1165

T H E S I S

T E S T S   O F   A R C   L A M P S

by

S. S. Young.   C. R. Jacobus

June 18, '08.

TESTS OF ARC LAMPS

Outline.

I. History & Theory

II. Data

III. Curves.

IV. Discussion;

1. Photometry.
2. Carbons.
3. Power Factor
4. Regulation.

V. Conclusions.

History and Theory.

In the year 1800 Volta observed the spark, in which year, also, Davy discovered the particularly bright spark between charcoal points separated in air or in liquids, with pressure from 150 elements. In 1808 Davy with a battery of 2000 elements exhibited the first true arc, a flame of about four inches long, before the Royal Institution at London, England. The discharge was maintained between horizontal charcoal points and due to the currents of heated air, it assumed a path which was arched, hence the name "arc."

In 1838, Gassiat showed that the temperature of the positive electrode was much greater than that of the negative, in which experiment he had two wires of the same substance and diameter, and that which formed the positive pole of a horizontal arc was melted enough to bend down, while the negative remained perfectly stiff. In the same year with the aid of Walker, Sturgeon and Mason, he observed the relation of the arc at the pole of a magnet.

This effect of a magnet on the arc has been utilized practically in the repulsion of the arc downward, by the blow down coils on the flaming arc lamp, now in use. These blow-down coils (shown in Fig. 2) are connected so that the magnetic flux from their cores passes between the carbons in a direction, away from and perpendicular to the plane of the paper. Now the current flowing through from the position (suspended carbon) to the negative carbon, creates a flux which flows in a clockwise direction, when the observer is looking in the direction of the current, or in other words the flux at a point directly above the center of the arc has a direction toward and perpendicular to the plane of the paper, while at a point diametrically opposite the direction of flux is away from the plane of the paper; therefore we have a weakning of flux a alone the arc and a strengthening of field below the arc, and consequently the flame is blown down as it were, giving a better distribution of light.

In 1843 Foucault used gas coke carbons to replace the charcoal before used, and in the same year Graves used the salts of sodium and potassium to increase the length and steadiness of the arc, a principle which is also used in the flaming arc today.

In 1867, Edlund discovered that with a constant current the apparent resistance is equal to a constant resistance plus a resistance which varies directly with the length of the arc. In his experiments he used a battery to send a current through an arc of known definite length, then putting out the arc and pressing the carbons tightly together, he measured the distance by which he had to separate the plates in a copper voltmeter, so as to bring the current to the same value as before. Doing this for various lengths of arc he found that as long as the current was kept constant the length of the copper voltmeter, which represented the arc, could be expressed by a constant length plus a length which varied directly with that of the arc. Putting his results in the form of an equation he found that r equals a plus b l, where r is the apparent resistance of the arc, l its length, and a and b constants for a constant current.

He found, however, that when the current was varied, a and b both diminished as the current increased, so that the apparent resistance of the arc for a given length decreased with the increase of the current.

Edlund performed his experiments with the idea that there was a back E. M. F. in the arc caused by the disintegration of the carbon particles. On his third experiment he found that when an arc was produced with a somewhat large current between carbon poles, the arc continued for a short time after the circuit was broken, so that if the circuit were closed again quickly after the break had been made, the arc was not put out. But on the other hand, when silver poles were used the arc did not continue for over 1/80 of a second after the circuit was broken.

From this he concluded that if carbon poles were used, and if immediately after breaking the circuit the carbons were switched on to a galvanometer, a momentary current would be sent by the arc through the galvanometer, and the existence of the back E. M. F. would be made certain.

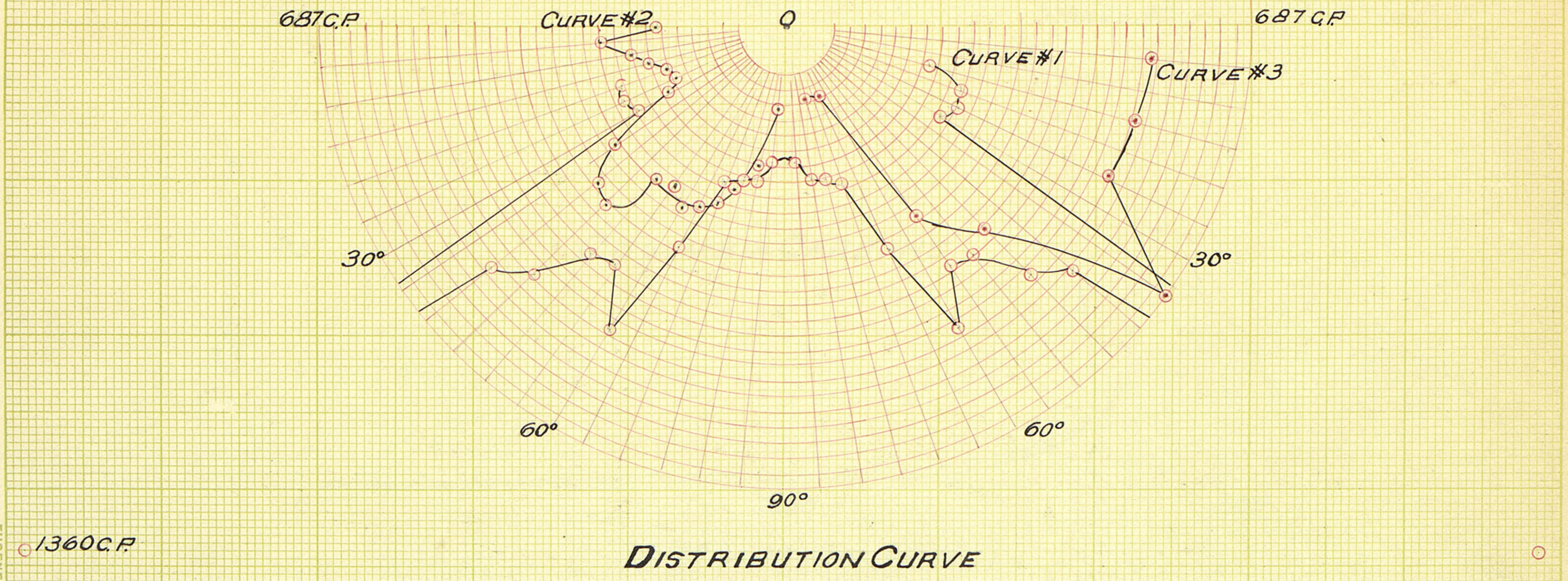
In 1885 Penkert found that a in Edlund's equation, r equals a plus b l, varied inversely as the current, but he pointed out that he diminished more quickly than the current increased. He explained that latter fact as being due to the air surrounding the arc becoming very hot when the current was large, and so acting itself as a conductor.

He considered the question of the existence of a back E. M. F. in the arc, and showed that the mean value of Aa was about 35 volts, in which A was current. He thought, however, that an

E. M. F. of this magnitude could not be set up by the disintegration of the carbon, as Edlund has supposed, and that if this E. M. F. was produced it should increase with the current.

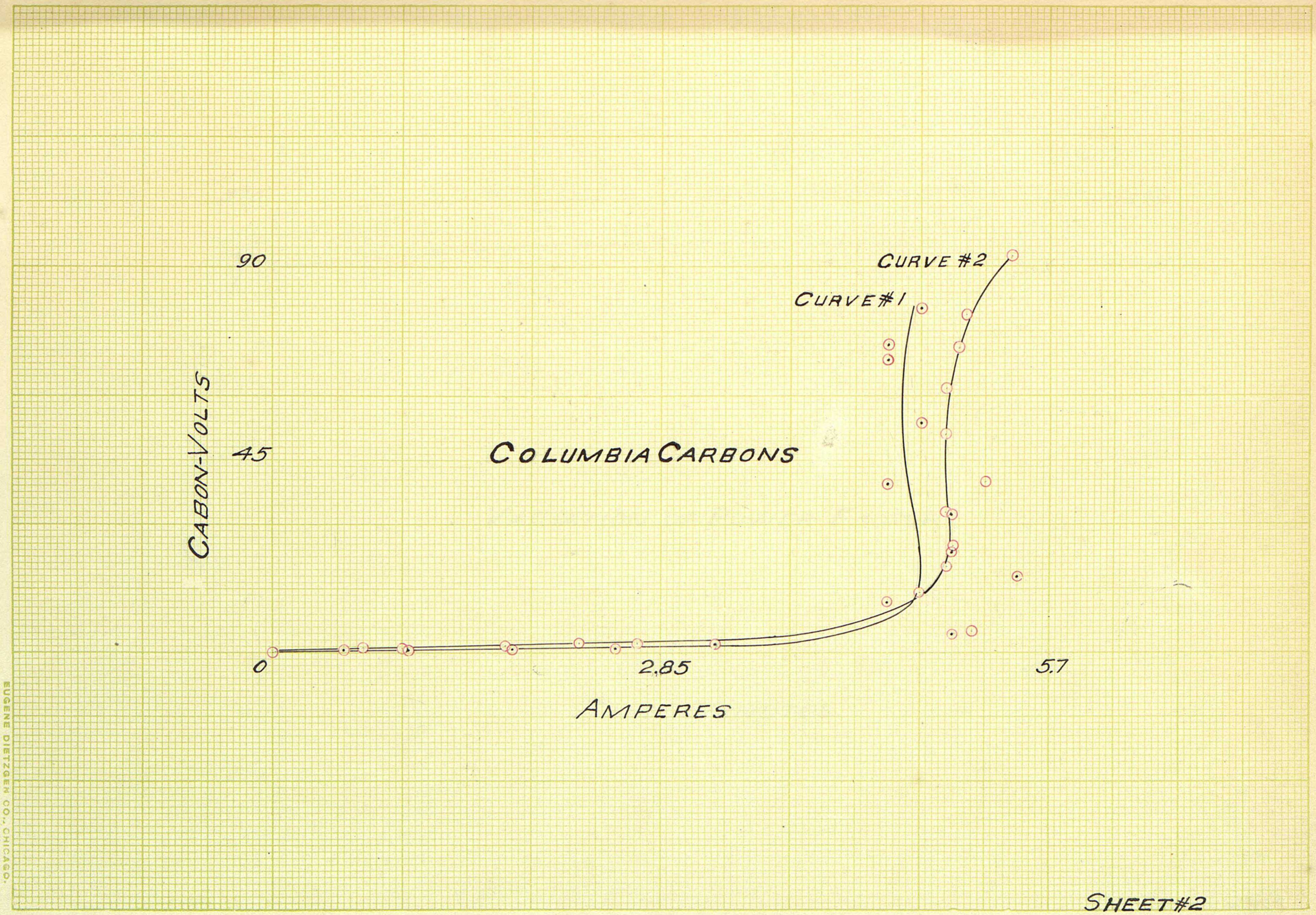
The above facts, however, do not satisfactorily explain the conditions that exist in the arc. The latest and most reasonable explanation is afforded by the "Ionic theory" applied to the arc, and is as follows: The current is carried by ions. These ions are preduced, either within the cathode (plus carbon) by the high temperature, or at the boundary surface, or by impact of the positive ions on the molecules of gas formed by the heat and consequently breaking these molecules into the current carrying ions, or through the gas by impact of the actions on the negative ions at high temperatures, or at the boundry surface of the anode (minus carbon) by the impact of the negative ion.

