EFFICIENCY of the TYPE A.T.B. FORM D. GENERAL ELECTRIC ALTERNATOR.

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Tests made on 150 K.W. Alternator at Manhattan Ice, Electric Light and Power Co.'s Plant, Manhattan, Kansas.

I. Description and theory of the Alternator.
II. Efficiency of the Alternator.
III. Incandescent Light System and Line Distribution.
IV. The Arc Lamp System.

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DISCUSSION.

Revolving Field Alternator.

No. 62299 Type A.T.B. Form D.

Class 12 - 150 - 600 33 Amperes.

Volts No load 2030 - Full load 2300.

The above machine is installed in the Manhattan Ice, Light, and Power Company's plant at Manhattan, Kansas. This Alternator is put out by the General Electric Company and is known as one of the"smaller" machines. In this kind of machine the "barrel" winding is used, employing only one kind of coil. The armature coils are held in place by means of beach wood wedges which also serve to protect the coils from any foreign matter that may work into the air gap. The armature case is made of a good quality of sheet iron annealed and the laminae insulated by japan.

The revolving field is a special design of this Company. The pole pieces are made of heavy sheet iron punchings one sixteenth of an inch in thickness and fastened together by means of rivets. The pole pieces are secured to the field ring by means of grooves and secured by the use of keys. The poles are wound with flat copper ribbon with the edge to the field piece. Every turn is thus exposed to the air making it impossible to have excessive heating of the coils upon the inside. As the ribbon is flat there is a large bearing for each turn upon the insulation thus not allowing any opportunity for a shifting of the coils and thus short circuiting the machine. Sheets of expressly prepared paper are used in insulating these field turns.

Fastened to the shaft and within the shield is the small direct current armature of the exciter. On this size of machine the

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*Basis - Reist in Electrical Review.

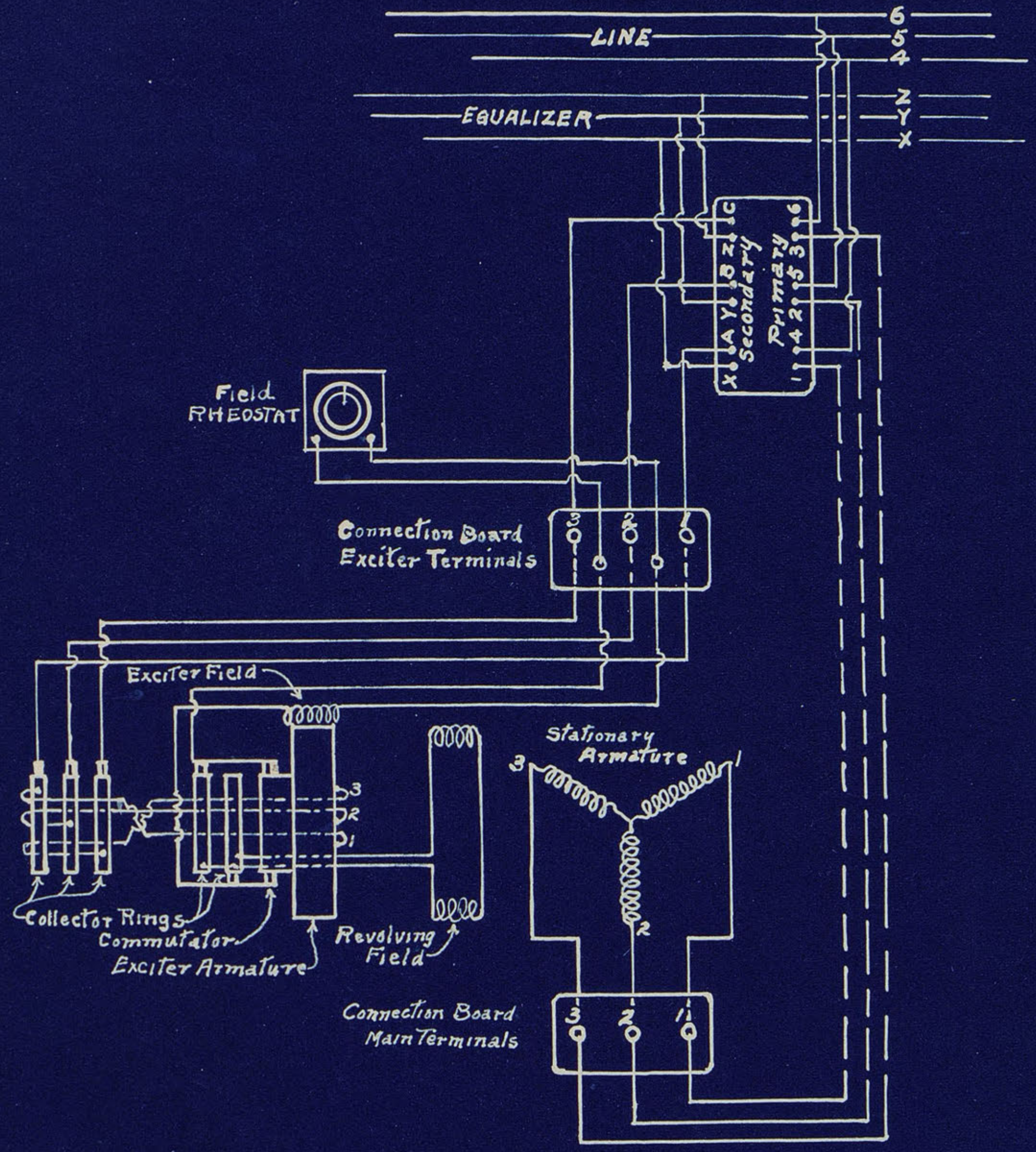

Fig. 1.

Diagram of Revolving Field, Three phase Generator with Compensating Device

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exciter is wound for about sixty volts. These exciter armature coils are form made and placed in open punched slots. Three taps are taken at equal intervals from the armature to three collector rings on the end of the shaft to be used in regulation for constant voltage. Just above the direct current armature and within the shield of the alternator, is found the direct current shunt field having the same number of field coils used in the alternator hence the two operate in synchronism.

The bearings are spherical, self oiling, self aligning and are lined with an anti-friction metal. The bearing next to the pulley being quite large thus making the shaft stiff and preventing excessive heating.

Theory of potential regulation in Form D.

It is a known condition that when the load of a generator is increased with constant field excitation the potential will drop with increase of load. This drop is due to armature resistance, inductance and armature reaction upon the field poles thus reducing the amount of effective flux. The potential of a point some distance on the line will show a still greater drop due to line resistance and inductance. The problem of potential regulation is to secure a regulator that will maintain the voltage at the machine terminals constant or to compound for line drop, in order to keep up the required voltage at the loaded terminals of the line. In the alternator the power-factor of the inductive load must be considered in order that the machine may regulate for a motor load for a non-inductive lighting load or for a combined inductive and non-inductive load.

The method used in this type of machine is mechanically simple and is reliable for quite wide and rapid variations of load, the grestest fluctuation being due to lack of constant speed from the engine. The pulsating current in the exciter armature is by construction in synchronism with the alternating current in the alternator armature having the same speed and the same number of poles. Over the three collector rings which are connected to three taps off the exciter armature referred to above. The exciter armature receives current from the series transformer of the line. This current passing through the exciter armature reacts magnetically upon the exciter field in proportion to the strength and to the phase relation of the alternating current. The magnetic field then produced which determines the potential of the exciter is produced by the combined effect of the shunt field and the magnetic reaction of the alternator current.

