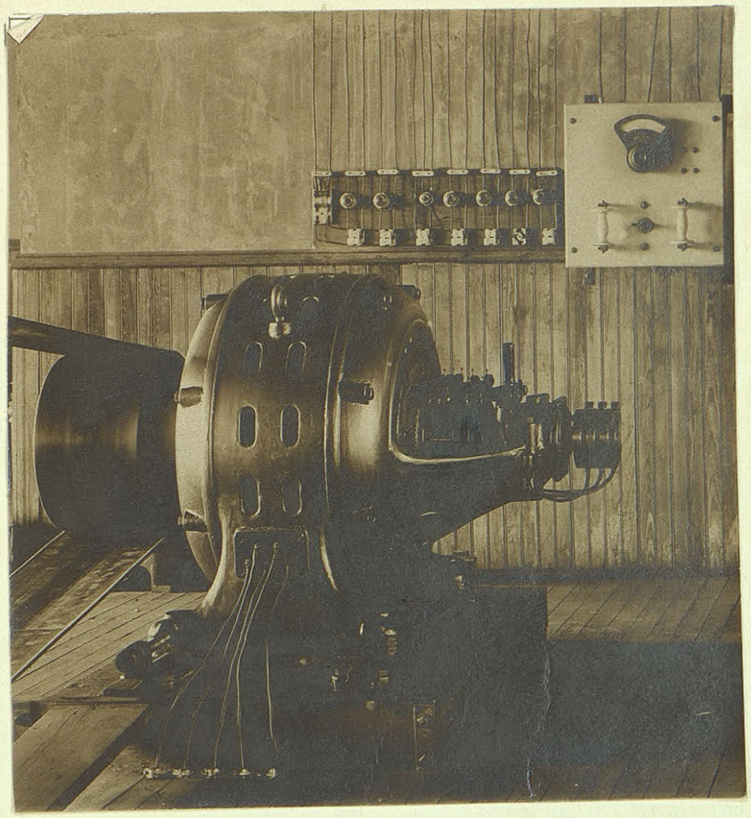
Tests of a 75 K.W. General Electric Alternator.

Type ATB

by

W. C. Lane.

Earl Wheeler.



GENERAL ELECTRIC ALTERNATOR
TYPE ATB

Rating:-

ALTERNATING CURRENT GENERATOR.

No.- 66727.   Spec.- 35114.

Type.- ATB.   Class.- 8 - 75 - 900.

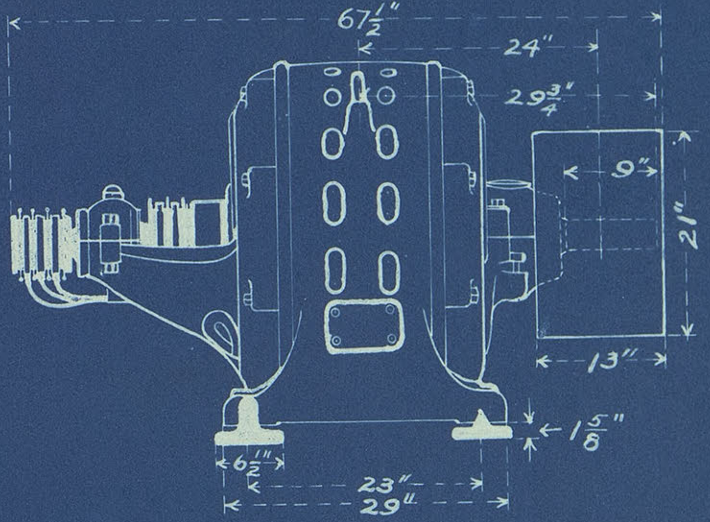
Form.- D.   Amperes.- 19.   Speed.- 900.

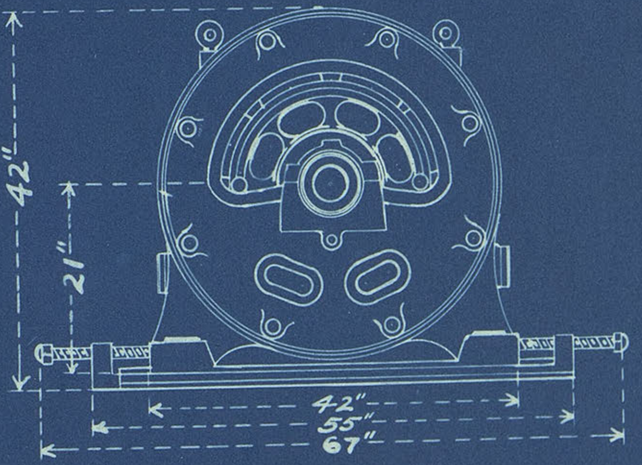
Volts no load ------------------ 2080.

Volts full load ---------------- 2300.

General Electric Company,
Schenectady,
New York.

DIMENSIONS OF ALTERNATOR.





CLASSIFICATION.					WEIGHT.	
TYPE	POLES	KW	SPEED	FORM	RAILS.	NO RAILS.
ATB	8	75	900	D	4750	4570

EW.

Description of Alternator.

The generator tested is in the power plant of the Manhattan Ice, Light and Power Company, Manhattan, Kansas. Its regular work is to carry the lighting load during the second half of the night. It is belt driven by a 14" x 21," Erie City, simple, non-condensing engine of one hundred and fifty horse power capacity at ninety five pounds steam pressure. The engine's normal speed is one hundred and seventy eight revolutions per minute. The power is transmitted by a pulley nine feet, three inches in diameter to a twenty one inch pulley on the generator shaft.

The generator is manufactured by the General Electric Company, Schenectady, New York. It is the revolving field, stationary armature type and is self excited from a direct current shunt generator carried on the same shaft. The armature windings of the alternator are of the distributed, "barrel" type. The core is of cast steel punchings laid together with suitable ducts to insure good ventilation through all parts. The coils are form wound and are laid on the core and held in place by beach wood wedges, which are driven into slots over the coils. This allows the speedy removal of damaged coils. As the armature is stationary, the insulation can be made more secure. In these machines the armature insulation is required to withstand four or five times the normal working pressure. The armature is wound with sixteen coils per phase and is Y connected. It has a total of forty eight coils, each coil consisting of eighteen turns. The connectors are No. 12, B.&S.G. copper wire, there being two in multiple. Each phase of the armature is guaranteed to carry eighty per cent of the machine's rated output in single phase current.

The poles of the revolving field are laminated and are fitted to the steel hub by means of dove-tailed slots, the poles being held in place by taper keys. This design makes each pole readily accessible. The field coils are wound with flat copper strips, .025" x .625". There are one hundred, fifty and one-half turns per spool. The strip is wound edgewise, each coil consisting of a single spiral, a layer of a special prepared oil paper being the only insulation between successive turns. This winding allows each turn to be exposed to the air, giving a very good surface from which to dissipate the heat.

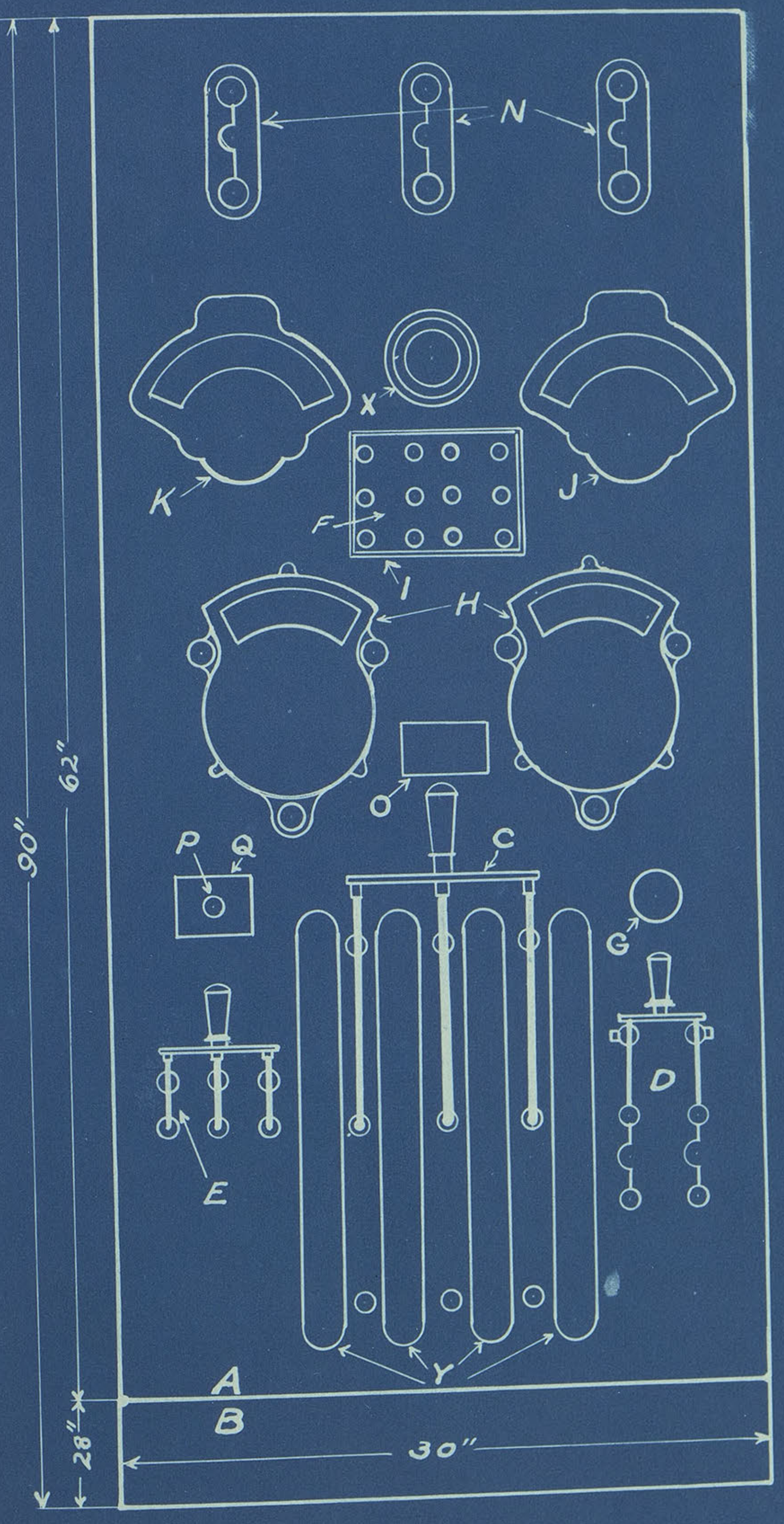
Within the shield of the machine is the direct current armature of the exciter, so wound as to give a pressure of about fifty volts on full load. The exciter is a shunt generator with the same number of poles as the revolving field. Immediately outside of the commutator are two slip rings to which the revolving field is connected. The brushes of these rings are on the same rocker arm as the brushes of the exciter, the revolving field being shunted directly over the exciter brushes, through these rings. The field of the exciter is also shunted over the exciter brushes, the switchboard rheostat being in series with it. On the outside of the bearing are three slip rings through which the current from the series transformer reaches the exciter armature, so as to effect compounding. All these slip rings are of cast steel, fitted with carbon brushes with spring tensions.