Stark and Cassuto have ashown that the lower the temperature of the anode (negative carbon) the smaller the drop in potential. Their explanation is that a hot substance emits negative ions and that this emission of such ions produces an E. M. F., which at the anode opposes the current. If this is true then, the existence of the apparent back E. M. F. in the arc is explained, and also the disapearance of the back E. M. F. when the circuit is opened.

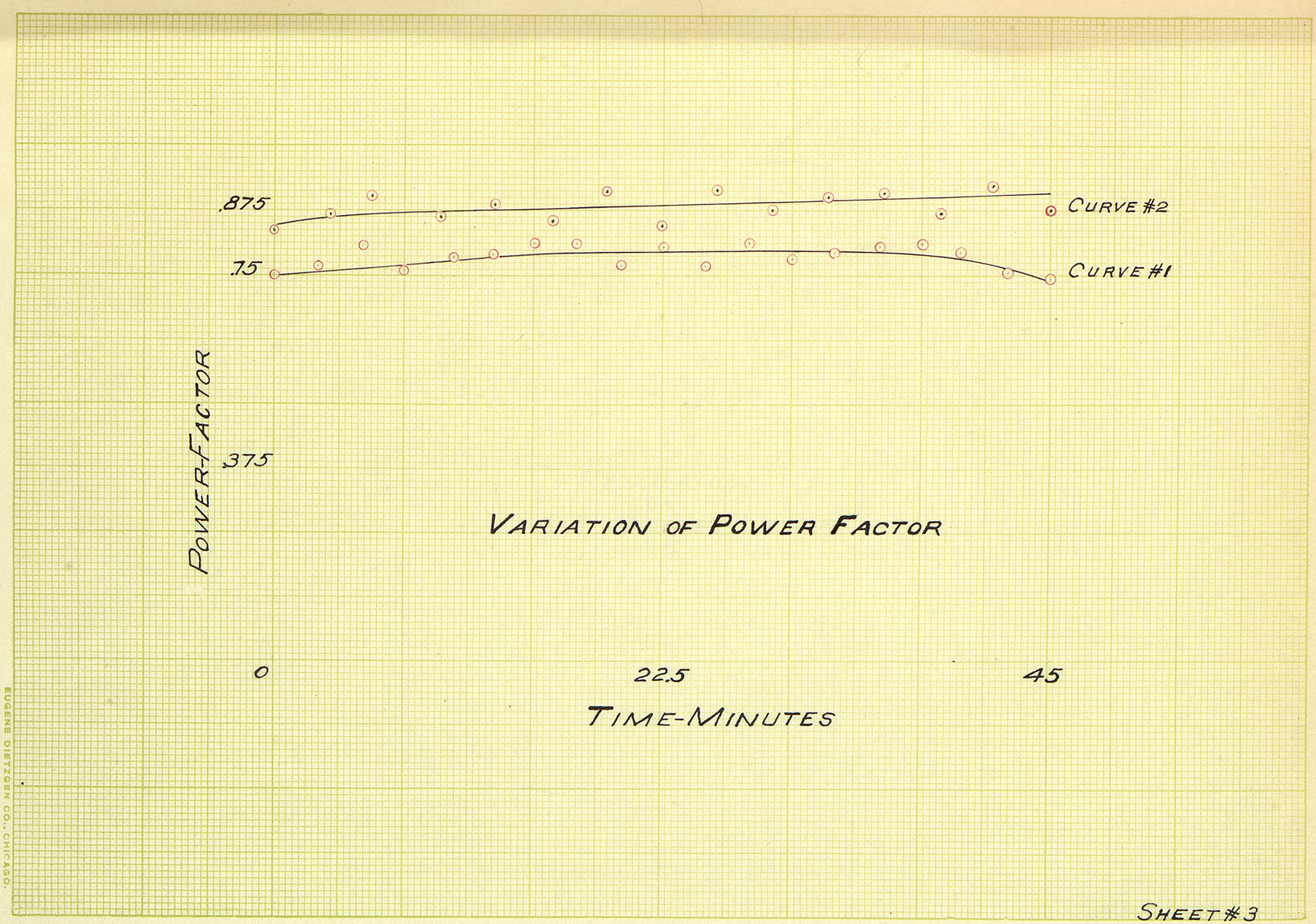


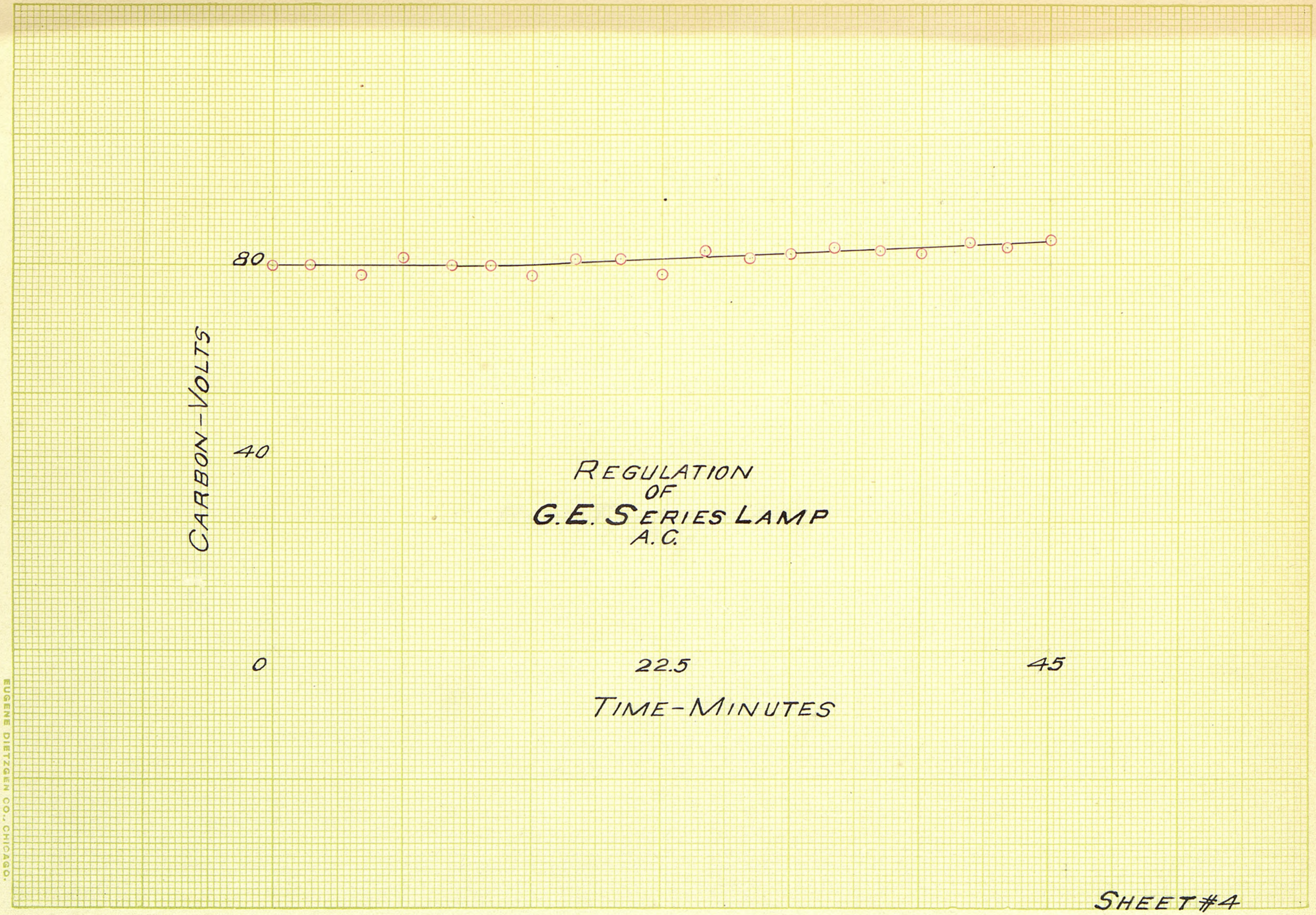