The connection between the two armatures is so made that the poles induced in the exciter armature are ahead of the field of the exciter magnetization, but not so much so but that their combined effect is to increase the current of the exciter and consequently the field of the alternator. If the current lags the exciter field poles approach the poles produced by the alternating current in the armature thus tending to prevent fall of voltage.

In figure 6" let curve 1 represent the magnetizing effect of the simple shunt field of the exciter, and assuming that the exciter field bo so placed that the magnetizing effect of the current through the armature has its maximum directly under the pole pieces its effect might be represented by curves. It will be seen that this magnetic effect is stationary with regard to the exciter pole pieces since the alternating current passed into the exciter armature is synchronous with its speed and is passed in in such a way as to cause the magnetic wave to move in the direction opposite to that in which

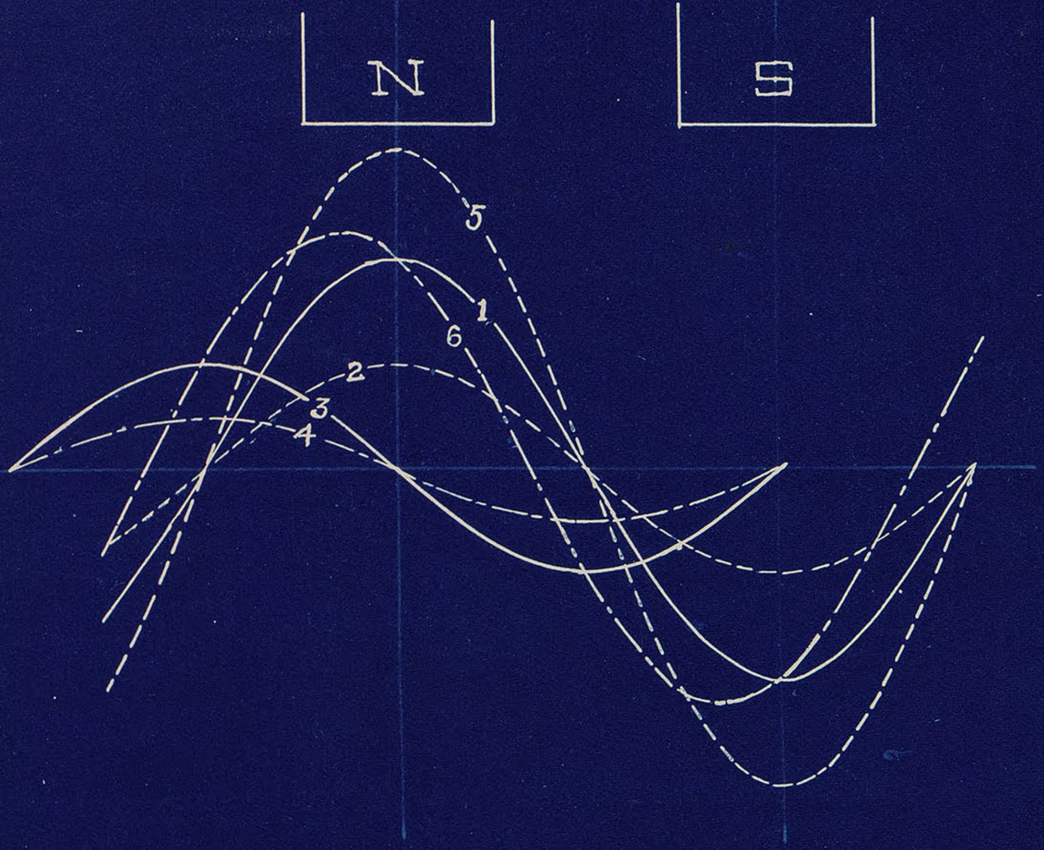

Fig. 6.

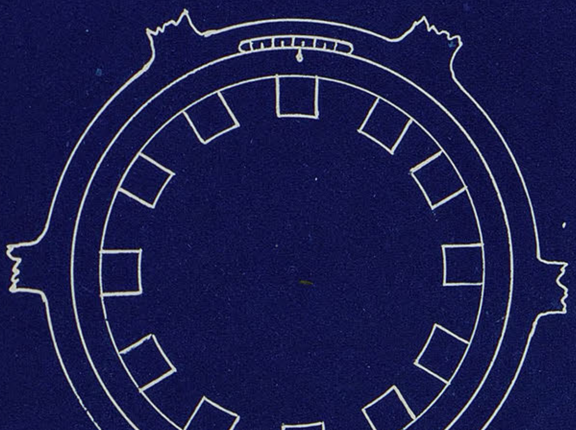

Fig. 7.

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the exciter turns. In this case the combined effect or the sum of the two will be represented by curve 5. Ordinarily the magnetizing effect in the armature is shifted with reference to the magnetizing effect of the pole by turning the field structure into such a position that the magnetizing effect of the armature leads that of the field as is shown by curve 3. Combining curves 3 and 1 it produces curve 6 which has a higher magnetic effect than 1 alone. As the power factor is decreased curve 3 approaches curve 2". As 3 shifts to 2 and combined with 1,it changes from 6 to 5, thus we may say that the magnetizing effect will gradually increase as the power factor decreases which is the essential feature in compounding for a variable load with variable power factor.

Table No. 1.

Volts at Mach.Ter.	K. Watts Out put.	Volts at Mach.Ter.	K. Watts Out put.
112	18.800	118	103.600
114	20.360	117	100.800
114	27.200	118	100.000
114	28.660	119	84.700
114	28.720	119	72.800
114.5	38.600	115	58.800
114.5	51.200	114	48.800
117	71.200	114	41.800
118	83.200	114.5	21.400

Table No. 2.

Volts at Excite Ter.	Watts imput Alternator Field.	Volts at Excite Ter.	Watts imput Alternator Field.
36.2	1048.35	55	2464.20
38.	1155.2	55	2420.00
38.8	1202.8	56.2	2526.75
39.5	1248.2	54.5	2376.2
39.9	1274.61	54	2332.8
40.8	1331.71	47	1767.2
41.5	1377.8	44	1548.8
46.2	1704.78	43.5	1511.8
51	1843.2	34	924.8

The accompanying table will show the practical working of the regulation of the voltage of the machine. Taking table No. 1, the voltage at the machine terminal at the beginning of the run was 112 volts; from this point the voltage raised or fell as the load increased or decreased. However it is also seen that the voltage does not quite reach its maximum with maximum load. This would have been the ideal condition. This discrepancy may be accounted for in one of several ways the most probable of which are perhaps; (a) inaccuracy of instruments in reading down scale; (b,) inaccuracy in reading instruments or (c,) a large wattless component which requires compensation for resistance. The over compounding effect to keep the line terminal voltage constant may be easily noticed in examining this table.

In table No. 2 may be seen the relative increase of exciter voltage and a strictly corresponding increase of power used in the alternator field with increase of load.