The bearings are lined with an anti-friction metal. They are spherical, self aligning and self oiling. The bearing on the pulley end is much larger than the one on the commutator end and thus reduces heating to a minimum.

The mechanical design in general is such as to make all parts accessible. The distribution of the iron makes practically all the magnetic material effective, consequently the efficiency per unit weight is high while the weight per kilowatt output is low.

PLATE I

SWITCH BOARD.

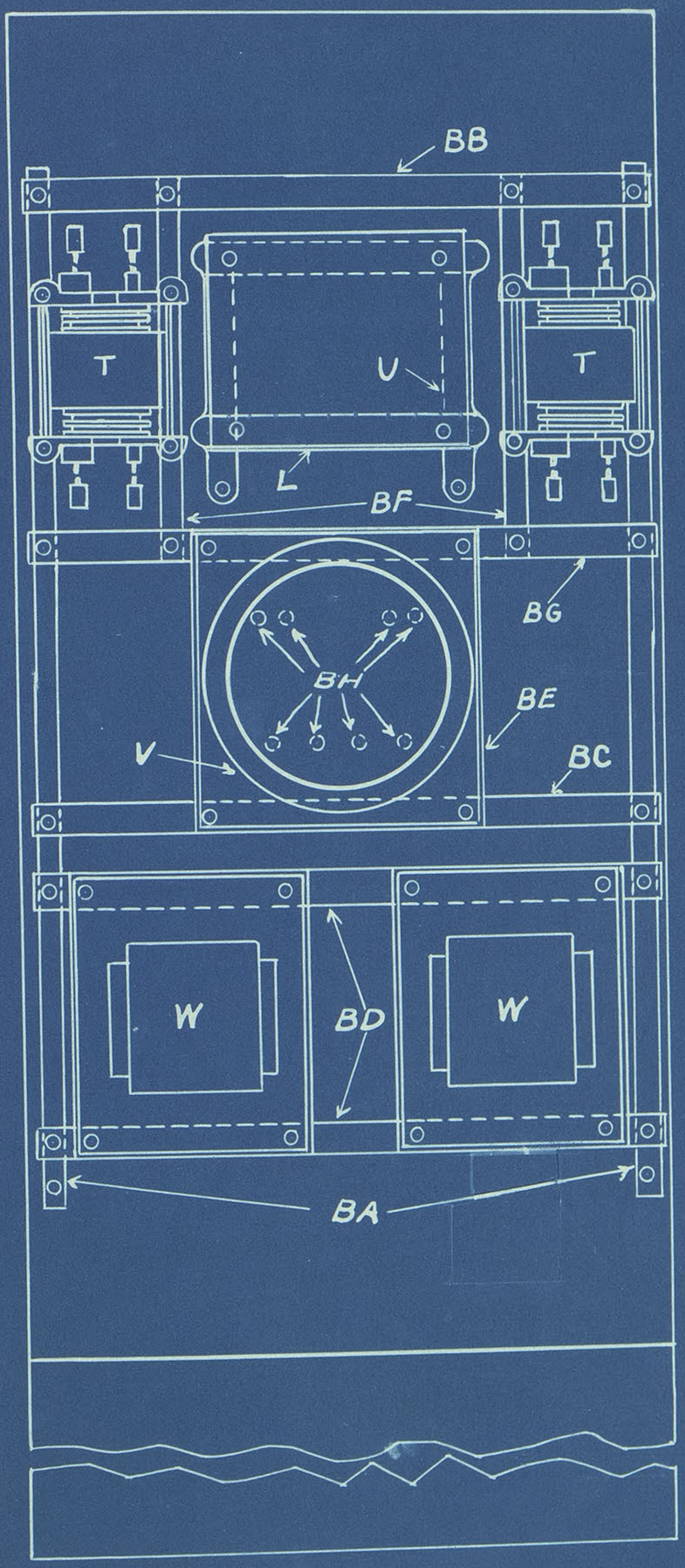


FRONT VIEW.

E.W.

SWITCH BOARD.

PLATE II.

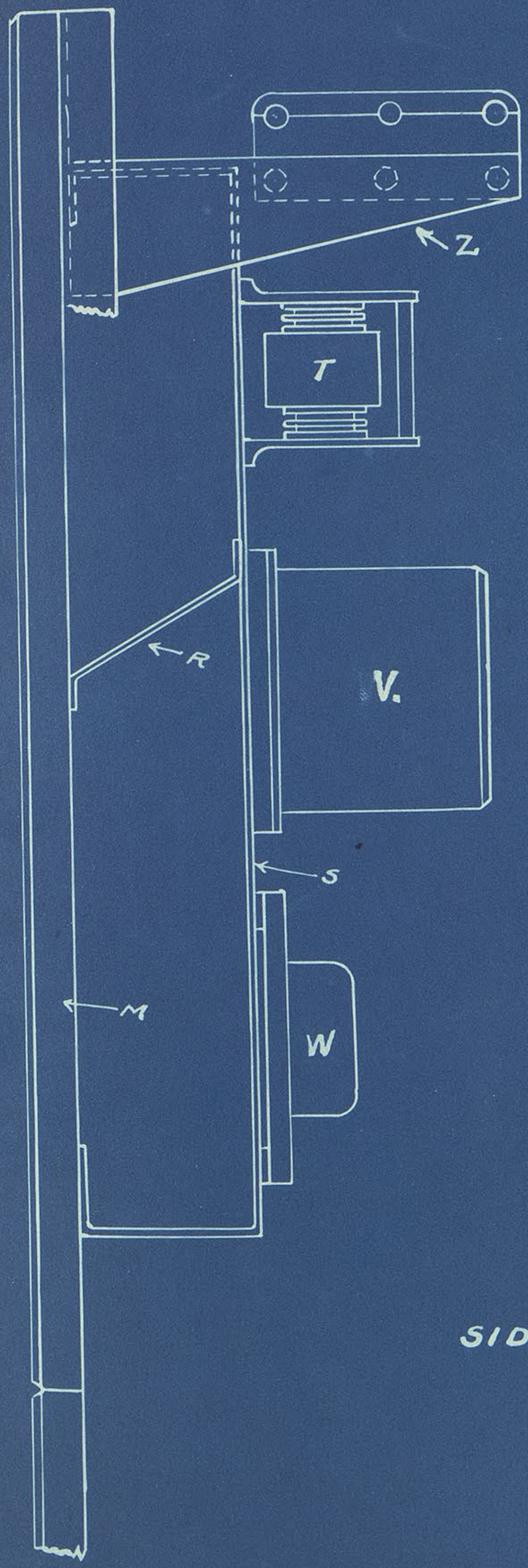


BACK VIEW.

EW.

SWITCH BOARD.

PLATE III.



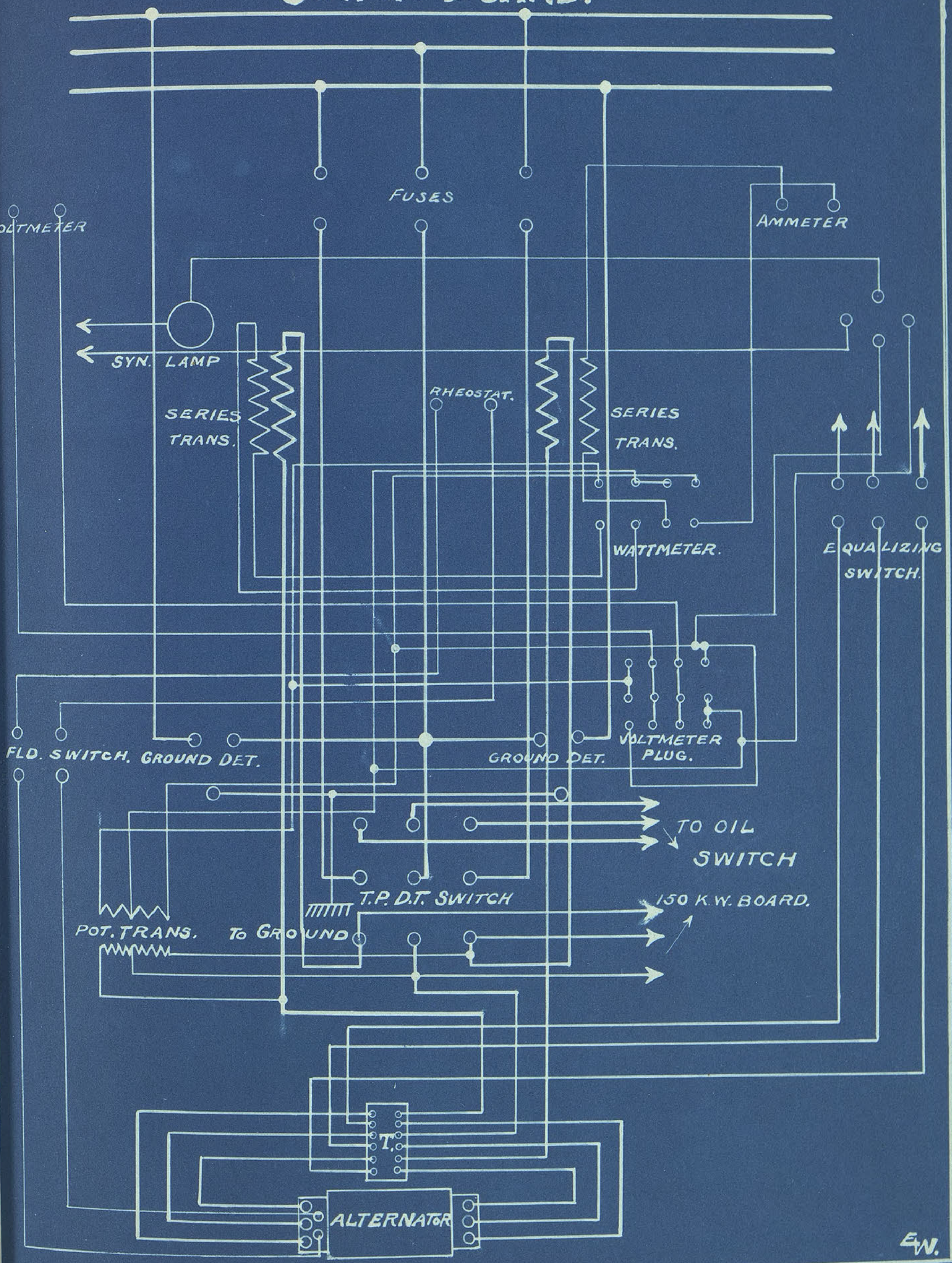
SIDE VIEW.