DISTRIBUTION CURVE

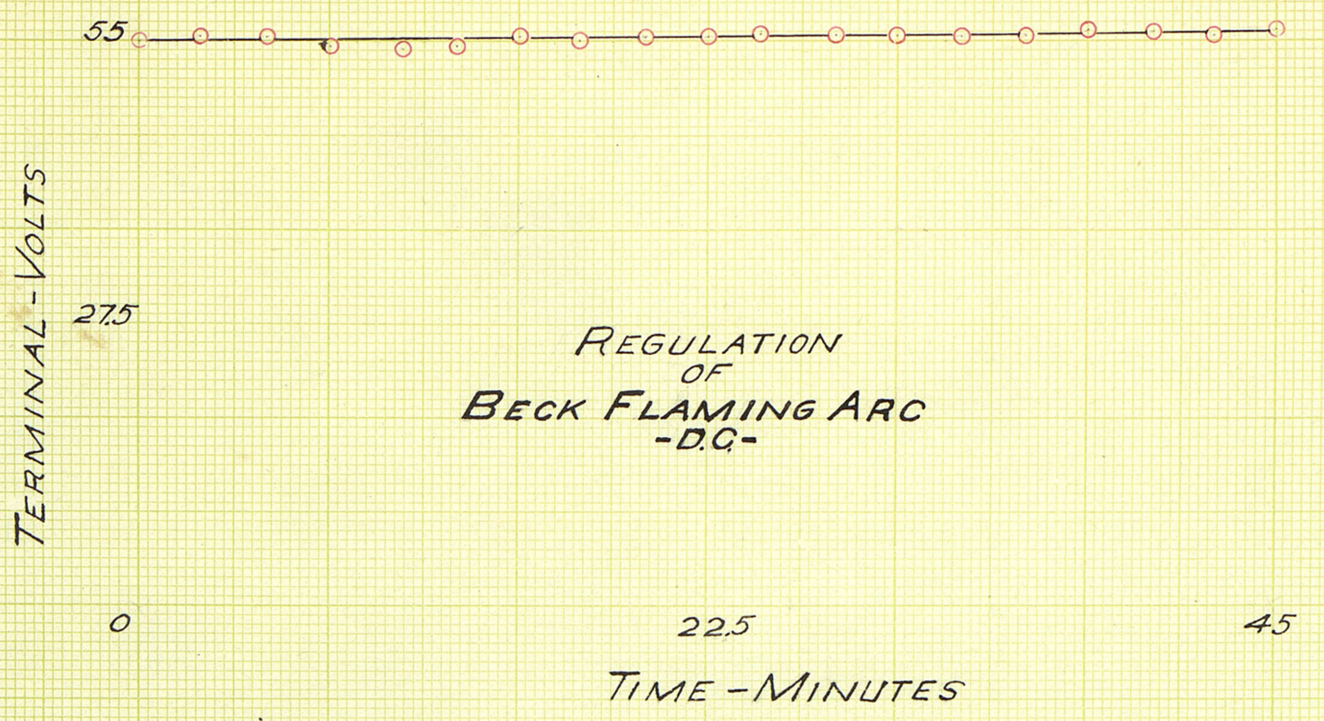
SHEET #1



COLUMBIA CARBONS
CURVE #1
CURVE #2
90
45
0
2.85
5.7
CABON-VOLTS
AMPERES
SHEET#2
EUGENE DIETZGEN CO., CHICAGO.

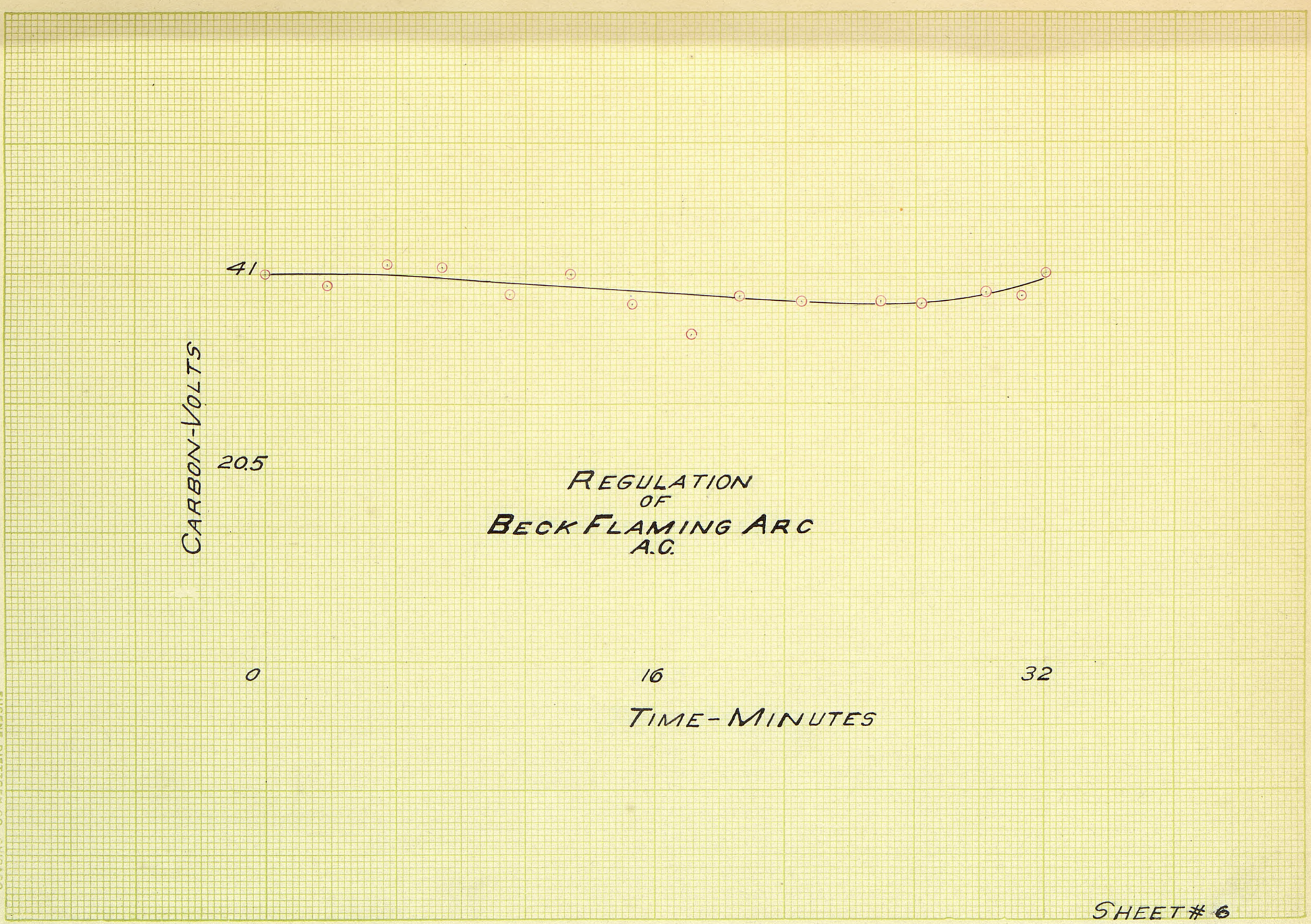

.875
.75
.375
0
22.5
45
Curve #2
Curve #1
Power-Factor
Variation of Power Factor
Time-Minutes
Sheet #3
Eugene Dietzgen Co., Chicago.

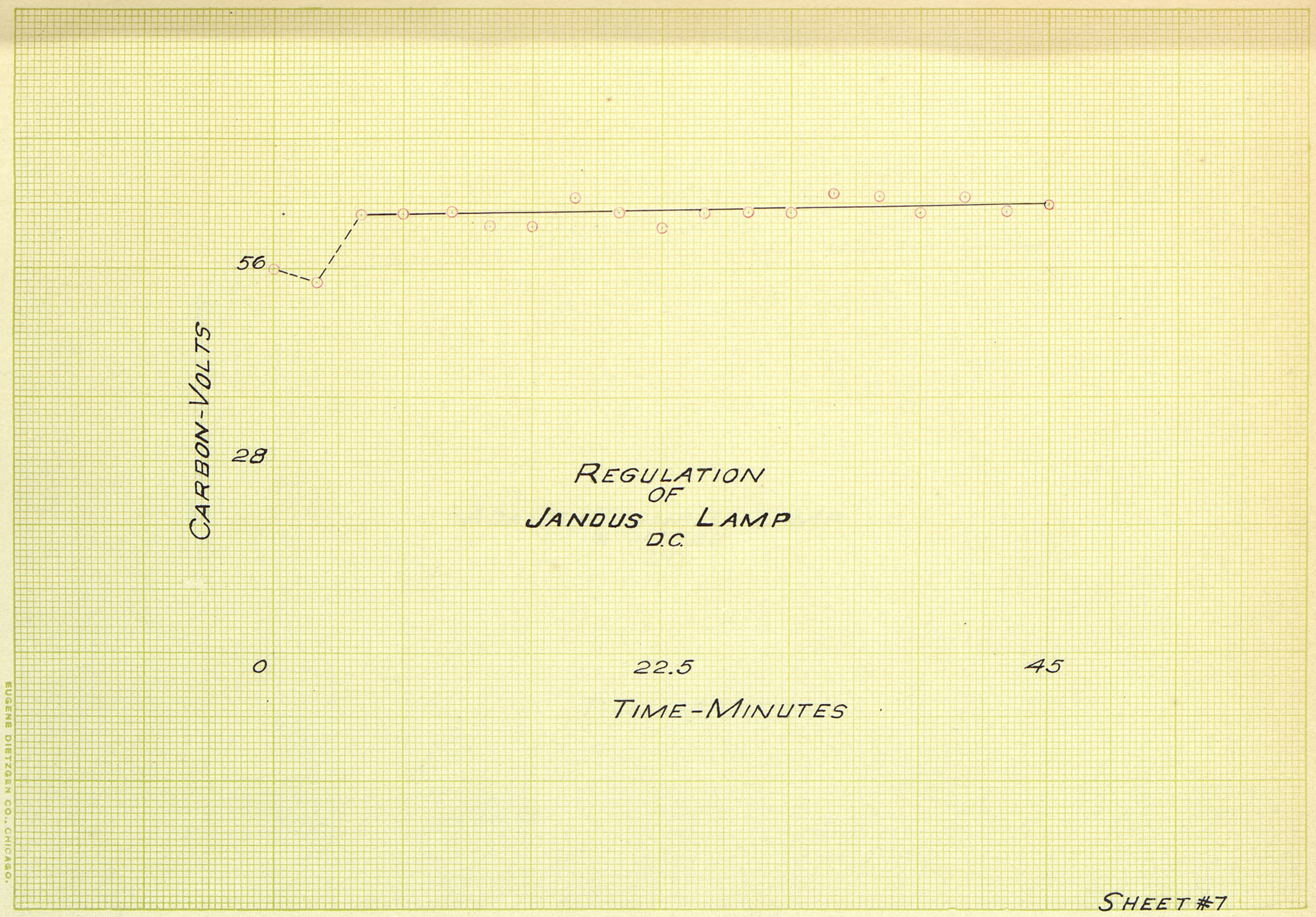

REGULATION
OF
G.E. SERIES LAMP
A.C.
CARBON-VOLTS
80
40
0
22.5
45
TIME-MINUTES
SHEET #4
EUGENE DIETZGEN CO., CHICAGO.