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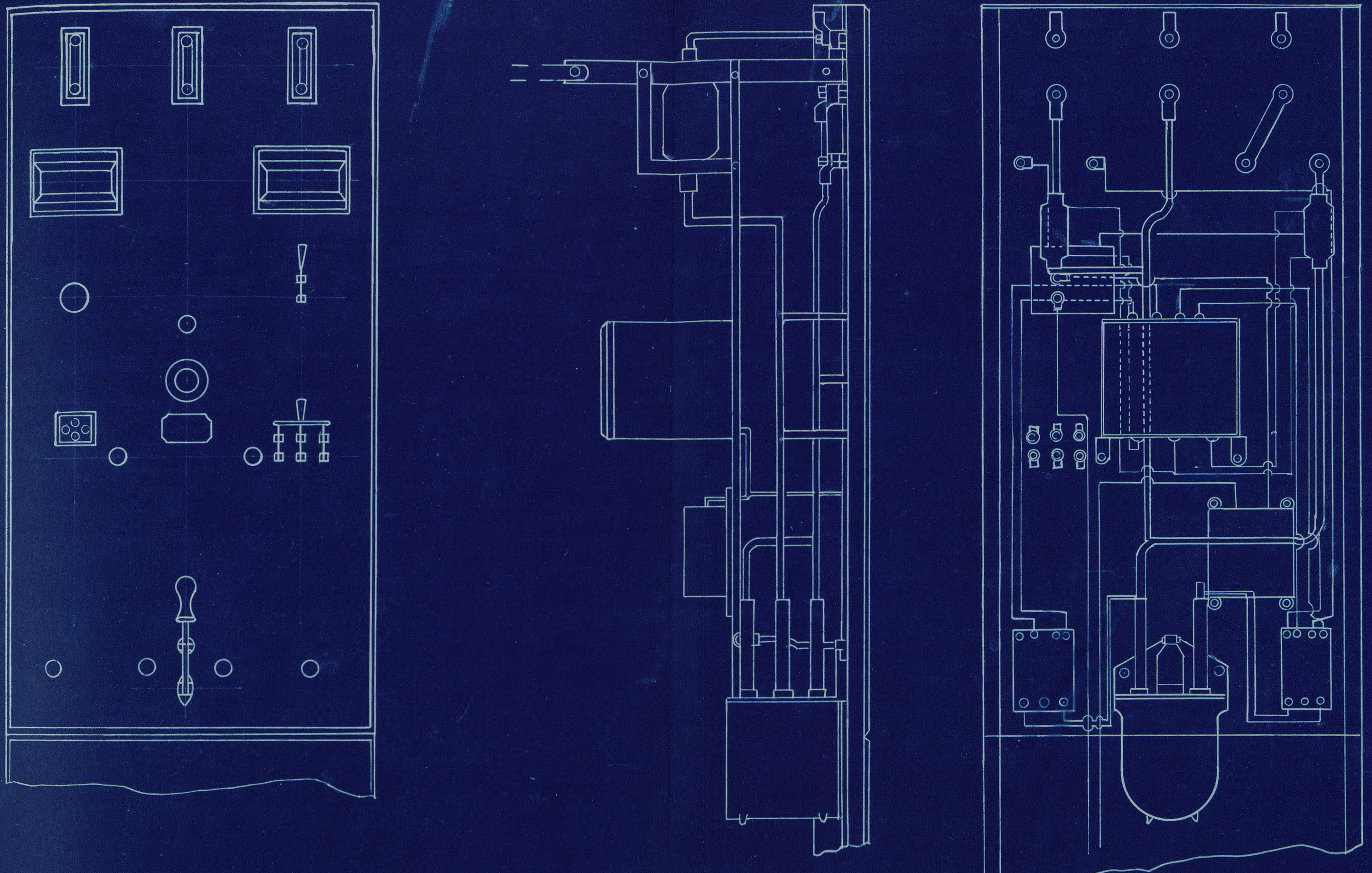


SWITCH BOARD

TLP

EFFICIENCY of ALTERNATOR.

Probably the most important test in connection with this thesis is the commercial efficiency test of the generator. The plant is in daily operation and therefore it was necessary to make the test while the generator was carrying its usual normal load. The efficiency test was taken Saturday night which was the time of heaviest load, the test continuing from 6:00 P'M' until 12 P.M. Readings were taken every 15 minutes until 8:00 P.M. and every half hour thereafter.
The commercial efficiency of of a generator is the ratio of the output measured at the machine terminals, to the input at the pulley. To measure the output a Watt meter and ammeter are put in each of the two outside circuits and a volt meter between each of the outside lines and the middle line as shown in Fig. 2. The working pressure of the line is 2300 volts so that potential transformers were placed between the lines to reduce the voltage and bring it within the range of the instruments. The watt-meters alone will measure the power but the ammeters and volt-meters are used to determine the power-factor. The power input was determined by indicator cards taken from the engine at each reading of the output. The engine driving the generator is a Bates Corliss with cylinder 18" X 42" running at 90 R.P.M. It is connected to the generator by a heavy belt and an idler pulley is used to give the belt more pulley surface. On account of the difficulty of removing the belt, a card could not be taken with engine running light, so it was found necessary to proceed in another way.
A number of cards of the engine running generator light was taken and power necessary to run generator alone subtracted from power required

for engine and generator light. The value of power required to drive the generator light was furnished by the manufacturers of the generator. The generator losses running light are 1.2 K.W. From this data the power input and power output may be calculated. The exciter for the generator is on the main shaft and its losses are charged to the generator. Complete data of the six hours run are given in Table . The load varied from 18 to 103 K.W., the highest load being only about 2/3 full load capacity of the machine, so that the efficiency is not maximum efficiency. The power required for the engine and generator running light is 15.25 H.P. or 11,276 K.W. The generator consumes 1.2 K.W. then the engine with belt consumes 10,176 K.W. The power input will be the power as computed from the engine cards at each reading less 10,176 K.W. The output will clearly be the sum of the two watt-meter readings. The watt-meters used were standard Portable Weston instruments, one a (0 - 3 K W) and the other (0 -B K.W.)

The series windings are placed in the main line while the pressure terminals are connected to the transformer the same as the volt-meters. The potential transformers have a ratio of 20 to 1, and so the watt-meter readings should be multiplied by 20 to give the true load. The normal speed of the engine is 90 R.P.M. and that of the generator 600 R.P.M. As the load increased the speed of the engine decreased somewhat. On heaviest load the engine speed was 86 R.P.M. and that of the generator 570 R.P.M.

It was not possible to put an ammeter directly in the alternater field circuit so that the current was calculated from the resistance of the field coils and the voltage of the exciter current. As the exciter itself has stationary fields the current in the exciter can be measured directly with an ammeter. The resistance of the revolving field of the generator was carefully measured with a post office box and found to be 1.15 ohms at a temperature of 25°C. In computing the current in the alternator field which had a temperature of 49°C. the following correction was made.

t_1 = temperature of copper when cold Res. is measured.

R_1 = resistance at temperature t_1.

t_2 = temperature of copper when hot.

R_2 = resistance of copper at temperature t_2.

First reducing to zero degrees $R_o = \dfrac{R_1}{1 + .0042t_1} = 1.04$ ohms.