BB	FRAME. ALSO BG, BF, BC, BDBA
BE	BASE OF WATTMETER.
BH	WATTMETER TERMINALS.
Z	BRACKET AND SUPPORT FOR BUS WIRES.
Y	BARRIER FOR C.
X	HAND WHEEL FOR L.
W	POTENTIAL TRANSFORMERS.
V	WATTMETER 15 AMP. POLY. IND.
U	TRIPOD FOR L.
T	CURRENT TRANSFORMERS.
S	BRACES AND FRAME.
R	ANGLE BARS.
Q	RECEPTACLE 600 V. 4 PT. SYN.
P	PLUG. 600 V. 4 PT. SYN.
O	NAME PLATE.
N	FUSE BLOCKS. 100 A. 2500 V.
M	BLUE VERMONT MARBLE BOARD.
L	RHEOSTAT FOR EXCITER.
K	AMMETER. 35 AMP
J	VOLTMETER. 175 V.
I	RECEPTACLE 600 V. 12 PT. POTENTIAL.
H	GROUND DETECTOR 2300 V. S.P.E.S.
G	SYNCHRONIZING LAMP.
F	POTENTIAL PLUG. 600 V. 4 PT.
E	SWITCH. 125 V. 100 A. T.P.S.T.D.
D	SWITCH. 125 V. 200 A. T.P.S.T.C.B.
C	SWITCH 2500 V. 200 A. T.P.S.T.Q.
B	SUB BASE FOR A.
A	PANEL A.T.G. 2500 V. 19 A.

E.W.

SWITCH BOARD.

PLATE IV.



Theory of Compensator.

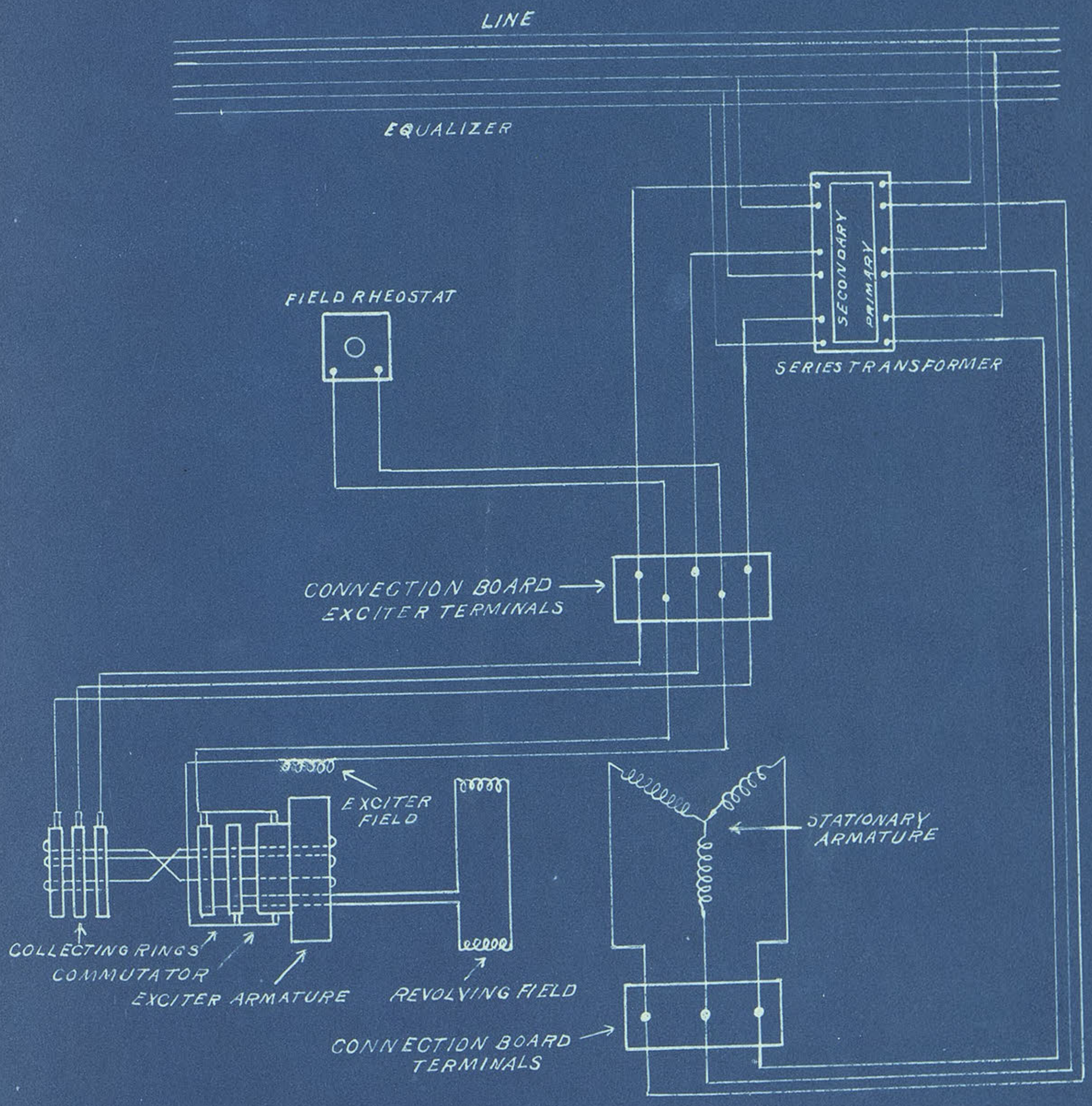
When the load on an electric generator, direct or alternating, is increased, the potential will fall unless the field excitation is increased. This is due to three things, ohmic resistance, armature induction, and the reaction of the armature on the field poles which reduces the field flux. There is also a line drop for points at some distance from the generator, due to line resistance and inductance. As a larger part of the electrical apparatus manufactured is designed to work at a constant potential, the importance of a device that will compensate for this generator and line drop is self evident.

Direct current machines are compounded by passing the main current through a few series turns placed on the field poles, the number of turns being so adjusted that the excitation of the machine will increase as the load increases. The same result has been obtained on alternating current machines by passing an induced part or a shunted part of the main current through a rectifying device and using it to increase the field excitation. This produces the desired result as long as the current is in phase with the E.M.F.; but when the current lags as in the case of an arc lamp or an induction motor load, the apparatus refuses to operate satisfactorily. The device employed by the General Electric Company in the construction of their compensated alternator is the first one constructed that will compound for all load conditions whether the current be lagging, leading, or in phase with the E.M.F. Though ingenuous, this device is simple in construction and gives an automatic regulation equalled by no other apparatus up to the advent of this company's T.A. regulator.

The means by which these results are accomplished are illustrated by Plate V. The shaft of the generator which carries the revolving field also carries the armature of the exciter. This has the same number of poles as the alternator. Besides the commutator and the two slip rings through which the direct current reaches the revolving field, the shaft carries three collecting rings. Over these rings the exciter armature receives current from a series transformer, the amount of which varies directly as the load. Since the exciter and alternator have the same number of poles and a common shaft, the two act in a synchronous relation. This being true, it is possible to connect the three slip rings to points in the exciter armature such that the impulses of current from the series transformer will furnish the required additional field excitation. The reactions that take place in the exciter armature under different conditions of load are illustrated in Plate VI.

Figure 5 represents the polarities induced in the arma-

PLATE V.



CONNECTIONS OF GENERATOR

WCL

PLATE VI.

FIG. 1.

