Bands. 10° Above.

Obs. No.	Current	Volts at Terminals	Motor Ratio	Block Rig.
1.	5.3	108.2	8.8	1919.5
2.	5.4	108.0	15.75	
3.	5.4	108.0	11.75	
4.	5.2	108.5	13.5	
5.	5.0	108.8	14.5	
6.	4.8	108.8	10.75	
7.	5.2	108.5	24.0	
8.	5.2	108.5	9.7	
9.	4.9	108.0	19.5	
10.	5.2	108.0	13.25	
11.	5.0	107.8	17.0	
12.	5.6	108.0	23.5	
13.	5.4	108.8	14.5	
14.	4.8	108.8	14.75	
15.	4.8	109.0	13.0	
16.	4.9	108.1	11.0	
17.	5.2	108.0	12.0	
18.	4.9	107.5	13.0	
19.	5.2	108.5	11.5	
20.	5.5	108.6	14.75	
Total	102.9	2166.4	286.50	
Mean	5.15	108.32	14.33	

May 19, 1891.

Alabaster Bulb. 20° Above.

Obs. No.	Current.	Volts at Lamp	Photo Ratio
1.	5.0	109.0	16.75
2.	5.4	108.2	1.4
3.	5.7	108.4	19.0
4.	5.6	109.0	10.0
5.	5.4	108.0	14.0
6.	5.7	107.8	10.0
7.	5.1	107.5	13.0
8.	5.4	108.5	9.5
9.	5.3	109.0	10.0
10.	5.2	108.5	8.5
11.	5.3	108.2	8.9
12.	5.3	109.0	13.5
13.	5.5	108.4	12.0
14.	5.4	109.0	12.0
15.	5.7	108.8	15.0
16.	5.4	108.5	11.5
17.	5.5	108.2	14.25
18.	5.3	108.0	11.75
19.	4.8	108.2	12.25
20.	5.3	108.5	16.75
Total.	107.3	2168.7	246.05
Mean.	5.37	108.44	12.31

May 19, 1887.

Alabaster Bulb. 32° Above.

Obs. No.	Current.	Volts at Lamp.	Photo Rdg.	
1.	5.5	108.0	8.1	Part of
2.	5.5	108.5	11.5	bulb
3.	4.8	107.5	10.0	shaded
4.	4.7	109.0	9.5	by top
5.	5.5	107.3	10.25	of lamp.
6.	5.5	107.2	6.2	
7.	4.7	109.5	13.0	
8.	5.0	108.2	21	
9.	5.0	108.0	15.75	
10.	5.5	108.0	11.75	
11.	5.1	108.5	120	
12.	5.6	108.1	15.75	
13.	5.5	108.8	8.4	
14.	5.5	107.0	16.0	
15.	5.3	109.5	7.4	
16.	5.0	108.2	11.75	
17.	5.6	109.0	14.00	
18.	4.8	108.5	10.75	
19.	5.3	107.5	8.6	
20.	5.3	109.5	8.5	
Total	104.7	2167.8	215.80	
Mean	5.24	108.39	10.79	

May 19, 1917.

Alabaster Bulb. 40° above.

Obs. No.	Current	Volts at Lamp	Watts per C.P.	Remarks
1.	5.2	108.1	7.0	0920.0
2.	4.8	108.0	4.6	
3.	4.8	108.2	6.8	
4.	5.6	108.8	5.6	One-half
5.	5.2	109.0	5.8	of bulb
6.	4.8	109.2	4.9	shaded
7.	5.1	109.0	4.6	by top
8.	4.6	109.1	6.1	of lamp.
9.	4.8	108.2	6.0	
10.	4.8	108.0	6.0	
11.	4.9	107.8	4.0	
12	5.0	108.1	7.8	
13	5.3	108.0	4.8	
14.	5.2	108.1	6.4	
15	4.8	109.5	6.7	
16.	5.4	108.5	7.8	
17.	5.5	108.2	3.8	
18.	5.0	108.5	9.0	
19.	5.1	108.2	4.5	
20.	4.9	108.6	5.2	
Total	100.8	2169.1	119.4	
Mean	5.04	108.46	5.97	

May 19, 1897.