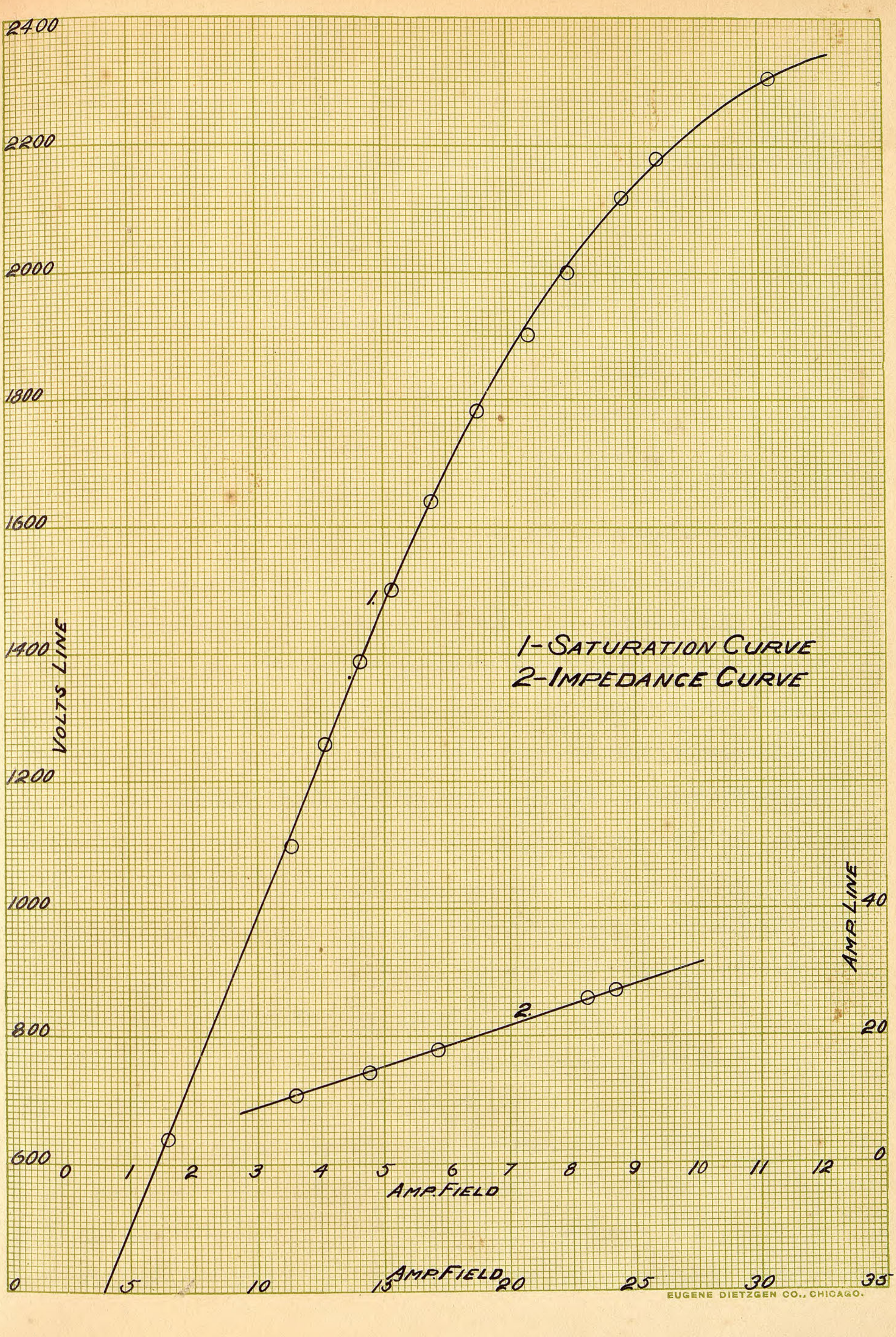
Then temperature at t degrees $R_t = (1 + .0042t) R_o$.

For temperature of 49° $R_{49^\circ} = (1 + .0042 \times 49)\, 1.04 = 1.25$ ohms.

Then at 49° the resistance of the fields is 1.25 ohms. From this data the alternator field current can be calculated and this together with the current in the exciter field is the total current generated by the exciter. This total current varied from 6-1/2% to 2-1/2% of the total output of the generator on loads during the test. The exciter current at different loads is given in the data and the watts consumed in the exciter and alternator fields. It will be noticed that for the same output with the inductive arc lamp load a larger exciting current was required than with an incandescent load which is non-inductive.

Saturation Curve Data.

Exciting Current.		Open Circuit.
Volts	Amp.	Volts
2.1	1.82	202
7.5	6.52	640
13.1	11.39	1100
14.7	12.78	1260


2400
2200
2000
1800
1600
1400
1200
1000
800
600
0
VOLTS LINE
1-SATURATION CURVE
2-IMPEDANCE CURVE
1.
2.
AMP. LINE
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12
AMP. FIELD
0 5 10 15 20 25 30 35
AMP. FIELD

Data Con.

Volts	Amp.	Volts.
16.2	14.98	1390
17.6	15.30	1500
19.5	16.95	1640
21.8	18.95	1780
24.	20.87	1900
25.9	22.52	2000
28.5	24.78	2120
30.	26.08	2180
35.	30.43	2308

Temperatures were taken at seven places during the run, and the temperature of moving parts were taken just after the generator was stopped. Three thermometers were placed in openings af the armature laminations of the alternator, two placed in the windings of the armature through openings on the side and one in each of the bearings. The greatest rise of temperature in the armature laminations was 29.4° C above the room temperature and in the ammature windings there was a rise of 17° C. in the bearing on pulley and a rise of 17.5°C and in bearing on commutator end the maximum rise was 11°C.

The following is the temperature of revolving parts taken just after the generator had stopped.

	Temp.Fah't.	Rise in Temp.Fah't.	Rise in Temp.Cent.
Commutator	100°F	23°	12.8°
D.C. Field coils (stationary)	98°F.	21°	11.7°
D.C. Armature	99°	22°	12.°
D.C.Collector rings	91°	14°	7.7°
Trailing pole tip	120°	43°	24°

Leading pole tip - - - - - - - -118° - - - - - -41° - - - - - - - - 22.7°.

Field coils (revolving) - - - 120° - - - - - 43° - - - - - - - - 24°.

The impedence of one coil of alternator armature was taken. This was done by short circuiting the generator through an ammeter and taking open current voltage with a constant field current. It is common practice to take readings at various field strengths until the armature current is from 1/3 to 1/2 full load current of machine.

The impedence of the machine is the apparent resistance or the resistance due to pure ohmic effect and that due to induction. As in ohm's Law $I = \frac{E}{R}$ and $R = \frac{E}{I}$ then in the case of an alternator armature coil.

Impedence $(Z) = \frac{(E)\text{ open circuit voltage}}{(I)\text{ short circuit amperes}}$ this to be taken at a constant field excitation. The coil tested in this machine had an impedence of 1.6758 ohms with 11 amperes through ammeter, and dropped to 1.5625 ohms with 27 amperes. Data is given in table for Impedence.

Impedence Data - 150 K. W. Alternator.