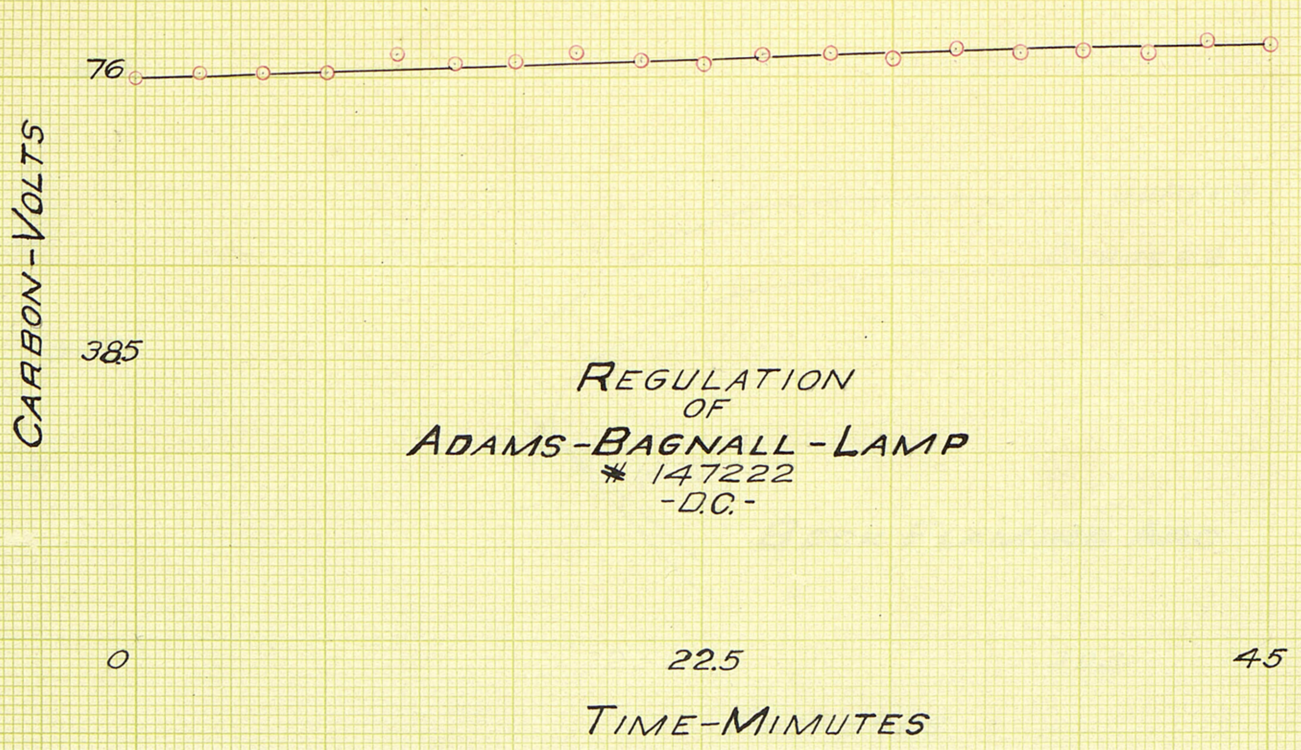
55
27.5
0
22.5
45
TERMINAL - VOLTS
TIME - MINUTES
REGULATION
OF
BECK FLAMING ARC
-D.C.-

SHEET #5


41
20.5
Carbon-Volts
Regulation
of
Beck Flaming Arc
A.C.
0
16
32
Time-Minutes
Sheet # 6
Eugene Dietzgen Co., Chicago.



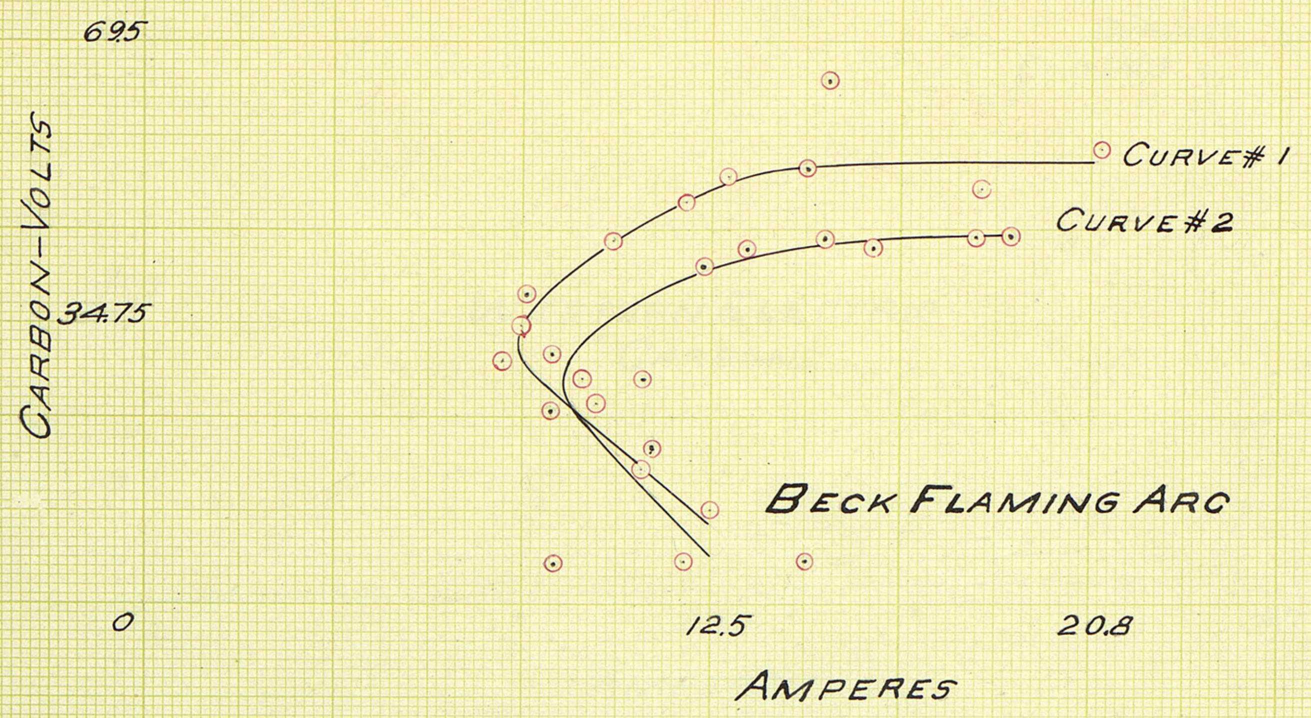
Regulation
of
Jandus Lamp
D.C.
Carbon-Volts
56
28
0
22.5
45
Time-Minutes
Sheet #7
Eugene Dietzgen Co., Chicago.