Alabaster Bulb. 50° above.

Obs. No.	Current	Volts at lamp	Photo's Rate	
1.	5.1	108.0	3.1	
2.	5.3	107.5	1.7	
3.	4.8	108.2	4.0	Bulbs
4.	4.8	108.5	1.6	nearly
5.	5.4	108.2	3.3	all
6.	5.4	108.7	1.9	shaded.
7.	5.3	109.0	2.5	
8.	5.2	109.0	2.0	
9.	5.5	109.0	2.3	
10.	5.6	108.2	2.5	
11.	5.6	108.0	3.0	
12	5.5	108.0	2.8	
13.	5.4	108.5	2.6	
14.	5.7	109.0	3.7	
15.	5.6	108.0	3.4	
16	5.1	108.5	1.9	
17.	4.8	108.5	3.2	
18.	5.4	108.8	1.7	
19.	4.8	108.0	2.5	
20	5.2	108.1	1.8	
Total	104.8	2167.7	50.8	
Mean	5.24	108.39	2.54	

Summary of Vertical Distribution with alabaster bulb.

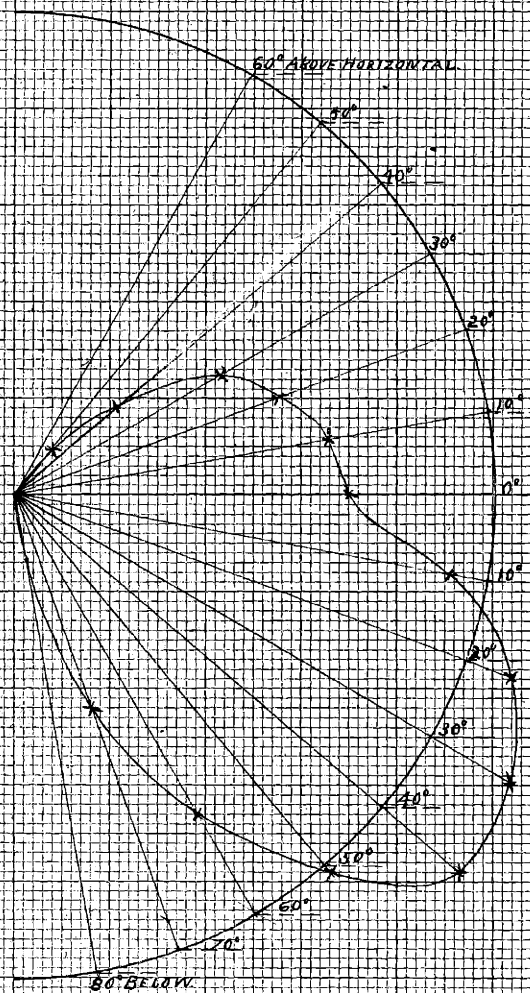
Elevation	Mean Current	Mean Volts at Lamp.	Mean Photo. Ratio.	Candle-Power (uncorrected)	Candle-Power corrected for Mirror & Globe.
50° above	5.24	108.39	2.54	27.92	29.81
40° "	5.04	108.46	5.97	65.63	70.07
30° "	5.24	108.39	10.79	118.6	126.6
20° "	5.37	108.44	12.31	135.3	144.5
10° "	5.15	108.32	14.33	157.5	168.2
0°	5.30	108.27	14.68	161.4	172.3
10° below	5.31	108.18	19.78	217.4	232.1
20° "	5.20	108.25	23.71	260.6	278.2
30° "	5.30	108.08	25.54	280.7	299.7
40° "	5.20	108.10	25.87	284.4	303.6
50° "	5.16	108.18	21.48	236.1	252.1
60° "	5.21	108.00	16.30	179.2	191.3
70° "	5.19	108.26	10.04	110.4	117.8
Total	67.91	1407.22			
Mean.	5.22	108.2			
Cor. Mean	5.04	108.3			