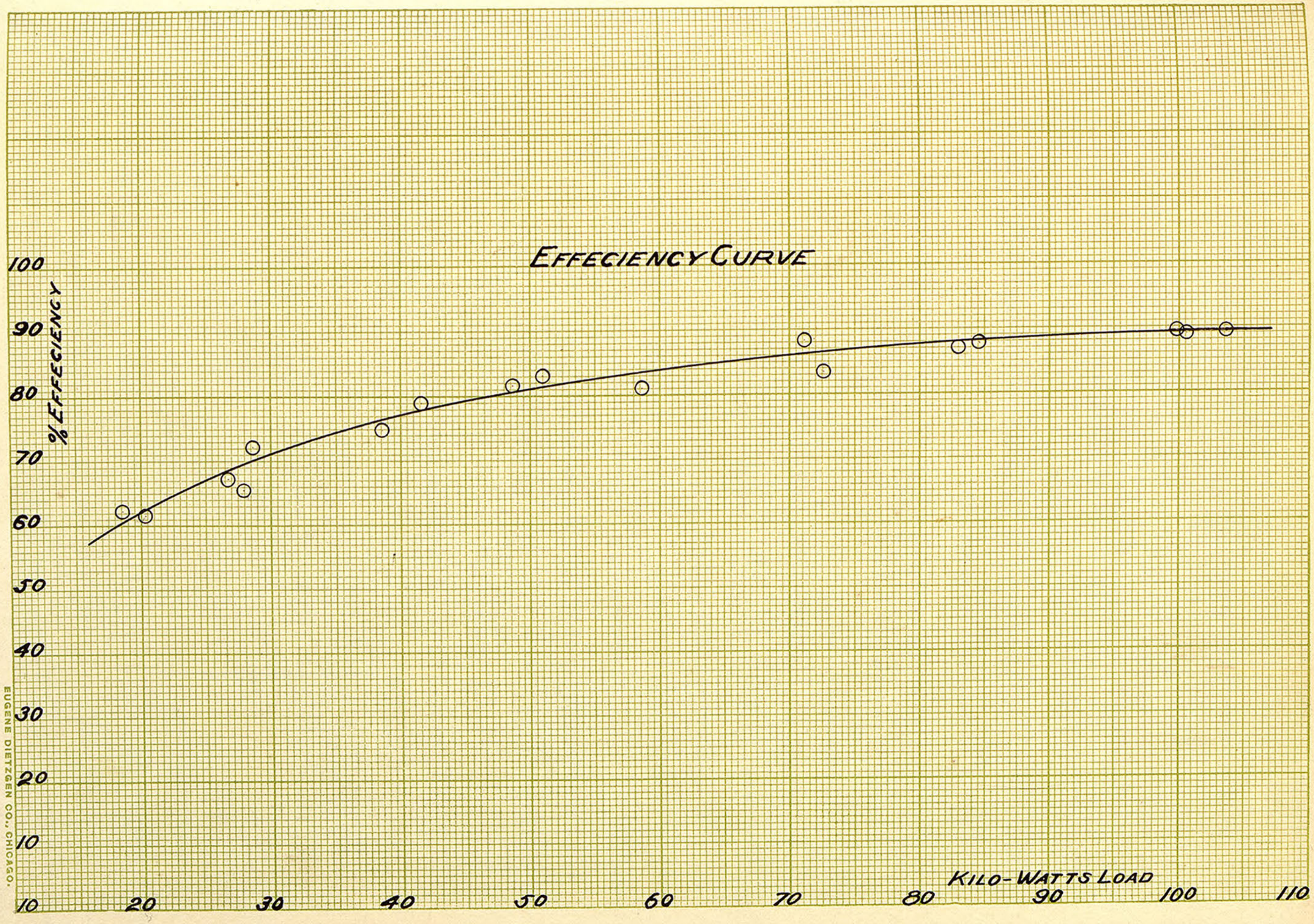
Exciting Current.		Open Circuit.	Short Circuit.	Impedence.
Volts.	Amp.	Volts.	Amperes.	Ohms.
4.1	3.56	360	11	
5.5	4.78	486	14.5	1.6758
6.7	5.82	592	18	1.644
9.5	8.26	820	26	1.577
10	8.69	850	27.2	1.5625.

Complete data for Efficiency Test. —Taken May, 7. 1904.

	Speed		Temperatures. F.					Leg No. 1.			Leg No. 2.			Exciter Current			Exciter Field	Alt. Field.	Alt. Input	Alt. Output		Per-cent
Time	Eng.	Gen.	Room	Pulley Bearing	Exc'tr Br'ng	Laminations	Arm. Wdg's	Kilo-Watts	Amp	Volts	Kilo-Watts	Amp.	Volts	Ex. Field Amp	Ex. Volts	Alt Field Amp.	Watts	Watts	K-Watts	K.-Watts	Power Factor	Efficiency
6:00	90	600	76	94	84	102	87	11.	5.55	2240	7.	3	2180	3.85	36.2	28.9	139	1048	30.14	18.8		62.3
6:15	90	600						12.36	5.53	2280	8.	3	2240	3.6	38	30.4	142	1155	33.36	20.36		61.8
6:30	89.5	592	77	98	88	110	92	16.4	7.1	2280	10.8	5	2200	3.62	38.8	31.	140	1202	40.36	27.20	1.	67.4
6:45	89.3	590						17.06	8.18	2280	11.6	5.5	2200	3.68	39.5	31.6	145	1248	43.89	28.66	.932	65.3
7:00	89	595	78	102	92	112	96	16.72	7.88	2280	12	6.	2200	3.69	39.9	31.9	147	1273	39.79	28.72	.921	72.1
7:15	89	594						23.2	10.2	2290	15.4	7.5	2190	3.73	40.8	32.6	142	1331	51.58	38.60	.97	74.8
7:30	89	592	77	105	94	116	96	29.6	12.8	2290	216	11.	2160	3.81	41.5	33.2	158	1377	61.58	57.20	.964	83.1
7:45	87.5	583						41.6	17.2	2340	29.6	14.3	2186	4.38	46.2	36.9	182	1704	80.64	71.20	.995	88.3
8:00	87.4	580	78	108	97	122	101	48.8	20.1	2360	34.4	16.3	2176	4.5	48.	38.4	216	1843	95.73	83.20	1.	86.9
* 8:30	86.4	575	78.5	108	95	126	106	39.6	22.	2360	64	29	2230	5.2	55.5	44.4	288	2464	116.65	103.6	.904	89.1
9:00	86.4	575	78	110	97	128	106	38.4	21.9	2340	62.4	28.5	2220	5.1	55.	44	280	2420	113.16	100.8	.88	89.2
930	86	570	79	110	97	132	108	38.	21.4	2360	62	25.25	2250	5.3	56.2	44.9	297	2526	111.94	100	.931	89.7
10:00	86	567	77	106	96	131	106	25.2	17.4	2380	59.4	26.75	2280	5.15	54.5	43.6	280	2376	96.82	84.7	.827	87.5
10:30	86	569	75	106	93	128	104	15.8	15	2390	57.	25.25	2310	5.1	54.	43.2	275	2332	87.32	72.8	.789	83.3
11:00	87	577	76	108	93	125	103	9.8	13.4	2300	49.	23.	2250	4.05	47.	37.6	190	1767	73.29	58.8	.712	80.2
11:30	88.5	590	75	107	91	121	100	5.8	12.9	2280	43	20.	2240	3.75	44	35.2	165	1548	60.03	48.8	658	81.3
12:00	88	570	74	104	90	120	97	1.8	12.2	2280	40	18.	2260	3.71	43.5	34.8	161	1511	52.37	41.8	.622	79.8
o 12:00	88	569						10.4	3.	2290	11.	3.	2290	2.93	34	27.2	99.	924	38.33	21.4	1.	55.8

* Arcs put on   o Arcs turned off

H.T.