Regulation
of
Adams-Bagnall-Lamp
147222
-D.C.-

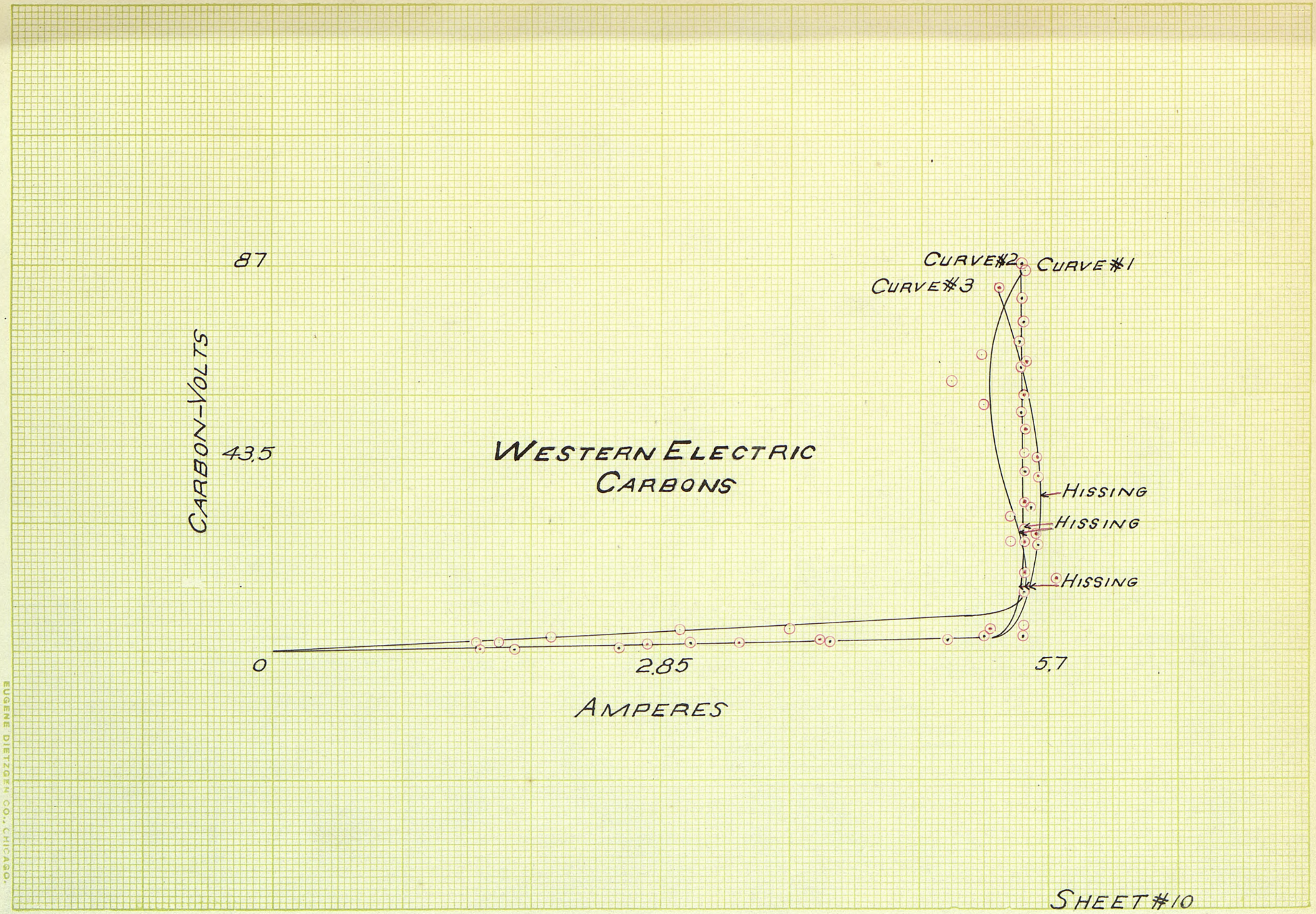
Sheet #8

Eugene Dietzgen Co., Chicago.



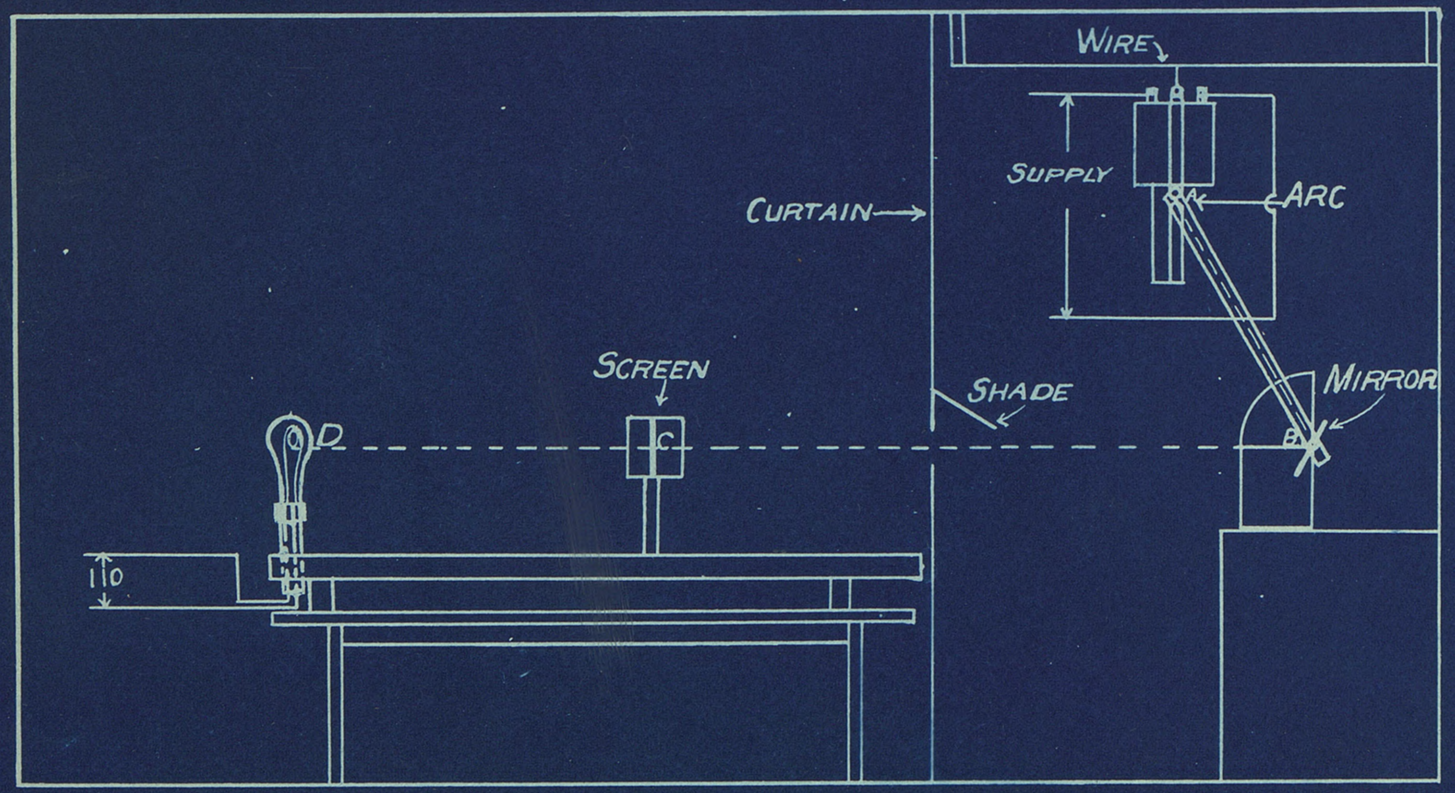
Sheet# 9

EUGENE DIETZGEN CO., CHICAGO.



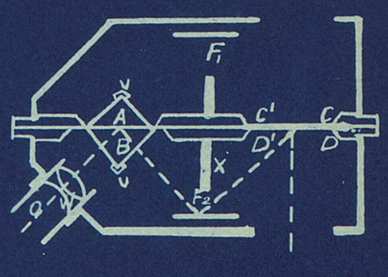
SHEET #10

EUGENE DIETZGEN CO., CHICAGO.



WIRE
SUPPLY
ARC
CURTAIN
SCREEN
SHADE
MIRROR
D
C
B
10

FIG. 1. A.



F1
A
B
C'
C
D'
D
X
F2

FIG. 1. B

BECK FLAMING LAMP.

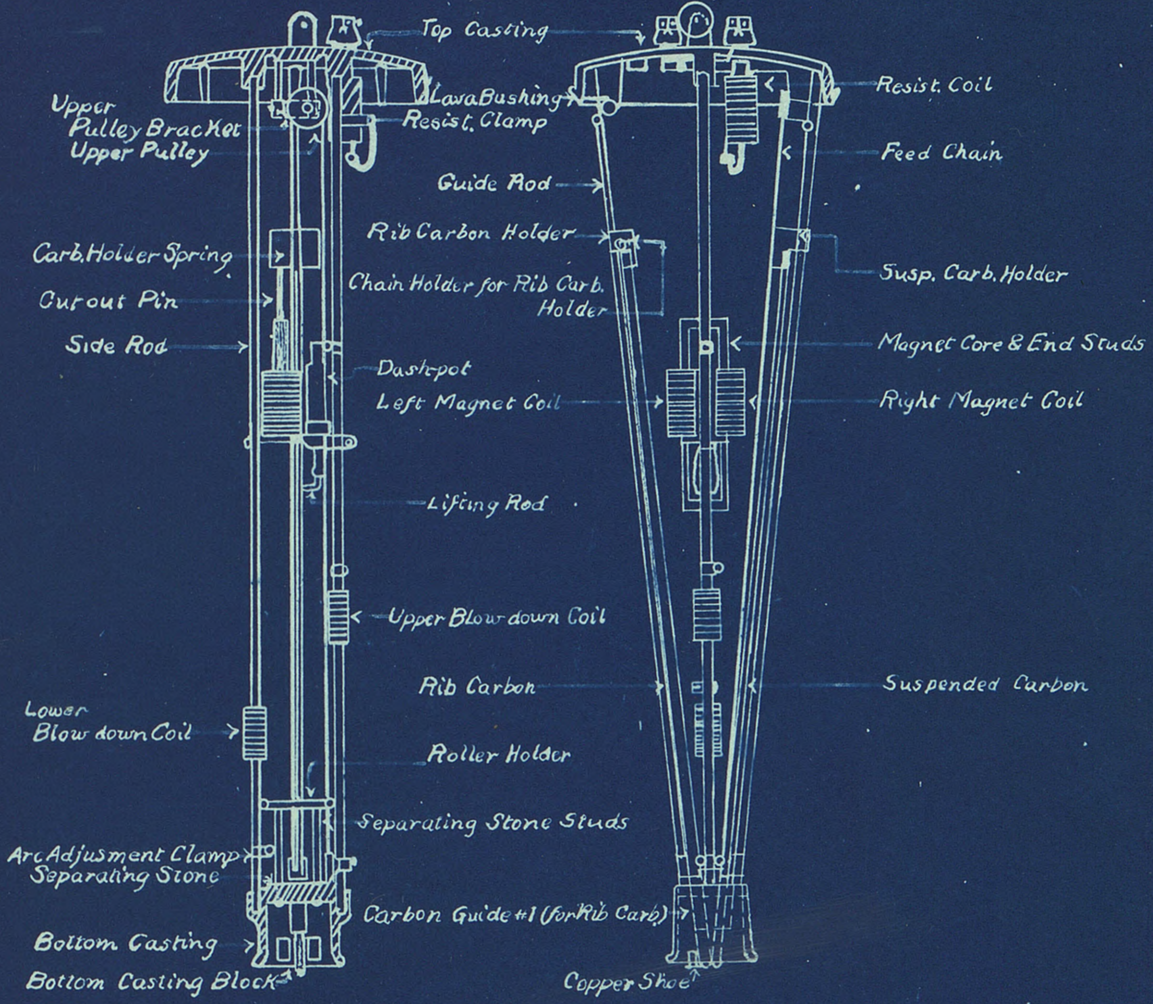


FIG. 2.