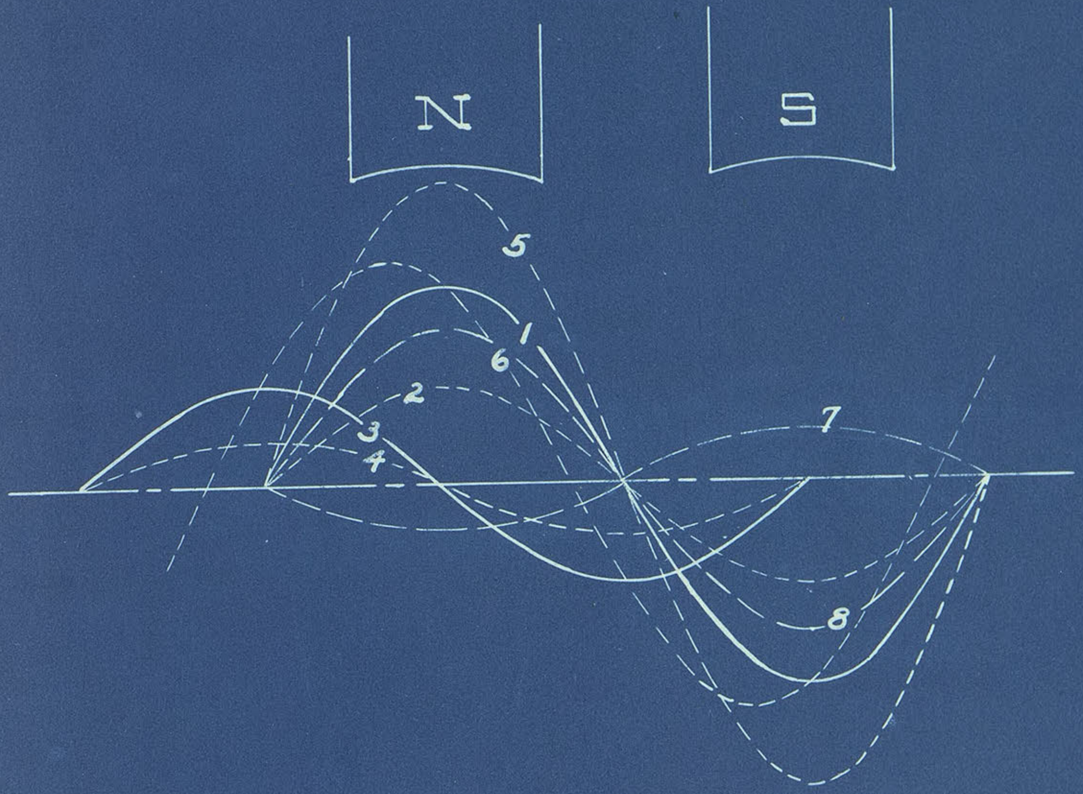


FIG. 2

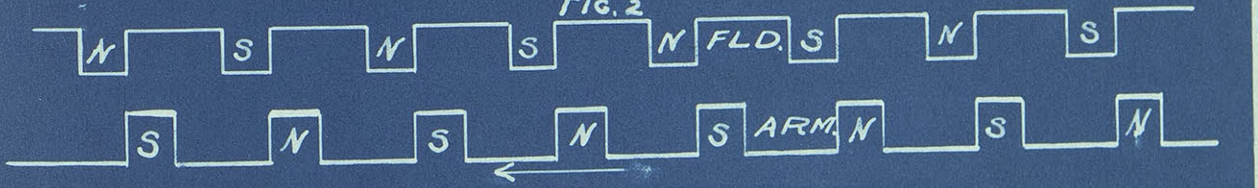


FIG. 3

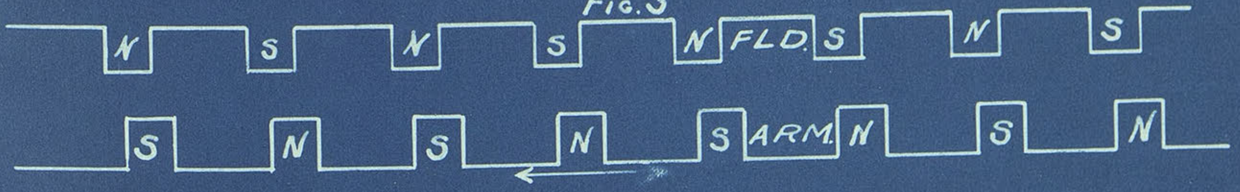


FIG. 4

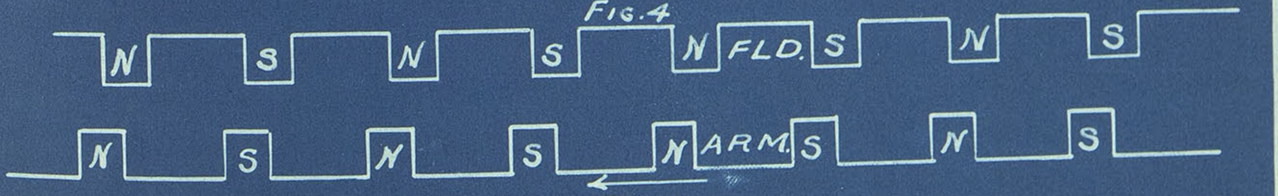
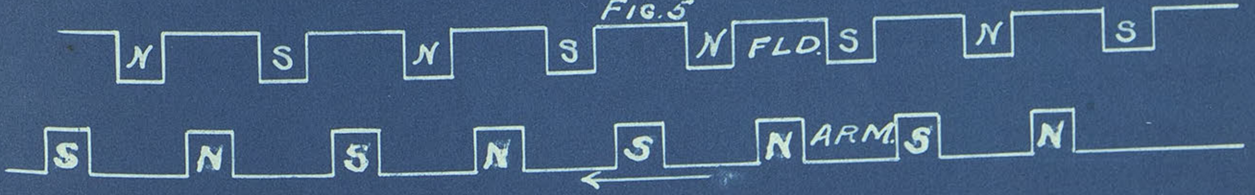


FIG. 5



E.W.

ture under a non-inductive load. The induced poles produce a skewing of the field flux and weakening the excitation. When a lagging current is introduced by the compensator, the excitation will be weakened to a still greater degree; for poles of like polarity will be formed more nearly opposite one another. The effect of a leading current is just the opposite to that of a lagging current. Unlike poles are formed opposite one another so that the field flux is strengthened. An abnormal rise in voltage is the result. If, now, the field poles are shifted forward a few degrees the armature poles induced by the compensating current will occupy the position indicated in Figure 2. The result will be that the field flux is strengthened. In the case of a lagging current, the armature poles will have reached a position more nearly opposite the field poles as in Figure 3. The field will thus be strengthened to a greater degree than it is in the case of a current in phase with the E.M.F. A leading current will cause poles of like polarity to be formed approximately opposite one another so as to weaken the field excitation. Figure 1 shows these relations in another manner. Curve #1 represents the flux due to the field pole; #3, the flux produced by the compensating current when the current is in phase with the E.M.F., and #6 is the resultant flux. When the current lags, #3 will move forward to the position of #2, and since #1 is stationary, #5 is the resultant.

From this it is evident that a lagging current will increase the effective flux of the exciter and thus increase the exciter voltage. Where the machine is run without the compensator the exciter acts entirely independent of the alternator. Neither a change of load nor a change in the phase relation of the current and E.M.F. affects it in the least. Curve #7 shows the flux due to the compensating current when the current leads the E.M.F. The resultant of #1 and #7 is #8.

The curves show, (a) that the field excitation increases directly as the load when the current is in phase with the E.M.F. (b) that the field excitation is strengthened by a lagging current, the increase of excitation varying directly as the angle of lag and (c) that the field excitation is weakened by a leading current, the weakening effect varying directly as the angle of lead. The compensating device is thus seen to regulate the excitation for all kinds of load.

Synchronous Impedance Test.

"The synchronous impedance of a generator is that impedance, which if connected in series with the outside circuit and an impressed voltage of the same value as the open circuit voltage at the given speed and excitation, will permit a current of the same value to flow as does flow."

In other words, it is equal to the open circuited voltage of the generator divided by the short circuited ampereage, each quantity being determined at the same speed and excitation. These quantities are determined from the saturation curve and the short circuited characteristic.

The saturation curve was plotted with volts as ordinates and field amperes as abscissa, the value of the co-ordinates being determined in the following manner. The machine was run at constant normal speed and the excitation was varied from zero to its normal value. Simultaneous readings of open circuit generator voltage and exciter voltage were taken for each value of the excitation. As this machine is so constructed that it is impossible to measure the field current of the generator, the field current was calculated from the values of the exciter voltage and the field resistance. The field resistance was measured by the usual fall of potential method. Corrections for temperture were made by means of the following empirical formula:-

$$R_0 = R_t/(1 + .0042t) ,$$

in which t is the temperture of the windings, R_t is the resistance at t^o degrees Centigrade and R_0 is the resistance at 0^o degrees Centigrade.

Data for Field Resistance.

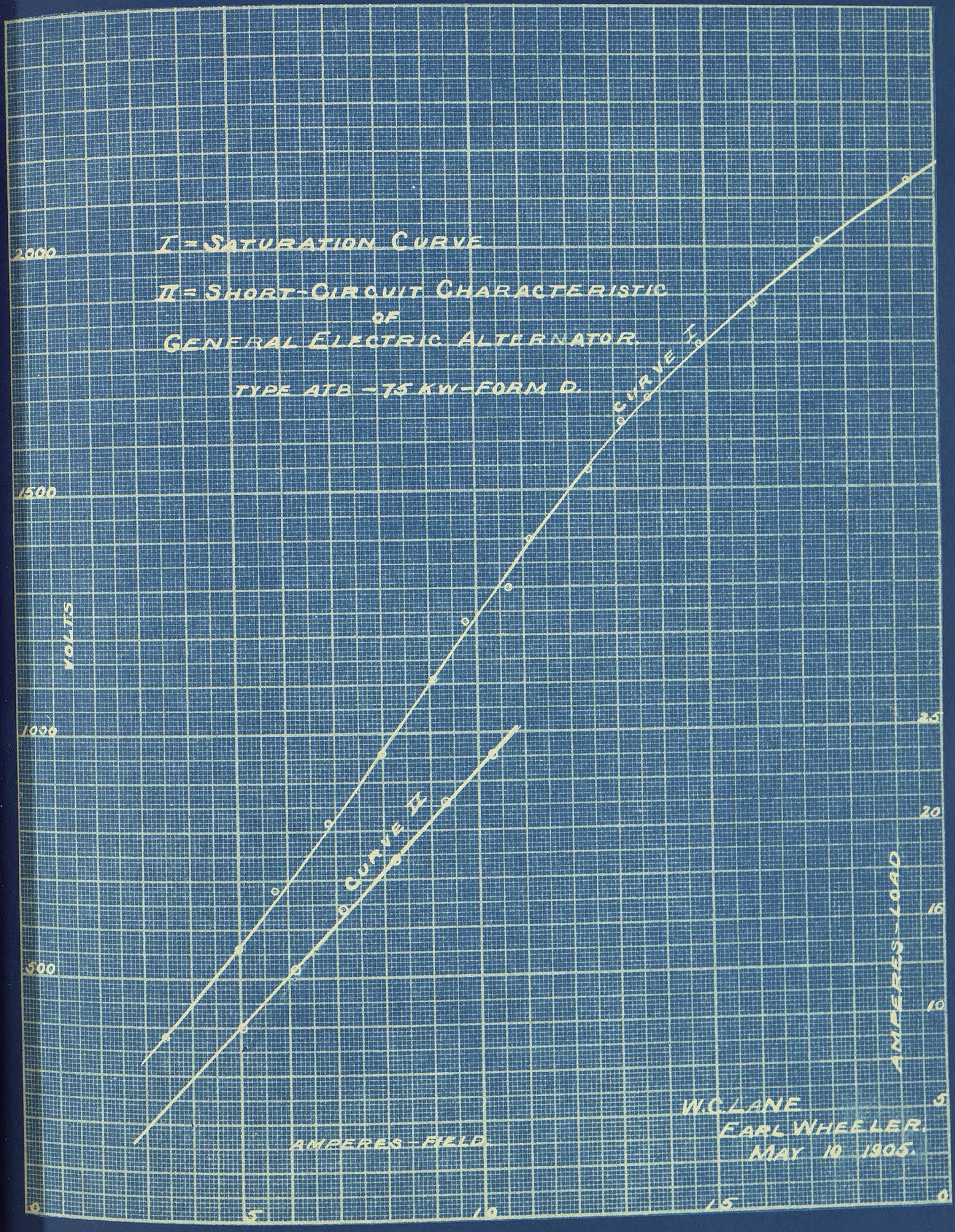
Volts	Amperes	Ohms
1.850	1.00	1.850
3.825	2.23	1.715
5.700	3.46	1.682
7.800	4.78	1.632
3.893	2.32	1.678
1.943	1.04	1.861

Mean, ohms ------------------- 1.736

Temperture ------------------ 38.3°C.

Data for Saturation Test.