EFFECIENCY CURVE
% EFFECIENCY
100
90
80
70
60
50
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20
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KILO-WATTS LOAD
10
20
30
40
50
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90
100
110
EUGENE DIETZGEN CO., CHICAGO.

THE INCANDESCENT LIGHT SYSTEM

and LINE DISTRIBUTION.

The Incandescent System of the Manhattan Ice, Light and Power Co., is a simple one, and is probably as efficient a one as commercial installations are apt to be. The three phase primary line is carried on 42 foot poles, 125 feet apart from the plant at the corner of 1st and Yuma Streets, to the corner of Poyntz and 3rd Streets about five and one-half blocks distant. This point is the assumed center of distribution. (It is marked in light lines on the map). The generator is compensated to maintain constant potential at this point. On this primary line a pressure of 2080 volts is maintained. The average full load current is about 20 amperes. The primary wires up to the center of distribution are No. 3, rubber covered, carried on glass insulators on wooden cross arms; the three wires forming a triangle with the apex down. As the secondaries, primaries and arc light circuits are carried on the same poles there is at times considerable crowding of lines, and, although the three legs of the primary circuit are kept well separated they are really very close since these lines are tapped off from the primaries and in some places are as close as six inches to primary wires.

The heaviest part of the lighting service is within three blocks of the center of distribution, and includes the business portion of the city. (Within the light circle on the map). Within this circle are 13 transformers, supplying 3050 16 c.p. incandescent lights. The capacity of these transformers is 155.5 K.W. and the load is 152.7 K.W. so that as a whole they are underloaded, although some

Manhattan
Kansas

Pop. 5000

Distribution Of
Arc Lights X
and
Transformers O

individual members of the group are overloaded.

The problem on this line as on any other is to secure good regulation and high efficiency with minimum cost of installation. For the last two purposes the transformers are kept loaded to their fullest possible capacity. As in most cases only part of the lights are ever running at the same time it has been found allowable to overload with lights about 10 or 15%. This gives high efficiency and low cost of installation, but on a rainy day or in winter when the evenings are short and all lights are apt to be on it causes a big voltage drop, and it is then that the customers complain.

In the business portion of the town there could probably be a more economical placing of transformers, than the present system. Nos. 3, 2, and 1 could be combined at or near where No. 2 is now situated. They could be replaced by one 40 K. W. transformer. This would allow for the growth of the system in that district. The efficiency of this transformer at 3/4 load would be about 96.5%. This is but little greater than that of the three combined and running at full or nearly full load, but when the three are running on light loads this efficiency of the 40 K. W. size would be much the greater. This difference in efficiencies is not so important as it would be, did the transformer run all day, but there is a marked difference in the cost of installation, and a difference in the % of regulation, two important factors not to be neglected. The drop on No. 3 at full load is about 2.5 volts, while that on a 40 K. W. size would be hardly measurable. A growth of the system is the natural reward of good regulation, so that large transformers pay from this standpoint. And when the transformers are not fully loaded and the efficiencies are cut down due to this the large sizes are still more economical. Small transformers, if run all day, entail an enormous loss due to their exciting currents, and in such cases it would be merely a waste of capital to install them. This holds with only slightly less force for installations when transformers are likely to run for much of the time with no load or a very light load.

Then again Nos. 12 and 29 could be combined at or near 12 with a saving of wire and transformers. Nos. 13 and 14, and Nos. 15 and 16 could be combined in a similar manner. This would provide one large transformer in the center of each alternate block of the business portion of the city, place all lines in the alleys and by so doing add materially to the appearance of the streets.

The primary lines from the center of distribution out for a distance of about three blocks are No. 6 wire. After that they are No. 8 wire. The secondaries from the transformers to the customers' conform to the Underwriter's rules. In order to distinguish secondaries, arcs and primaries form each other, the different circuits are carried on insulators of different color; primaries on green, arcs on amber, and secondaries on dark blue. Transformers are of the ratio of 20 to 1 and the secondary voltage is 104.

The Watt-hour meters used are of three different types, Thomson's Indicating, Thomson's High Torque, and the Gutman. All have given varying degress of satisfaction.

There is connected with this plant a transmission line to Eureka Lake 6-1/2 miles away, supplying that place with light. The transformer is of 25 K.W. capacity but it supplies 935 lights, about 87% overload. This should not make a transformer drop of more than

3.5 or 4 volts at full load, that is when all lights are on. The actual voltage on the secondaries, the transformation ratio being 20 to 1, drops from 104 at no load to 92 at full load. The remainder of this drop can be accounted for by the line drop-over the 6-1/2 miles of line.

TRANSFORMER TABLE.

No.	Capacity K.W.	– 16 cp.lamp.	Lamp load.	Overload Lamps.	%	Underload. Lamps.	%
1	15	300	275			25	8.3
2	7.5	150	175	25	15		
3	5	100	129	29	29		
4	8	80+80	190	30	18		
5	10	200	176			24	12
6	4	80	72			8	10
7	2	40	52	12	30		
8	6	12	15	3	25		
9	4	40	75	35	87		
10	4	40	44	4	10		
11	4	40	40				
12	14	80+200	245			35	12.5
13	5	100	88			12	12
14	35	300+400	450			250	35
15	25	500	477			23	4.6
16	15	300	239			61	20.3
17	9	80+100	173			7	3.8
18	8	80+80	178	18	11.2		
19	5	100	108	8	8		
20	4	80	50			30	37.5

Transformer Table Continued.

No.	Capacity K.W.	16 C.p.lamp.	Lamp load.	Overload Lamps.	%	Underload. Lamps	%
21	2	40	33			7	17.5
22	15	100+200	283			17	5.6
23	1	20	33	13	65		
24	5	100	95			5	5
25	4	80	108	28	35		
26	2	40	44	4	10		
27	2	40	48	8	20		
28	5	100	104	4	4		
29	30	600	655	55	9.1		
30	.6	12	5			7	58
31	25	500	935	435	87		

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THE ARC LAMP SYSTEM.

On account of the effect of the arc lamps on the generator and the incandescent load on the generator it was thought best to make a few tests on the arc circuit. The system used in this plant is the Western Electric Series Enclosed A. C. constant current system.