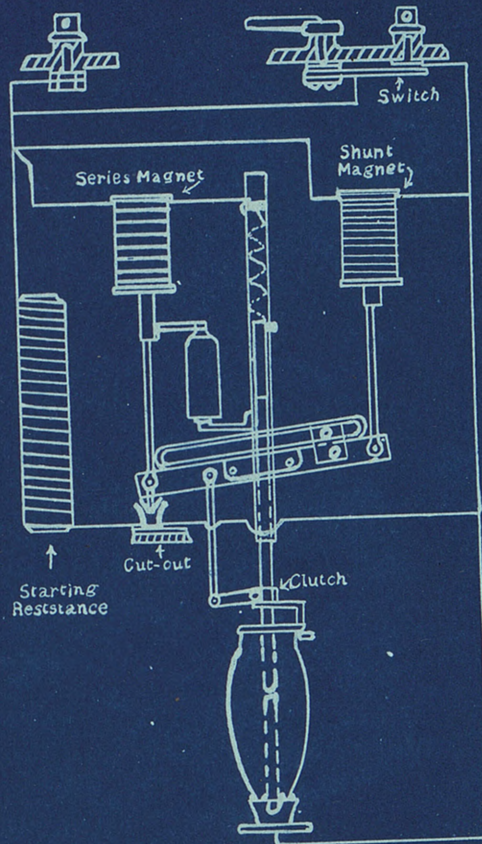


DIAGRAM FOR ADJUSTING CONSTANT CURRENT CARBON FEED
ENCLOSED ARC LAMP, FORM 3

FIG. 3.

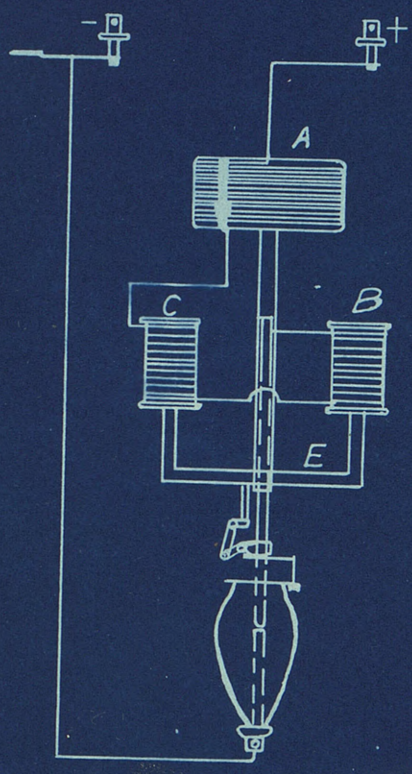


FIG. 4.

CONTACTS AND LEADS FOR MEASURING RESISTANCES

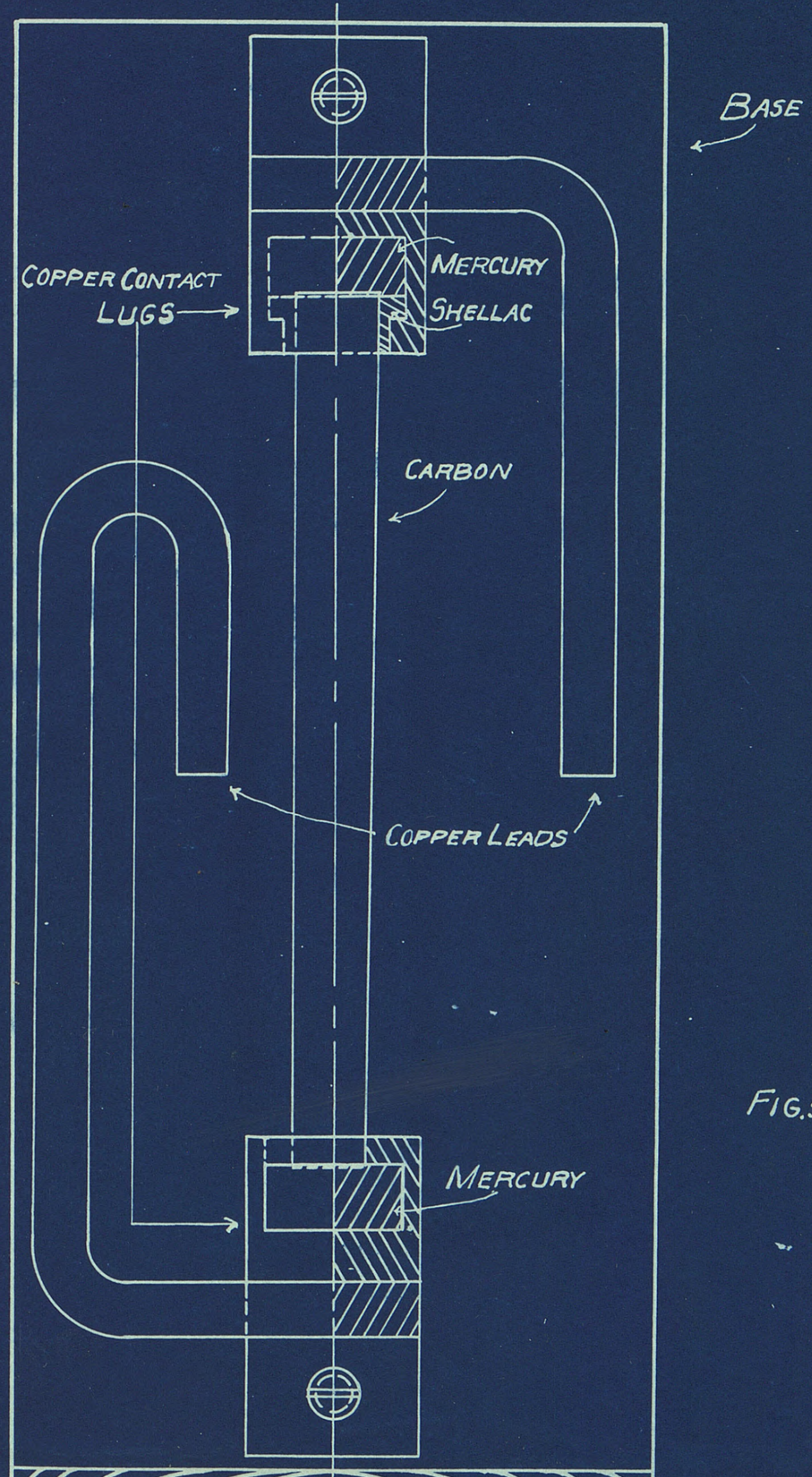


FIG. 5.

Data Sheet No. 1.

Curve No. 1 -- Flaming Arc, D. C.

With opal globe.

C. P.	Angle (Hor)	Amps.	Terminal volts.
200	85	11.5	52
230	80	11	50
232	95	12	52
245	70	11.5	52
355	65	13	56
513	60	10.5	52
428	55	11	55
435	50	11	55
578	45	11	52
555	40	12	50
1360	35	10	52
260	30	9.5	50
280	25	11	52
277	20	12	--
225	15	11	50
254	10	11	55
x 1390	5	10.5	56
x 1400	0	10.5	56
406	0 (open)	10.5	56
2000	90° (open)	11	55

Sheet No. 3 Curve No. 2.

Flaming Arc, A. C., with Oval Globe.

Time 1:53	Power	Watts.	Amp.	Volts.	C. P.	Angle (Hor)
0	.84	625	13.5	55	117	85
3.25	.86	600	12 5	55.5	152	80
6 5	.90	620	12 5	55.	159	75
9 75	.86	620	13	55.5	162	70
13.	.885	280	12	55	183	65
16 25	.855	290	12 5	55	165	60
19 5	.21	700	14	55	202	55
22 75	845	610	13	55 5	253	50
26.	.91	650	13	55	193	45
29 25	.--	---	---	55	187	40
32 5	.875	650	13 5	55	219	35
35 75	.90	620	12 5	55	268	30
39.	.906	550	11	55	207	25
42 25	.865	550	11 5	55	213.5	20
45.5	.92	620	12 5	54	204	15
	.87	550	11.5	55	213	10
	.87	550	11.5	55	199	5
	.91	500	10	55	215	0
2.55	.86	520	11	55	192	5

Sheed No. 1 Curve No. 2.

Flaming Arc, D. C. . With Opal Globe.

Power factor	Watts	Angle	Volts	C. P.	Amp.
.865	620	85	55	130.5	13
.903	620	80	55.5	206	12.5
.85	610	75	55	249	13
.894	600	70	56	254	12
.872	650	65	55	284	13.5
.88	630	60	55	300	13
.854	600	55	55	280	12.8
.835	620	50	55	290	13.5
.875	650	45	55	372	13.5
.875	6500	40	55	360	13.5
.895	690	35	55	300	14
.865	620	30	55	200	13
.855	660	25	55	177	14
.915	650	20	55	185	13
.875	600	15	55	210	12.3
.91	600	10	55	223	12
.936	650	5	55.5	270	12.5
.865	620	0	55	191	13
.905	600	5	55	250	12

Sheet No. 1 Curve No. 3.

Adams --Bagnall D. C. with clear globe, cored carbon.

C. P.	Angle.	Ampere.	Volt.
107.5	75	5.5	113.5
110	65	5.25	"
569	55	"	"
648	45	"	"
687	35	"	"
528	25	"	"
536	15	"	"
544	5	"	"

Sheet No. 2 Curve No. 1. Jand lamp -Columbia Cored Carbons.