#	Volts Field	Amperes Field	Volts Observed	Volts Terminals
1	6.0	3.44	19	380
2	8.8	5.00	28	560
3	10.0	5.72	34	680
4	12.0	6.87	41	820
5	14.0	8.00	48	960
6	15.9	9.09	55.5	1110
7	17.1	9.79	61.5	1230
8	18.5	10.70	65	1300
9	19.5	11.15	70	1400
10	21.8	12.44	77	1540
11	23.0	13.14	82	1640
12	24.0	14.72	84	1680
13	26.0	14.89	90	1800
14	28.0	16.00	94	1880
15	30.5	17.45	100.5	2010
16	34.0	19.40	107.0	2140
17	38.0	21.75	113.0	2260



I = SATURATION CURVE

II = SHORT-CIRCUIT CHARACTERISTIC
OF
GENERAL ELECTRIC ALTERNATOR.

TYPE ATB – 75 KW – FORM D.

W.C. LANE
EARL WHEELER.
MAY 10 1905.

The short circuited characteristic was plotted with amperes load as ordinates and field amperes as abscissa. The co-ordinates were obtained as follows. One phase of the generator was short circuited through an ammeter. The machine was run at normal speed and the excitation was varied so that the current in the single phase was varied from zero to twenty five per cent over load. Simultaneous readings of amperes load and exciter voltage were taken at each variation. As in the preceding test, the field current was calculated from the exciter voltage and the resistance of the revolving field.

Data for the Short Circuited Characteristic and Impedance of the Generator.

#	Volts Field	Amperes Field	Amperes Load	Volts Terminal	Impedance per Phase
1	8.80	5.02	10.0	560	56.00
2	10.75	6.14	12.9	700	54.26
3	12.50	7.13	16.0	835	52.19
4	14.40	8.22	18.4	990	53.80
5	16.25	9.30	21.4	1140	53.27
6	18.00	10.30	23.8	1265	53.15

Mean Impedance, ohms ---------------------- 53.78

The abscissa of the two curves are plotted to the same scale so that a load and the corresponding voltage can be easily determined. Find the voltage on the saturation curve

1000

for any value of field excitation. The load on the short circuited characteristic for the same excitation corresponds to this voltage. The impedance is equal to the quotient of the volts by the amperes.

Machines having a high impedance will not be damaged upon being short circuited. As this machine has a rather high impedance it would probaly stand a short circuit for a short time.

Efficiency of Alternator.

The inportant question in the manufacture of a commercial alternator is how much of the mechanical power expended at the of the machine will be realized at the bus bars of the switch board in the form of electrical energy. The commercial efficiency of a generator is the ratio of the output to the input in some definite unit of work.

The instruments were inserted in the line as shown by Figure 6, Plate VII. The series coils of the instruments were placed in the secondaries of the switch board current transformers. Since two wattmeters will measure all the power flowing in a three phase circuit, both switch board current transformers were used, an ammeter and a wattmeter being placed in each. The ratio of transfomation of these current transfomers was three to two. The voltmeters and potential coils of the wattmeters were placed over the low tension side of the potential transfomers. A potential transformer was placed between the middle and each outside leg, the ratio of transformation being twenty to one. Therefore, the sum of the wattmeter readings multiplied by thirty gave the entire output of the machine. The current coils were not placed directly in the main line because of a static effect.

Errors in measuring the output may have been caused from the following:- (1)Any error in the readings of the wattmeters

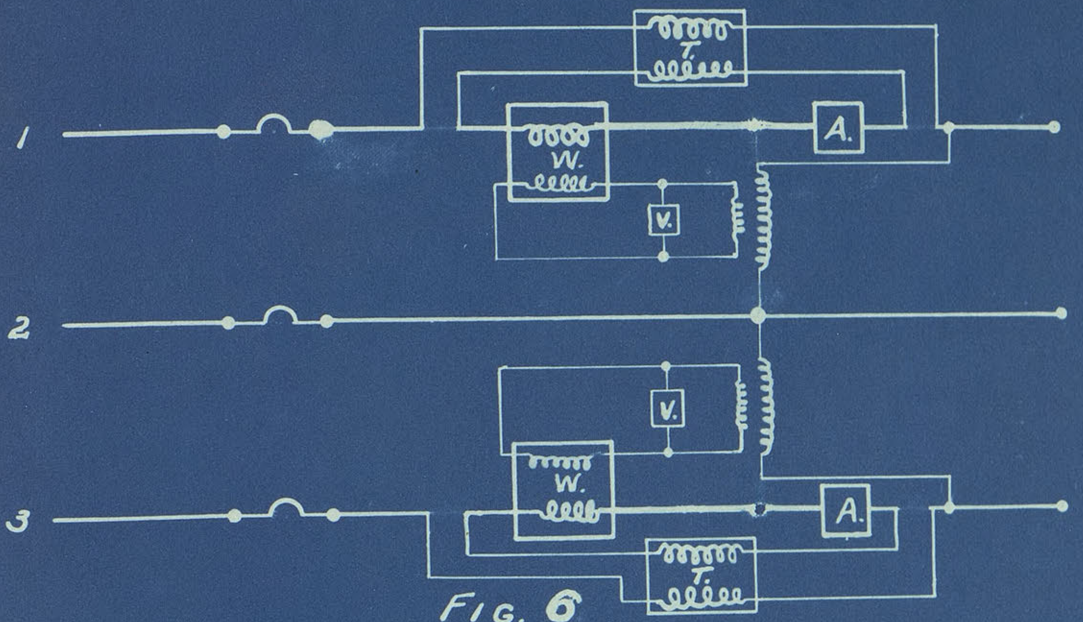


FIG. 6

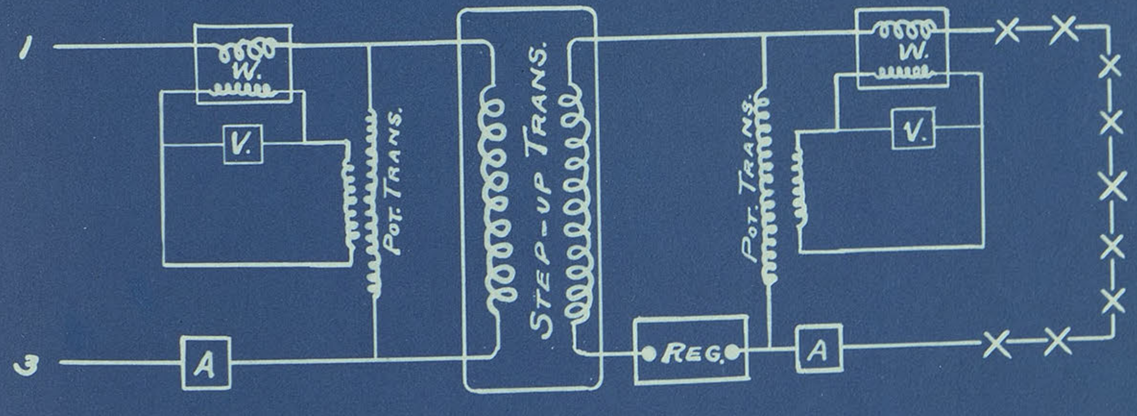


FIG. 7

E.W.

is multiplied by thirty and may have been of such a magnitude as to effect the efficiency. (2) The transformers, both current and potential absorb some energy, which loss was not taken into account in this test. (3) Instruments used with transformers should be calibrated in connection with them. In this test the the instruments were not calibrated with the transformers used. (4) Transformers to be used with instruments should be calibrated for a certain cycliage, which calibration was not made in this test. This error would effect the ratio of transformation and in that way effect the readings of the output.

The input was determined from indicator cards of the engine taken simultaneously with the wattmeter readings. The friction loss of the engine was determined as follows:- The generator was run at normal, constant speed, the fields being unexcited and three indicator cards taken on the engine. The value of the friction loss of the generator was furnished by the General Electric Co., which loss was 950 watts or 1.27 H.P. The average of the three indicator cards was found to be 8.67 H.P. The friction loss of the engine is, therefore, the difference of the two values or is 7.4 H.P. This loss was assumed to be constant and was subtracted from the indicated horse power to obtain the input to the generator at each load.

Data of the full load losses of the generator was furnished by its manufacturers. From this data the commercial and electrical efficiencies were computed for one-fourth, one-half, three-fourths, full load and one and one-fourth loads. In this computation the I^2R loss in the revolving field, the core and friction losses were assumed to be constant, the former being practically constant asseen in commercial efficiency data, #3.

It is seen from a comparison of the efficiency curves, I and II, that for full load, curve I falls much lower than curve II. It is known that the friction loss of an engine does not remain constant for all loads. If then the friction loss is higher for greater loads than for smaller ones, the efficiency of the generator for a large load would be to small because the computed input is to large. From the curves this is seen to be the case, as the generator is about one and one-half per-cent more efficient at full load for the manufacturers than this test shows. Owing to an inferior make of reducing motion, there may have been some lost motion in the indicator mechanism. This may have caused a greater input to have been recorded than was really expended.

Commercial Efficiency Data.

Plate I May, 16, 1905.

Time	Speed.		Temperatures					
	Engine	Generator	Room	E. Arm. W'd'n'gs	W. Arm. W'd'n'gs	Bearing P. End	Bearing Com. End
9:30	177	875	29.5	34.5	34.5	32.5	31.1
9:45	177	843	29.3	37.5	39.0	36.1	34.0
10:00	176	845	29.4	40.3	42.0	38.6	36.1
10:15	177	844	29.1	42.0	44.0	39.7	37.2
10:30	176	844	29.0	42.0	45.0	40.5	38.0
10:45	177	840	29.0	45.5	47.5	42.5	38.9
11:00	176	844	29.0	45.0	47.0	42.5	38.9
11:30	176	845	28.5	45.0	46.0	42.5	38.9
12:00	176	846	29.5	46.0	44.0	42.8	38.9
12:30	178	845	29.0	46.5	47.0	43.0	39.0
1:00	177	848	27.0	44.0	46.0	43.0	38.9
1:30	176	843	28.0	44.0	47.5	43.0	38.9
5:00	178	866	27.5	44.5	47.0	42.5	37.7
5:30	178	832	27.5	43.5	47.5	42.0	37.7
6:00	177	832	27.0	43.0	47.0	42.0	37.5

Maximum Tempertures at Stop.

Commutator of Exciter ------------------------------ 41.5°C.

RevolvingField --------------------------------- ---- 49.5 "

Field of the exciter ------------------------- - 43.5 "

Commercial Efficiency Data.

Plate II May, 16, 1905.