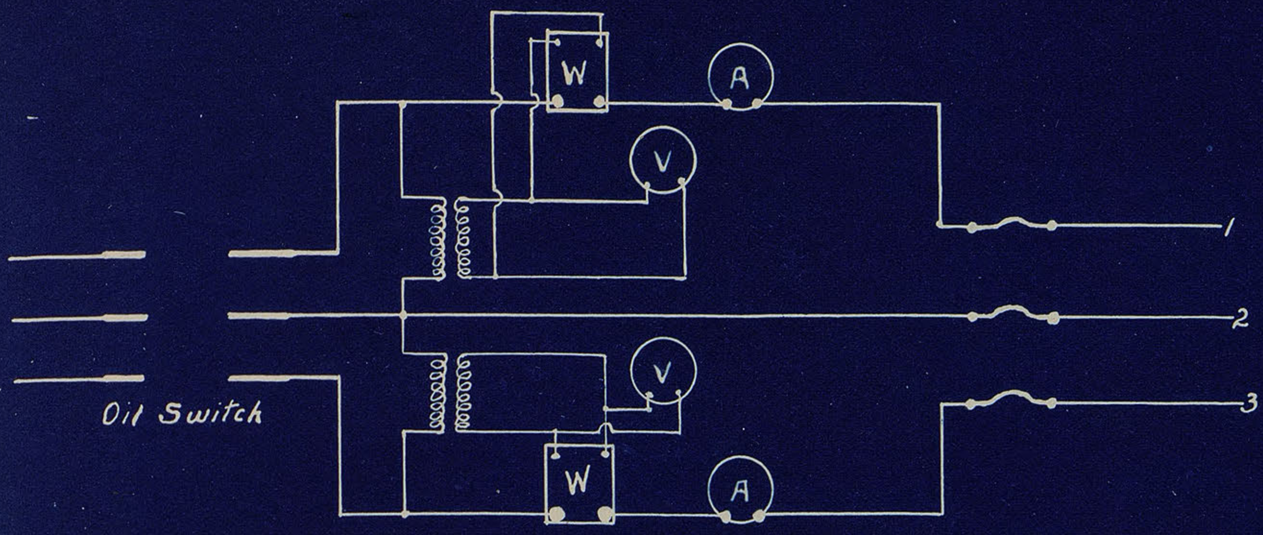

Fig 2. Showing connection of Instruments to measure Power and Power-factor.
for entire system.- 3 Phase.

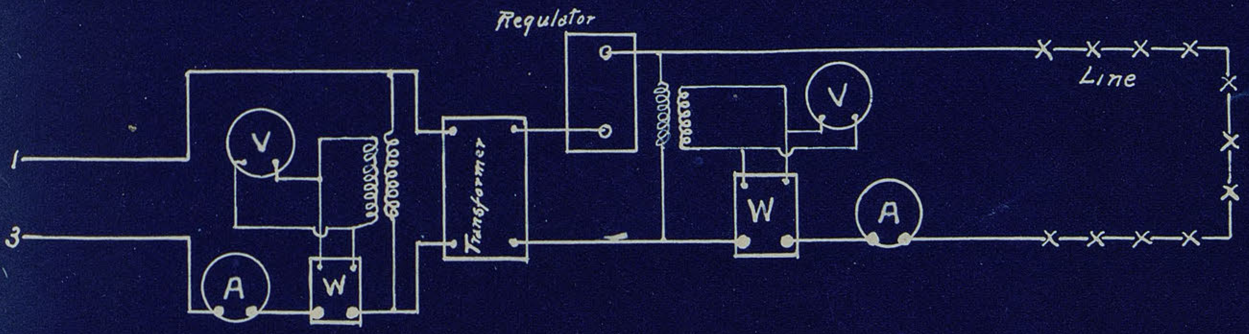

Fig. 3. Diagram of Connections for Arc Light Circuit.

H.T.

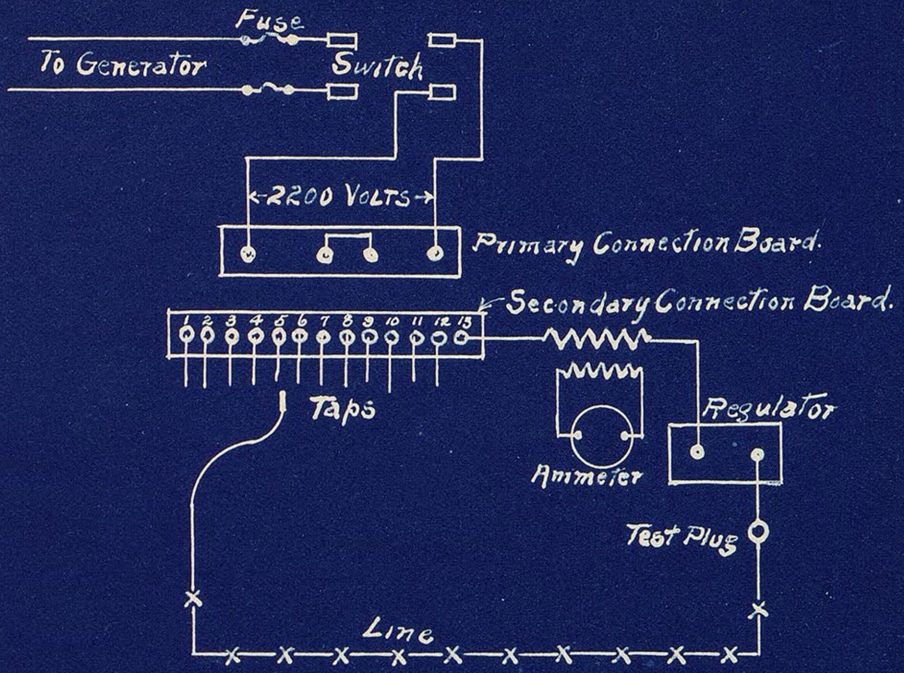

Fig. 4. Diagram of Series Enclosed Alternating Arc Lighting System.

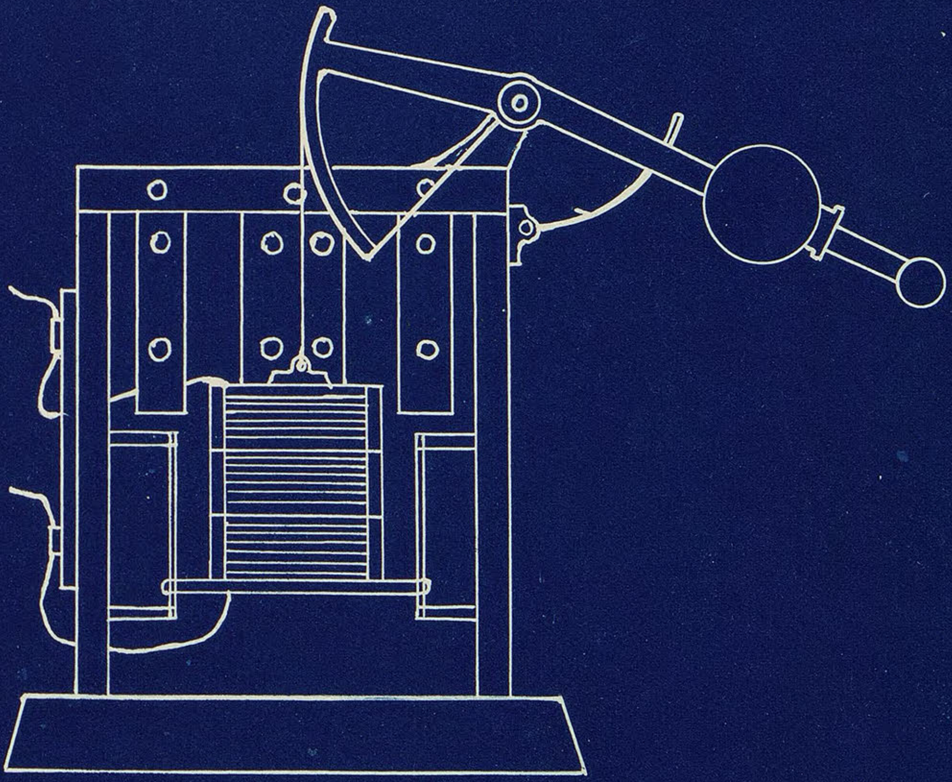

Fig. 5. Western Electric Constant Current Regulator

H.T.