Carbon Volts	Amp.	T Volts.
80	4.75	112
72	4 5	104
62	4 5	94
54	4 75	87
40	4 5	75
32	5	65
24	5	56
18	5 5	52
12	4 5	42
6	5	37
2	3 25	23

	Carbon Volts	Amp.	T. Volts.
	1	2.5	26
	1	1.75	12
	.8	1.0	7
	.75	.75	5
Hissing	20	5.5	52
	46	5.0	80
Flaming	78	8	130
Jumping	18	5	50

Sheet No. 2 Curve No. 2 A. B. Lamp, Columbia solid carbons.

Carbon Volts	Amp.	T Volts.
79	5.1	116
71	5.05	104
61.5	4.95	94
54	4.95	87
40	5.25	75
30	4.95	65
25	5.0	56
20	4.95	52
14	4.75	42
5	5.12	37

	Car. Volts	Amp.	T. Volts.
	2.25	3.15	23
	2	2.25	26
	1.5	1.7	12
	1	.95	7
	.95	.7	5
Hissing	22	4.75	52
	42	5.2	80
Flaming	92	5.4	130
Jumping	15	5.75	50

Regulation sheet No. 4   Power Factor sheet No. 3.   G. E. S.

Time	Power factor	Watts.	Car volts	Amp.	T. Volts.
0	.75	450	77	7.5	83
2.5	.77	475	77	7 7	80
5	.81	475	76	7 5	78
7.5	.76	460	74	7 5	81
10	.79	481	75	7 6	80
12.5	.792	500	75.5	7 9	80
15	.814	475	72	7 5	78
17.5	.814	500	77.5	7 4	81
20	.77	480	77	7 7	81
22.5	.805	475	76	7 8	90
25	.77	475	78	7 5	82.5
27.5	.813	500	78	7 6	81
30	.786	490	78	7 6	82
32.5	.794	500	78.5	7 6	83
35	.81	500	78	7 5	82.1
37.5	.814	500	78	7 5	82
40	.784	500	81	7 6	84
42.5	.754	475	78.25	7 6	83
45.	.744	475	79	7 6	84

Sheet #5 Beck Lamp. D. C. Machine.

Time	Amp.	T. Volts.
0	10	55
2.5	9.75	55.5
5	10	55 5
7.5	9	54
10	9.5	53.5
12.5	9	54
15	10	55 5
17.5	10.75	55 25
20	10	56
22.5	10.75	55 5
25	10	56 5
27.5	10	56 25
30	10	56
32.5	10.25	56
35	11	56
37.5	10	57
40	10	56.5
42.5	11	55.5
45	10.5	56.5

Test taken on C. W. # 984.

Sheet No. 6 Curve No. 2 Beck. A. C.

0	15	41	Carbon Volts
2.5	14.6	40	"
5	14.3	42	"
7.7	14.4	41.8	"
10.	14.5	39	"

Time	Amp.	Carbon Volts.
12.5	14.5	41
15	13 8	38
17.5	14 7	34.5
19.5	13	38.5
22	13 4	38
24 5	13	38
27	13 5	37
29 5	12 6	39
31 5	13	38
32 5	12 5	41

Sheet No. 7 Jandus D. C. Camp- Cored Carbons

Tested on C. &. W. #984

Time	Carbon Volts	Amp.	T Volts.
0	54	8	101
2.5	54	7.5	110
5	64	7	110
7 8	64	6.5	111
11	64	7	112
12 5	62	7 25	111
15	62	7 25	111.5
17 8	64	7 25	112
20	64	7	112
22 5	62	7	112
25	64	7	112
27.5	64	7	112
30	64	7	112

(Con)

Time	Carbon V.	Amp.	T. Volts.
32.5	67	6.5	112
35	66	6.5	112.5
37.5	64	7	112.5
40	66	6.75	113
42.5	64	7	112
45	65	6.75	112

Sheet No. 8 A. B. Lamps - Solid Carbon. Tested on

C. &. W. No.984.

Time	Carbon Volts	Amp.	T. Volts.
0	76	5	110
2.5	76.5	4.9	110
5	76.5	5 5	110
7.5	77	6	111
10	79	5 25	112
12.5	78	5	112
15	78	6	111.5
17 5	79.8	6 25	112
20	80	5 5	112
22 5	77.5	6	112
25	79	6	112
27 5	79	6	112
30	78.5	4 95	111
32 5	79	5 5	112
35	79.5	5 75	112.5
37 5	79	4 95	112.5
40	80.5	5 25	113
42 5	80	5 25	112
45			

Sheet #9 Curve No. 1 B. Lamp D. C.

Carbon Volts	Amp.
5	12
17	11
25	10
28	9.5
30	8
38	8.5
46.5	10.5
50	12
52.5	13
69.5	13.5
37.5	15.6
51	18.5
56	21

Sheet #9 Curve No. 2, B Lamp A. C.

5	11.2
5.7	14.1
28	11
20	11
31	9.1
38	8.5
42	12.4
44	13.2
54	14.5
65	15
45	15
44	16
45.5	18.25
45	19

Sheet #10 Curve No. 1 Ship Carbon (Colored)

On J. Lamp. Constant Potential.

	1	1.75
	1.3	2.5
	1.5	3
	2	4
	2 5	5
	3 5	5 5
	4 5	5 5
Hissing------------------	14	5 5
	24	5 6
	32.5	5 55
Hissing------------------	43	5 5

(Con)

	Carbon Volts	Amp.
	54	5.25
	64	5 25
	69.5	5 25
	75.5	5
	79	5 25
	87	5
Flaming -----------	90	4 35

Sheet No. 10 curve No. 2 Western Electric. (Colored)

	2.5	1.5
	3	1 65
	3 5	2
	4 5	3
	5	3 8
	7	5 5
	13	5 5
	16	5 5
Hissing-----------	19	5 15
	20.5	5 4
	25	5 4
	28	5 5
	37	5 4
Hissing -----------	40	5 3
	41	5 5
	44	5 5
	54.5	5 2
	61	5
	67	5 2
	74	5 5
	84.5	5
Flaming-------------	86	4 9

Sheet No. 10 Curve No. 3 Western Elec. (Solid)

	1	1.5
	2	2 75
	2.5	3 4
	3	4
	3 5	5 2
	5	5 25
	16	5 75
Hissing------------	17.5	5 1
	20	5 5
	26	5 6
	33	5 5
	39	5 6
	43	5 6
Hissing------------	49	5 1
	50	5 8
	59.5	5 5
	65	5 5
	82	5 3
Hissing -----------	87	4 8

Carbon Resistances.

Different makes		Consumption per hr.	Size, inches.	Ohma Resistance.
Western Electric	--solid		5/8 x 12	0.1960
" "	"		"	0.1698
" "	"		"	0.1609
" "	cored		1/2 x 9-1/2	0.1490
" "	"		"	0.1510
" "	"		"	0.1576
Columbia	Solid		"	0.1030
"	"		"	0.1245
Western Electric	"		"	0.1890
" "	"		"	0.1508
Columbia	"		"	0.1540
"	"		"	0.1430
"	Cored		"	0.1294
Excello-Carbon, A.C.	"	5.54		
Ship-Carbon, Vienna	"	1.38 gms.	1/2 x 12	
Western Electric	"	0.423	"	
Western Electric, solid,		0.280	"	0.1952
Columbia	electra solid	0.416	1/2 x 9-1/2	0.1372
"	cored	0.328	1/2 x 12	0.1294
"	solid	0.480		0.146
Excello-Carbon, D. C.		6.40		

Photometry.

The photometer is one of the most useful instruments a central lighting station could possess. In the field of accurate research it is rather doubtful whether it can be relied upon or not, but it is a very easy machine to operate and obtain fairly accurate results, making it on the whole, very desirable for comparing the ordinary lights on the market with a certain standard. The reputation of the photometer is probably due to its use in research work, which seems to have influenced the central stations.

The use of the photometer for measuring the intensity of light may not be very accurate but since it is the only instrument in this field, if used more extensively it would soon be put on the market in a more perfect form. One of the most difficult problems to master in the photometry of lights is the difference in color of the lights, under comparison. This color makes it very hard toget a good balance with an ordinary screen and almost impossible to get results that will check. Thus, in measuring the candle power of arc lights it was found that a carbon filament lamp as a standard produced a very decided orange color which was almost impossible to compare with the arc which is bluish in color. There is such a great difference in the candle power of these two lamps that it is extremely difficult to compare their intensity regardless of this color difference. After deciding that a carbon filament lamp would not do as a standard, , a tungsten lamp was calibrated and used. This light is very much whiter and the lamp used gave a candle power of 79 in one position as compared with 16 for the carbon lamps in a similar position. After thus eliminating part of the color difference it was found that the arc was a very irregular light, both in color and intensity, that is the color varied slightly with the intensity. Since the intensity and distribution of the arc is very irregular at the best, the results were only approximate values. However, the nature of the distribution of light could be studied in the different lamps which is in most cases of more importance than the intensity.

In testing arc lamps the candle power and distribution of the different lamps must be compared with the energy consumed by the lamp and if the lamps are A. C., the power factor is of great importance.

Beck Flaming Arc.

The Beck flaming arc lamp is one of the recent improvements in arc lamps. This lamp is a flaming arc using impregnated carbons, which are set at an angle as indicated in the diagram (fig. 2.). The carbons neet at a very oblique angle forming an arc which is arched downward by a magnet, represented in the diagram as blow down coils. These produce a flux across the arc in a direction such that it tends to cause a downward displacement and widening of the arc. The arc in this lamp is formed in a porcelain recess which becomes coated with a white deposit of calcium oxide forming a fair reflector. The light is reflected downward rather than outward as in the common vertical carbon arrangement. The regulation of this lamp is accomplished by varying the length of the arc, but not in the same way as in the common lamp, where the one carbon is raised or lowered by means of a clutch and electro-magnet. In the Beck lamp the carbons remain at a definite height in the cup-like recess and are moved horizontally by means of a block through which they pass, and an electro-magnet. This is clearly shown in the diagram. The carbons are fed downward as they are consumed by means of the weights at the top of each electrode. The negative carbon can only drop down until it rests on the copper shoe. By means of the chain and pulley arrangement the positive carbon can drop down only as the negative is lowered, which requires that the carbons be of about the same length and that they burn at about the same rate. This gives a more steady light than any other method of feed that was tested when operated under normal conditions.