	South Leg			North Leg			Power
Time	Volts	Amperes	K. Watts	Volts	Amperes	K. Watts	Factor
9:30	2420	13.58	29.70	2280	14.85	37.50	.964
9:45	2436	12.60	27.45	2280	14.10	31.50	.928
10!00	2426	10.73	22.80	2290	13.35	30.00	.933
10:15	2404	9.90	20.82	2280	12.08	27.30	.940
10:30	2390	9.08	18.45	2280	11.28	25.05	.942
10:45	2450	7.62	15.42	2330	10.50	24.00	.911
11:00	2412	6.84	12.26	2320	9.15	20.61	.898
11:30	2364	5.28	7.95	2330	6.03	13.50	.808
12:00	2342	4.88	7.17	2320	5.40	11.70	.787
12:30	2404	4.50	6.15	2390	4.80	10.50	.747
1:00	2420	4.44	6.00	2390	4.50	9.75	.732
1:30	2420	4.31	5.55	2390	4.20	9.75	.747
5:00	2410	4.08	5.67	2380	4.13	9.39	.766
5:30	2400	4.50	7.20	2350	4.43	10.05	.812
6:00	2410	4.05	6.30	2370	4.35	9.90	.807

Bearing on pulley end of shaft ---------------- 42.2° C.

Bearing on commutator end ------------------------ 39.4 "

Armature windings - west side ------------------- 44.0 "

Armature windings - east side ------------------- 41.0 "

Trailing pole tip - revolving field ------------ 48.0 "

Commercial Efficiency Data. . .

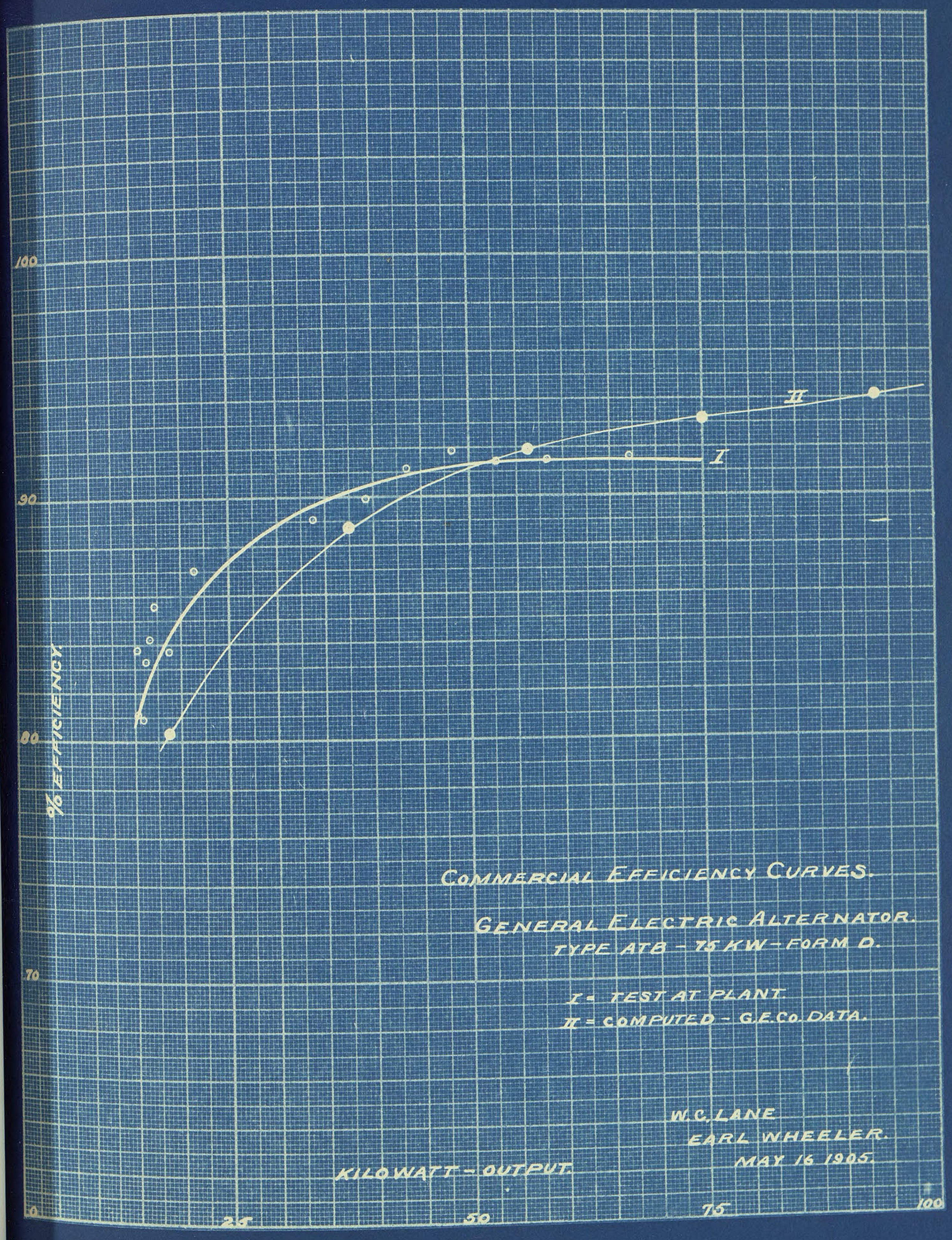
Plate III May, 16, 1905.

Time	Exciter Field			Revolving Field		
	Volts	Amperes	Watts	Volts	Amperes	Watts
9:30	49.2	3.22	158.5	49.2	27.44	1351
9:45	50.2	3.30	165.00	50.2	27.94	1397
10:00	49.5	3.25	161.0	49.5	27.65	1370
10:15	48.0	3.17	151.0	48.0	26.82	1276
10:30	47.2	3.10	146.5	47.2	26.37	1240
10:45	49.0	3.30	162.0	49.0	27.37	1338
11:00	47.0	3.20	150.5	47.0	26.37	1241
11:30	44.5	3.00	133.5	44.5	24.86	1104
12:00	44.0	3.30	132.0	44.0	26.26	1142
12:30	47.0	3.34	155.0	47.0	26.26	1241
1:00	47.0	3.30	156.8	47.0	26.26	1241
1:30	46.4	3.32	152.8	46.4	26.90	1172
5:00	46.6	3.32	154.6	46.6	26.03	1211
5:30	46.3	3.30	152.5	46.3	25.86	1992
6:00	46.8	3.30	154.8	46.8	26.09	1221

Commercial Efficiency Data.

Plate IV May, 16, 1905.

Time	K.W. Input	K.W. Output	Commercial % Efficiency
9:30	73.435	67.200	91.65
9:45	63.800	58.350	91.46
10:00	57.715	52.800	91.45
10:15	52.331	48.120	91.95
10:30	47.483	43.500	91.19
10:45	44.163	39.420	89.98
11:00	37.930	33.870	89.14
11:30	24.647	21.450	87.03
12:00	22.550	18.870	83.68
12:30	19.769	16.650	84.92
1:00	19.446	15.750	80.98
1:30	18.724	15.300	81.17
5:00	17.933	15.060	83.98
5:30	20.246	17.250	85.59
6:00	19.440	16.200	83.33



COMMERCIAL EFFICIENCY CURVES.

GENERAL ELECTRIC ALTERNATOR.
TYPE ATB – 75 KW – FORM D.

W.C. LANE
EARL WHEELER.
MAY 16 1905.

Data for Electrical Efficiency.

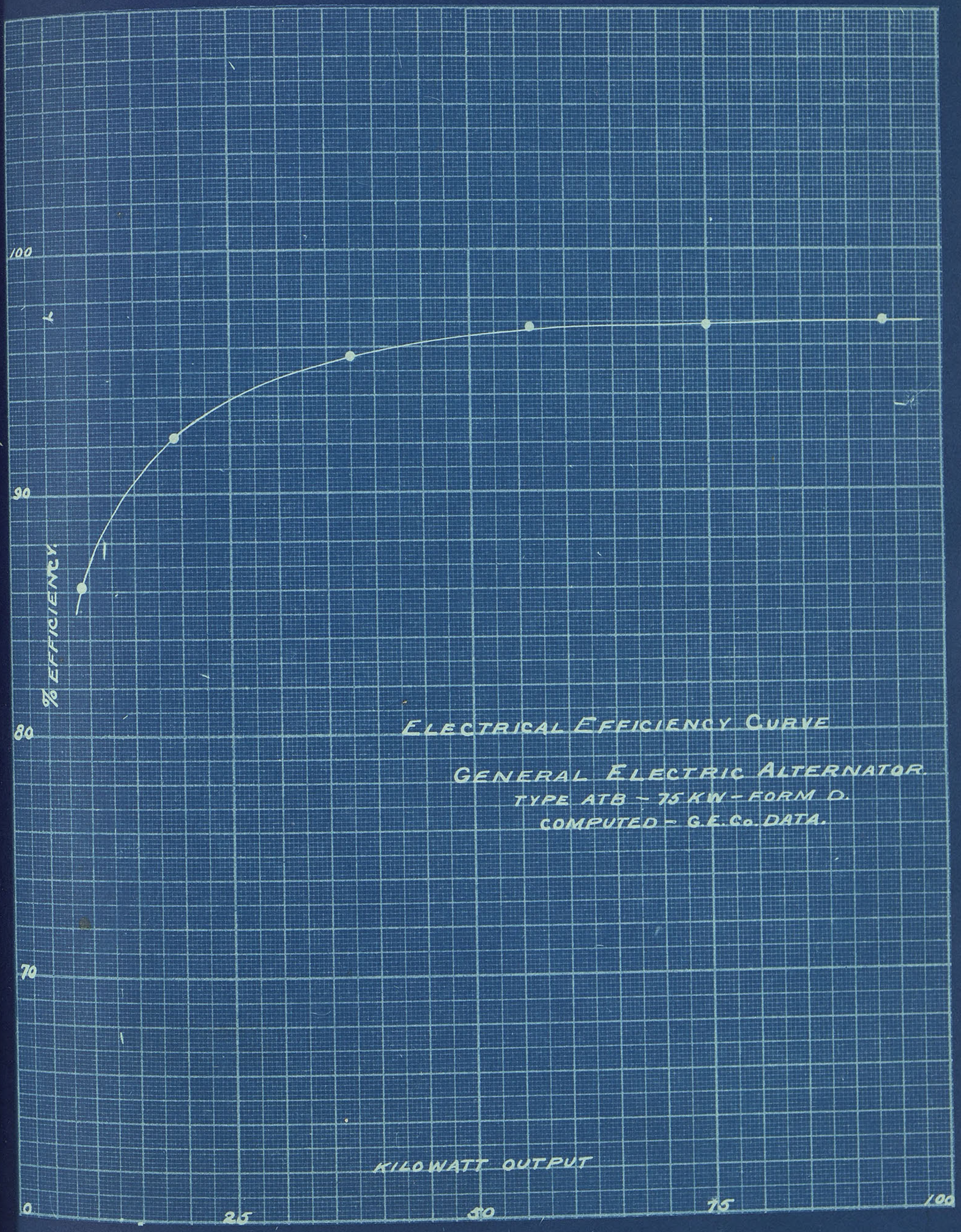
General Electric Co.