A diagram of the system with apparatus as installed is shown in Fig.4. and the connections of the instruments used in getting data are shown in Fig. 3. The primary circuit is connected to lines 1 and 3 of the three phase circuit shown in Fig. 2. This has a voltage ranging from 2100 to 2300. This line goes to the transformer shown in Fig. 4 where it is stepped up. The secondary has 13 taps. One line of the secondary circuit is permanently attached to tap No. 13 and the other to any one of of the other twelve, depending on the number of lamps on the circuit. In this case it is tapped on No. 12 which gives a secondary voltage at transformer terminals of 3300 volts. The lamps, thirty-one in number, and also the regulator are placed in series in the secondary circuit. These lamps take about 7 Amp. at about 77 volts. The thirty-one lamps would require a pressure of practically 2400 volts allowing for line drop, etc. But we have 3300 volts at secondary terminals of transformer and this must be cut down to 2400 which is done by the regulator. When the plant was first installed the transformer was not used as fewer lamps were used and the voltage from the generator was sufficient. When the number of lamps were increased it was necessary to install a transformer. The one now used is a 50 lamp transformer, while only 31 lamps are used, there being no size between 50 and 25 lamps. As was said before, this necessitates the regular cutting down the voltage to the requirements of the lamps. This in itself does not effect any loss except core losses in the regulator, but it causes a high induction, which gives a lagging current and consequently a low power factor. The regulator is shown in Fig. 5. It consists of a coil of wire supported from a balanced arm and free to move up and down. This coil is made to inclose a soft laminated iron core which is rigidly fastened to the frame. The amount of the core enclosed by the coil will depend on the number of lamps on the circuit and the secondary voltage at the transformer. The current on the arc circuit is adjusted by moving the counter weights on the lever arm. The principle of regulation is as follows.- Suppose at any instant there is an increased current due to poor regulation of a lamp or short-circuiting of a lamp, the increased current will draw the coil further up on the core which will produce a higher induction in the line due to more coils surrounding the core and this will tend to choke down the current. When the current is decreased it has an opposite effect which tends to increase the current. Thus it can be seen that with all parts well adjusted and free to move a very close regulation can be obtained. This regulator is very sensitive and any change in a lamp would materially effect the regulator. If a globe were taken off one lamp located in the room,and which was in the main circuit, a slight current of air would so effect the lamp that the regulator continually shifted. Under normal conditions of the line, the current in the arc circuit did not vary over .2 amp. or .1 Amp. above or below mean reading.

Tests of individual lamps gave results as follows:

Drop over lamp terminals average 77.5 volts.

Range 70 to 85 volts. Drop over carbons 66 volts. This gives a drop in the regulating mechanism of the lamp of 11.5 volts or a loss of 80.5 watts with 7 Amp. A lamp with a broken globe may effect the regulation of the system a great deal. With the globe off in a room with very little if any draught the voltage would vary from 10 to 100 volts over the lamp and the regulator continually shifted.

The current would vary from .5 Amp. to 1 Amp. Even a small hole in the globe greatly effects the steadiness of the arc. The lamps are so arranged that if the mechanism fails to act the lamp is short circuited through a coil which is inside the lamp. This is supposed to partly make up for the lamp, and also acts as a ballast or damper for the current. The drop over one of the coils is 20.5 volts.

Measurements of power were taken on both sides of the transformer and regulator. With 31 lamps in circuit, the power required for the arcs alone averaged 15 K.W. Average readings on the primary arc circuit gives 16.65 K.W. The difference between these readings 1.65 K.W. is lost in the transformer and regulator. This gives an efficiency for the transformer and regulator of 90% which is probably much lower than it would be with full load.

Arc Lamp Data - Direct on Arc Lamp Circuit Shown in Fig. 3.

Time	K. WATTS	Amp.	Volts	No.of Lamps.	Cos θ	θ
8:30	14.48	6.95	2230	31	.934	20° - 56'
8:30	14.50	6.95	2250	31	.927	22° - 2'
8:30	14.66	6.95	2290	31	.921	22° - 56'
9:00	15.10	6.96	2350	31	.923	22° - 38'
9:00	15.24	6.96	2370	31	.923	22° - 38'
9:00	15.20	6.96	2370	31	.921	22° - 56'
9:00	15.12	6.96	2370	31	.951	18° - 1'
9:30	15.20	6.95	2380	31	.919	23° - 13'
9:30	15.20	6.95	2380	31	.919	23°- 13'
9:30	15.16	6.95	2360	31	.925	22° - 20'
9:30	15.20	6.95	2380	31	.919	23° - 13'

Average 15:00

Arc Lamp Data. Primary Circuit. Connected as per Fig.3.

No. of Lamps.	K - Watts	Amp.	Volts	Cos θ	θ
31	16.60	11.85	2164	.654	49° - 9'
31	16.70	11.8	2156	.656	49°
34	17.40	11.75	2150	.694	46° - 3'
34	17.50	11.75	2160	.689	46° - 27'
36	17.80	11.7	2154	.706	45° - 5'

The power-factor of the whole arc lamp system is low. i.e. by the whole system is meant the transformer, the regulator and the arc circuit itself. With 31 lamps in circuit the power-factor is .655 while with the same number of lamps the power-factor on the lamp circuit itself, i.e. - not including the transformer and regulator, is about .92. This shows that the greater inductive effect comes at the transformer and regulator. By increasing the number of lamps to 36 the power-factor raised from .655 to .706 and which would gradually raise till full number of lamps (50) were on. Only 36 lamps were available so data could not be taken for a larger number. The power-factor is the ratio of the real Watts to the apparent watts and is expressed as a fraction which is the cosine of the angle of lag (θ) of the current behind the E.M.F. On the primary circuit Cos. θ = .655 and θ = 49° - 5'. On the arc circuit direct Cos θ = .92 and θ = 23°. The real watts are measured eith a watt meter, and the apparent watts are the product of the volt, amperes.

The arc lamp line has a total length of about 48960 feet, and is of No. 6 B. & S. wire. This gives a resistance of 19.3 ohms, or taking into account joints etc. about 20 ohms. With a line current of 7 Amp. this gives an I R loss of 980 watts on the line. As may be seen from the map the lamps are scattered over a considerable area and this causes a large line loss.

The general regulation of the arc system is quite good, the lamps give good steady light and seldom get out of order or cause "outs" as it is generally termed. This system seems to be especially adapted for small plants where it is not convenient or profitable to run a separate machine for arc lighting. The arc system which is an inductive load does not seem to interfere to any noticeable degree with the incandescent load. This is probably due to the compensating device on the generator. Just after the lamps have been trimmed and especially when they are first turned on they are rather unsteady and effect the regulator somewhat.

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