The negative carbon is ribed and impregnated with a salt which is principally calcium. The negative electrode is also impregnated with a salt and has a wire with a low fusing point which extends the entire length of the carbon.

Distribution.

The distribution curve for the D. C Beck lamp is shown on curve sheet No. 1, curve No. 1. This curve shows a maximum candle power of 1360 at an angle of 35 degrees to the horizontal when operated with an opal globe, which gives the rather outward distribution and is the cause of the irregular points on the curve. The low candle power under the arc, 90 degrees ray, is due to the ash tray in the globes. The mean hemispherical candle power is equal to 401.6 c p not allowing for coefficient of reflection of the mirror and with the opal globe.

The mirror absorbs, probably twenty per cent of the light. The opal globe is very irregular and absorbs as high as 85% at the 90 degrees angle and about 60% at the 0 degrees. The consumption is about 1.35 watts per candle power including regulating losses.

Curve No. 2 on the same sheet is for the Beck A. C. lamps, only one half of the curve being plotted for the sake of clearness. This shows a more uniform distribution but a lower c p. The power factor of this lamp is shown on sheet No. 3, curve 2 . The A. C. Beck lamp is not nearly so good as the D. C. lamp for regulation and it also makes too much noise for indoor lighting.

Curve No. 3 shows the distribution of an A. B. lamp, using cored carbons and a clear globe. The clear globe was necessary in order to measure the candle power with the arrangement we used. This lamp shows that the distribution is more outward in the A. B. lamp, which is what we would expect with vertical carbons. The mean humispherical c p is about 465 c p which gives an efficiency of 1.53 watts per c p as compared with 1.3 for the Beck.

The photometer scheme is shown in Fig. No. 1. This consists of a Lummer Brodhum screen on a photometer bar 285 cem. long with the standard lamp (Tungsten) set at 289.5 cem from the curtain separating the photometer set from the arc. In order to get the distribution of the arc a protractor was made with a long arm pivoted at the center of the circle. By placing a mirror at the center, movable about this same axis, the rays of light from the lamps could be measured for every five degrees by setting the radius arm, and then moving the lamp to a certain position with respect to the arm.

This apparatus worked well enough until the lamp got down near the horizontal, when it became necessary to pull the lamp to one side and place a screen near the hole in the curtain to keep the light from shining directly in the photometer side.

The distance that the ray of light must travel was easily calculated by measuring the constant distance inside the curtain and adding it to the reading on the bar. The curtain was made of sheeting painted with a heavy black paint, as were the walls of the room and protometer.

Carbons.

The resistances of the carbons were measured on the Carey Foster Bridge. Special contacts were constructed, as shown in Fig.5, the base consisting of a board 6" x 14" x 1/2", one end of which was nailed to the end of a modern block, (shown in cross-section at the bottom of the figure). The upper copper contact was bored out large enough to admit the largest carbon, and still leave a small clearance. The lower contact was simply drilled out large enough to admit the end of the carbon. Two large copper leads were soldered to the copper lugs and arranged so they could dip into the mercury cups of the Carey Foster Bridge. To get contact at the ends of the carbons the apparatus in figure 5, was turned with the top down; mercury was poured into the receptacle of the upper lug; the carbon was dipped into the mercury just enough to insure good contact on the end; melted paroffine was poured into the receptacle to keep the mercury from running out when the apparatus was in an upright position.

It was found that if the paraffin was heated too much that when pouring it ran down between the mercury and the side of the receptacle, or between the carbon and the mercury, or both, and also that if the paraffin was poured when it had begun to solidify, that it did not adhere enough to the sides of the receptacle to hold the mercury. Paraffin was used principally for its insulating properties; it also provided a good method for holding the mercury. The lower receptacle was just supplied with mercury until the latter made good contact with the end of the carbon.

The resistance of the different carbons, as measured by the above method, compare approximately with data given in Foster's hand book. It was found that the carbons of high resistance were more difficultly volatilized than those of lower resistance and hence more trouble in establishing the arc with low currents, especially in the A. C. arc lamps. It was also found that the voltage over the arc was less with cored carbons than with solid carbons.

The traveling of the arc is prevented by the use of cored carbons or by using a cored carbon as positive. Of the solid carbons tested, the travel of the arc was less with the Columbia solid electra than with the Western Electric solid carbons.

In general the electric relations of the carbons are the same, whether cored or solid, excepting those of the flaming arc. As an example of the above statement, take the curve #1 on sheet No. 2. This curve represents voltage and current relation using Columbia carbons in the Jandus arc lamp. The straight part represents the conditions, just before the arc is struck, and the drop in voltage corresponding to the different currents along this straight part are the drops due to carbon, and carbon contact resistance, respectively. After a certain current, say three amperes , is reached, the carbons begin to glow at the contact between them.

At the point where the curve changes rapidly is the hissing point, i. e. with a current of about 3.75 amperes. After the hissing there is a slight decrease of current due to increasing length of arc, the drop increasing. This cannot be explained by ohms law for the reason that as the length of the arc increases between certain limits, the cross-section increases in such a manner as to make the drop over the carbons increase at a greater rate than the current through the arc.

By a comparison of curve #1 and curve #2, in sheet No. 2, we see that for the same drop the solid carbon takes the larger current, due to the fact that the soild carbon has less resistance.

Comparing sheet #2 with sheet #10, we see that the Western Electric and Ship-carbon (corresponding to curve #1 on sheet #10) take more current for the same drop.

The flaming points for the different carbons could not be plotted (see data for sheets numbers 2 and 10).

A comparison of the life of different carbons may be seen by referring to data on carbon resistance. This is given in grams consumption per hour. From this table we can see that an objection to the flaming arc carbom (excello) is its short life and consequently frequent trimming required. The Ship carbon

(Vienna) gives about twice as long an arc as either the Columbia or Western Electric, but on the average about three times as much carbon is consumed, as is seen by the data.

Power Factor.

The power factor of an A. C. series lamp is much greater in most cases, than a constant potential lamp due to the extra induction necessary to hold the voltage of the arc at 70 to 80 volts, which is eliminated in the series lamp.

On curve sheet No. 3 are shown two curves plotted to power factor and time. Curve No. 1 is for a general Electric Series lamp, operated on a constant current transformer circuit with the speed of the generator kept constant. Comparing this with the Beck flaming arc, curve No. 2, the power factor of the G. E. lamp is lower in value and not nearly as regular as that of the Beck lamp, which started at nearly .875 and increased slightly in the 45 minute run. The Beck lamp is made to operate as in a series lamps or as two in series over 110 volt mains, which allow a reduction of the ballast; also the regulation mechanism in the Beck lamp has fewer magnetic coils.

Regulation.

The voltage regulation of the arc lamp is determined by sensitiveness of the regulating mechanism. On curve sheet No. 4 is shown the regulation of the G. E. series lamps under the same condition as for the power factor curve. Comparing this and the corresponding curves for the Jandus, constant potential, the Beck A. C. & D. C., and the A. B. lamp, it is evident that the Beck D. C. and Jandus show the best regulation. The irregular points for the Jandus is probably due to a change in terminal volts. The other lamps seem to give about the same regulation with the exception of the Beak A. C. lamps, which seemed to vary considerable. This however, is not due to the lamp itself as is shown by other data, but the fact that the lamp was operated on a machine running at one--half the rate voltage, which would be very low on the magnetization characteristic for an alternator, and did not give very steady voltage, since the speed of the prime mover was varying slightly.

Conclusions.

The results obtained with the Beck lamps show that they are adapted for lighting a large interior where the light does not need to be distributed over great areas; that is, the light is fairly steady and with opal globes does not strain the eye. By saying that this lamp would be very good for indoor use, we do not mean that it is not suited for outside use, but that it does not have as good a distribution for street lighting as the Adams Bagwall lamp, and others. The greatest drawback of the Beck lamp is the trimming, since they would need trimming every day for all night burning.

The flaming arc lamp has not been used with success in places where accurate color work is desired. However, arc lamps with cored carbons impregnated for a white light and placed rather high, give very good results.

The spectrum of the Beck lamp is not continuous, and has a predominance of blue rays. Beside the blue rays there seems to be some copper, which is due to the copper shoe and the wire in the positive carbon. Calcium rays are also present, showing that the core contains a salt of calcium.

By comparing the diagrams for the different lamps, it can be easily seen why the Beck lamp has so much better regulation than those burning the vertical type carbon. In these lamps such as the Jandus, and A. B., shown in Fig. 4, and the G. E. series arc, in Fig 3, as the carbons burn down the regulating mechanism works well enough until the clutch needs readjustment, which requires that the carbons drop together and the lamp is practically cut out for a very short time, until the increased current again regulates the arc. This, of course, causes a larger current to flow at the time of regulating and when there are a large number of lamps on a circuit, will tend to cause variations in the terminal voltage. Hence, an unsteady light is produced.

The Beck mechanism operates on a principle that insures a continuous feed as the carbons are consumed, and regulates the arc by means of the two magnet coils, (Fig 2), and the separating stone. These coils are in series with the arc and by means of a small idler and two racks on the armature and lifting rod they regulate the height of the separating stone.

In general, the D. C. arc is much the best for steady light, as for indoor work in as much as the light is rather downward; However, the arc travels around the electrodes, thus producing shadows. The A. C. lamp in the first place, makes too much noise and the light is distributed more in the horizontal plane than that of the D. C. The A. C. lamp does very well for street lighting and by running then in series, the line expense is very low.

S. S. Young,
C. R. Jacobus,

E. E. '08.