	1/4 Load	1/2 Load	3/4 Load	Full Load	5/4 Load
Watts Arm. Loss	54	215	375	950	1337
Watts Field Loss	1490	1490	1490	1490	1490
Watts Total	1544	1705	1865	2440	2827
Watts Out put	18750	37500	56250	75000	93750
Watts Input	20294	39205	58115	77440	96577
% Elec. Efficiency	92.39	95.62	96.79	96.85	97.07

Data for Commercial Efficiency.

General Electric Co.

	1/4 Load	1/2 Load	3/4 Load	Full Load	5/4 Load
Watts Arm. Loss	54	215	375	950	1337
Watts Field Loss	1490	1490	1490	1490	1490
Watts Core Loss	2100	2100	2100	2100	2100
Watts Friction L.	950	950	950	950	950
Watts Total Loss	4594	4755	4915	5490	5877
Watts Output	18750	37500	56250	75000	93750
Watts Input	23344	42255	61165	80490	99627
% Com. Efficiency	80.32	88.78	91.96	93.18	94.10



ELECTRICAL EFFICIENCY CURVE

GENERAL ELECTRIC ALTERNATOR.
TYPE ATB - 75 KW - FORM D.
COMPUTED - G.E.Co. DATA.

Regulation of Alternator.

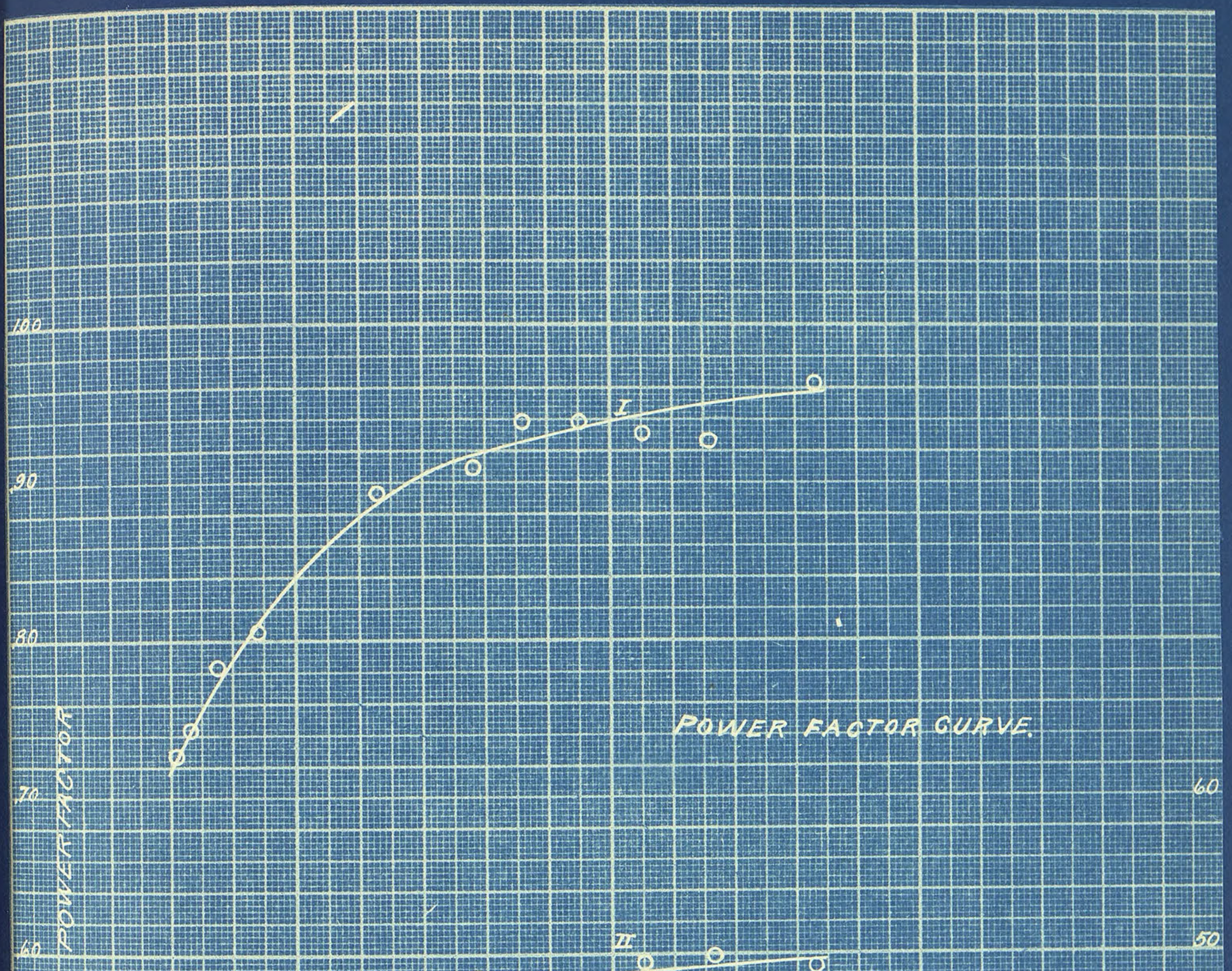
The regulation of the exciter voltage is shown by curve #2 on the following page. As was prevously stated, the object of the compensator is to regulate thexciter voltage for all conditions of load. A load composed of incandescent lights, alone, is non-inductive but when the voltage must be stepped down by transformers, as is usually the case in lighting, the load is slightly inductive. This requires an increase of a excitation. It is observed from thecurve that the voltage rises gradually as the load increases. The increase is less rapid at the heavier loads, for a given increase of load, than it is for an equal increase at the lower loads. This is due to the difference in the change in value of the power factor.

Power Factor.

The power factor of a circuit is the ratio of the effective watts in the circuit to the indicated watts. In other terms, it is that percent of the power in the circuit that is available for work.

The power factor is decreased by the introduction of either inductance or capacitance in the circuit. The latter produces a leading current and the former a lagging current. It is the former only that enters into this test.

As was stated above, an incandescent lighting load in combination with transformers produces a lagging current.


I
II
POWER FACTOR CURVE.
REGULATION OF EXCITER VOLTAGE
POWER FACTOR
EXCITER VOLTS.
KILOWATTS OUTPUT
100
.90
.80
.70
.60
.50
.40
.30
60
50
40
30
20
0
25
50
75
100

When the transformers are loaded to their rated capacity., the power factor has its maximum valueand approaches unity as a limit. As the load decreases the power factor becomes smaller and smaller until the secondaries of the transformers are open circuited when it is a minimum.

A test was made on the distribution system with the transformers "open circuited", that is as nearly "open circuited" as could be ascertained from the customers of the company. It was found that 7.65 kilowatts of electrical energy were being expended in the circuit. The resultant power factor was about seventy-one hundredths. As this value was thought to be high for a system equipped with Type H, G.E.Co. transformers, it was thought best to test the system for "grounds".

The following test was made:- One terminal of the primary of a "twenty to one" potential transformer was connected to one line wire, and the other terminal was grounded. A voltmeter was placed over the secondary of the transformer and a reading of sixty-five volts obtained. This, therefore, meant that there was a ground of thirteen hundred volts magnitude on the high tension lines of the system. Practically the same results were obtained on the other two lines. This test then proved that all of the power indicated by the wattmeters was not flowing through the primaries of the line transformers. Since the power factor of a "ground" is unity, the resultant power factor would be higher than that of a load of "open-circuited" transformers, which fact accounts for the large power factor obtained in the test.

The power factor curve on the foregoing curve sheet shows that for a great part of the night's run, that the machine was supplying only a little more than the core losses of the transformers and the "grounds".

The best power factor obtained was .962, which shows that the transformers were not loaded to their rated capacity at that hour.

Arc Light System.

On full load the only part of the distribution system that has any effect upon the phase relation of the current and E.M.F. is the arc light system. Because of its relation to the resultant power factor, a separate test was made.

The system consists of thirty-one Western Electric, alternating current, enclosed, series arc lamps. This number of lamps was more than one phase of the generator could operate therefore the system necessitated the employment of a "step-up" arc transformer. The transformer installed is a fifty light, Western Electric. It is made so as to give the proper voltage for any number of lamps between twenty-five and fifty. The transformer is much larger than is really needed but is the only standard size between twenty-five and fifty lamps. The secondary is made with thirteen taps as shown by Figure 9, Plate VIII. If it is set on number one, the secondary supplies enough voltage for twenty-five lamps. Each tap then will accomodate an increase of two lamps in the circuit. The transformer at present is set on number five. The secondary was found to be about twenty-five hundred volts, after the lamps were heated. Each lamp takes about seventy-five volts over the carbons, therefore the useful voltage is about twenty-three hundred and twenty-five volts. The line and lamps' mechanism drop varied from one hundred to one hundred and seventy-five volts.

PLATE VIII.

FIG. 8.