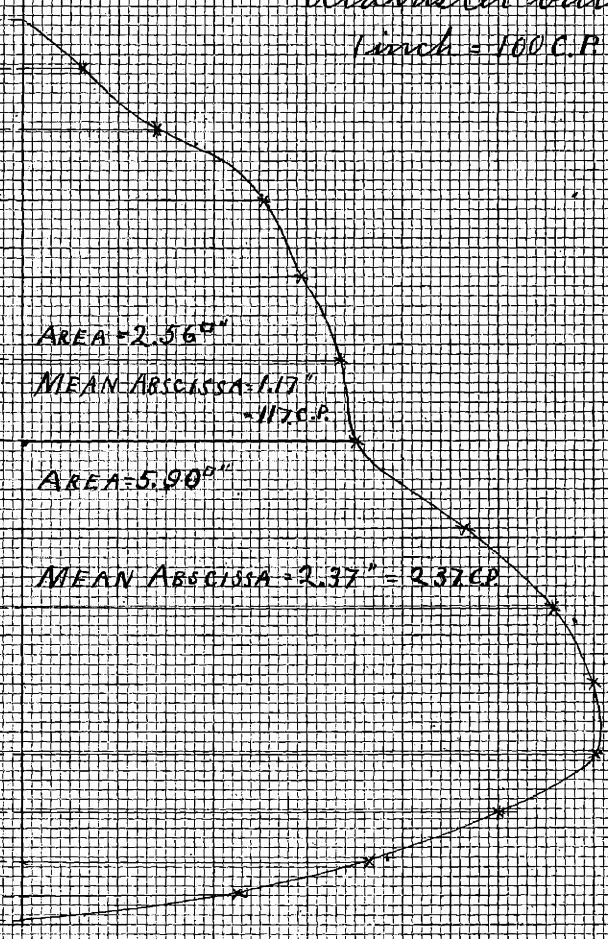
46a

Plot of the Distribution of Light on a Manhattan Enclosed Arc Lamp.

Alabaster bulb.

1 inch = 100 C.P.





AREA = 2.56 □"

MEAN ABSCISSA = 1.17" = 117 C.P.

AREA = 5.90 □"

MEAN ABSCISSA = 2.37" = 237 C.P.

TOTAL AREA = 8.46 □"

MEAN ABSCISSA = 1.81"

" " = 181 C.P.

May 29, 1897.

Resistance (hot) of series posts.

Current	Volts drop through series resistance	Volts drop through solenoid	
4.90	30.2	2.4	
4.90	30.1	2.5	
4.90	30.0	2.4	
4.91	30.0	2.4	
4.90	30.0	2.5	
4.88	29.9	2.5	
4.92	30.1	2.5	
4.91	30.0	2.6	
4.90	30.2	2.5	
4.88	29.9	2.5	
Total 49.00	300.4	24.8	
Mean 4.90	30.04	2.48	
Ave. 4.72	29.9	2.4	

Total Resistance = $\frac{E}{R} = \frac{32.2}{4.72} = 6.84\ \Omega$

Results (both tests.)

Watts in lamp 545.3

" " arc 372.0

Volts at " 73.8

% of work in arc 68.2%

Watts used in lamp per candle

	Clear bulbs	Alabaster
Mean Horizontal.	1.64	2.30
Mean Spherical	2.36	3.01

I would suggest that the apparatus be used, in the same way as has been described, for a series of runs of exactly the same condition, to see how the different results agree with each other. I think another run might give results that vary more by 20 or 30% from the preceeding due to the average position of the arc on the carbons.

I would also suggest that various currents and voltages be used, to see their effect.