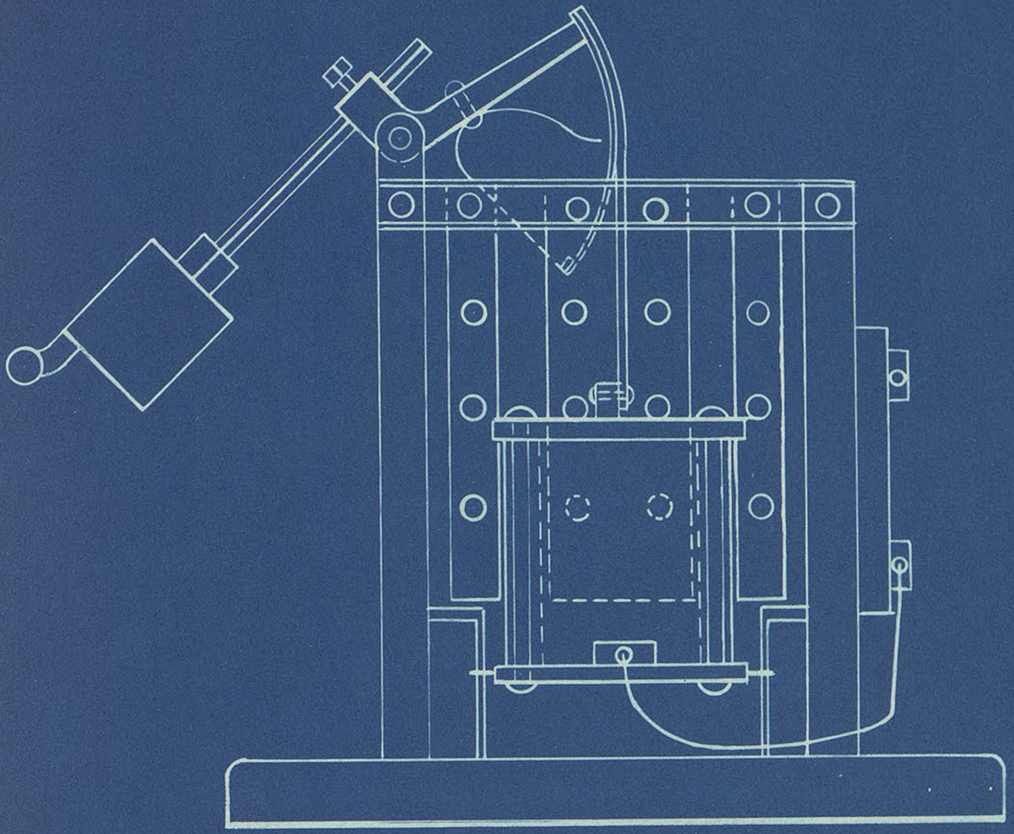
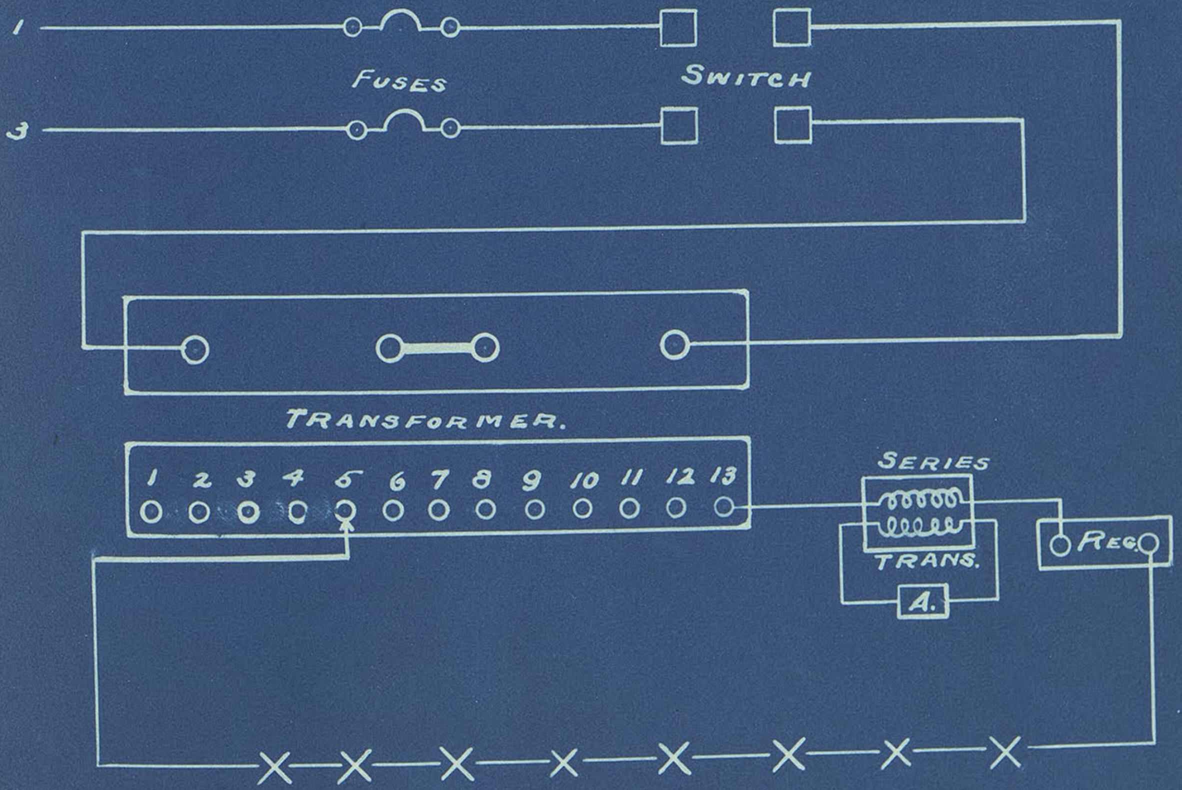


FIG. 9.



E.W.

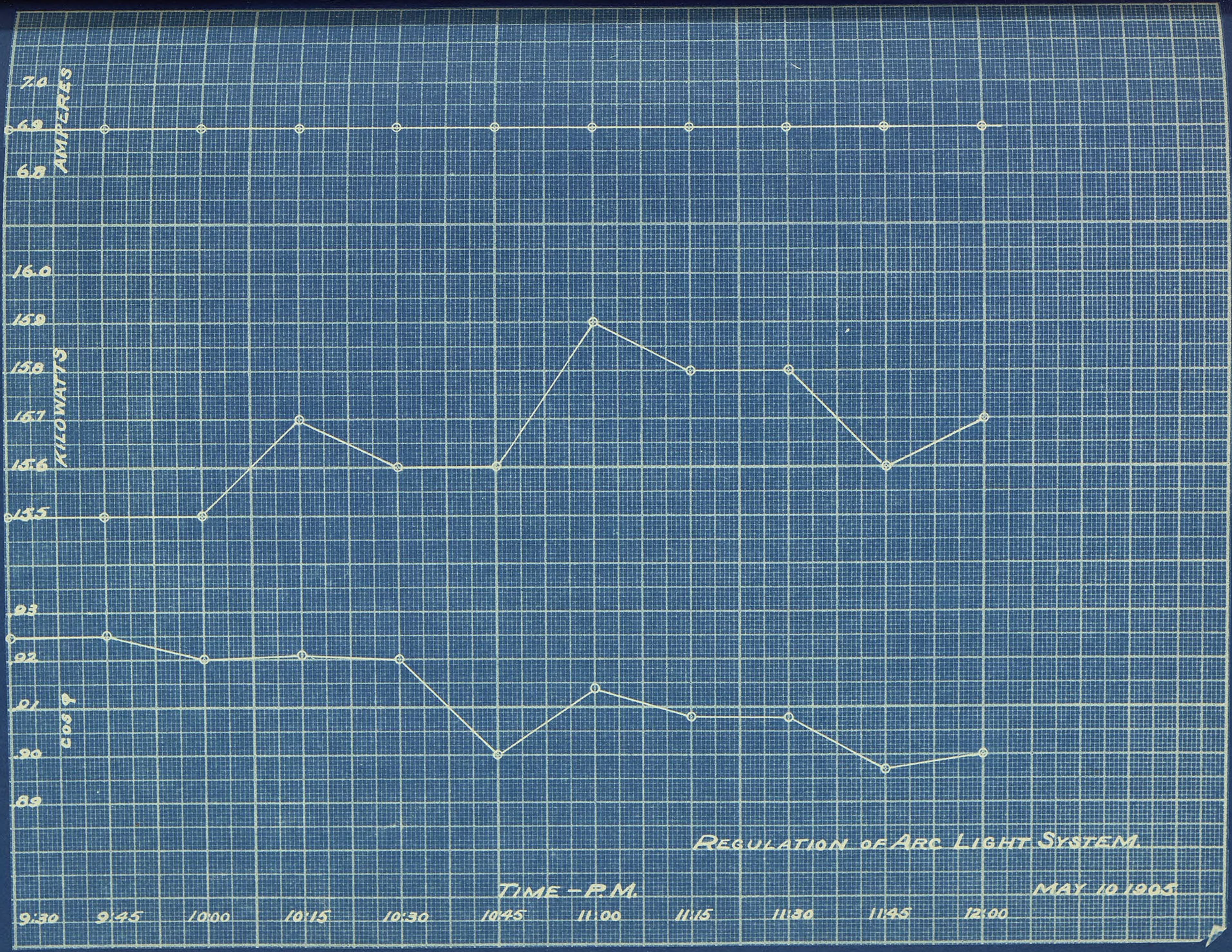
Since the system is a constant current one, the Western Electric constant current, series regulator was installed. This regulator is simply a choke coil moving in a vertical plane, the weight of the coil being counter-balanced by a suitable weight on an arm that operates over a knife edge. Figure 8, Plate VIII shows a sketch of the regulator. Projecting downward into the coil is a core of iron. This core is made of laminated sheets with suitable air ducts to enable good ventilation. The choke coil is divided into three smaller coils with an air space between each. On each side of the coil is a similar core of iron, that nearly completes the flux path. As the coil moves upward the air gap around the lower side of the coil is decreased and the current in the coil and line consequently increases because of the decreased magnetic reluctance of the flux path. As the coil moves down the reluctance of the path is increased and the current decreased. Therefore the amount of current flowing is directly proportional to the magnetic reluctance of the flux path. The balance is therefore set for a certain line current and as this line current varies on either side of the normal, the reluctance is so changed as to bring the current back to the normal value.

The test of the system consisted of placing an ammeter, voltmeter and wattmeter on each side of the "step-up" transformer as shown in Figure 7, Plate VII. Because of unavoidable circumstances the power factor of the primary circuit could not be obtained. The test on the secondary circuit shows the regulation of power factor, power and current consumption for a regular night's run. It is seen from the accompanying curves that the constant current regulator gives ideal current regulation, the current remaining 6.9 amperes throughout the test. It is also seen that as the lamps burn, the power consumption increases. At the beginning of the test the system consumed about 15.5 K.W. and after three hours of steady burning the power consumption had increased two hundred watts. The power factor of the system is excellent, being 92.5% on the start and fell to 90% after three hours burning.

From a comparison of the power curve and the power factor curve, it is seen that the power consumption increases as the power factor decreases. The lamps were in fair condition and no "cuts" were observed during the test.

Data for Arc Lamp Test.

Time	#Lamps	Volts	Amperes	K.W.	Power Factor
9:30	31	2330	6.9	15.5	.925
9:45	31	2430	6.9	15.5	.925
10:00	31	2440	6.9	15.5	.920
10:15	31	2470	6.9	15.7	.921
10:30	31	2480	6.9	15.6	.920
10:45	31	2510	6.9	15.6	.900
11:00	31	2520	6.9	15.9	.914
11:15	31	2520	6.9	15.8	.908
11:30	31	2520	6.9	15.8	.908
11:45	31	2520	6.9	15.6	.897
12:00	31	2520	6.9	15.7	.900



REGULATION OF ARC LIGHT SYSTEM.

MAY 10 1905.