T H E S I S

TEST ON A DELCO-LIGHT UNIT

Under

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By

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The Delco-Light unit consists of a gasoline engine, a direct current generator, and a 16 cell storage battery of the lead type. It is a very compact plant of about one KW capacity. The armature is mounted on the crank-shaft of the engine, and the switch board with the automatic devices for starting or stopping the engine is mounted on the frame. The dynamo operates as a shunt generator when charging the batteries or as a series motor when cranking the engine. When operating as shunt generator the series field is short circuited on itself. When the machine is used as a series motor the change in connections is made by a single switch which supplies the current from the storage batteries, and at the same time opens the circuit between the terminals of the series field.

The machine when operating on its own power with an open throttle will give a practically constant current. The power of the engine being so balanced that when the resistance of the circuit is increased or decreased the corresponding increase or decrease of current causes the engine to speed up or slow down as the case may be. When charging the batteries the speed is about 1050 R.P.M., the voltage about 40 and the current 25 amperes.

The engine is air cooled. It is covered with a jacket of sheet metal through which air is circulated by means of a heavy fly wheel in which a fan is built. This fan draws the air through the jacket and cools the engine. The generator is also cooled by the same means.

There are few bearings. The generator, being mounted on the crank-shaft, has none, so the only bearings are the two on the crank-shaft, one of which is a roller bearing and the other is a ball bearing, and those of the timer and valve mechanism. The cylinder is lubricated by mixing oil with the fuel, and the main bearings and valve gear are oiled from the crank case. This makes lubrication very simple as there are only two places to put oil, the rocker arm and other moving parts that may have friction not being equipped with oil holes.

The efficiency of the generator is high for so small a machine and the mechanical efficiency of the engine is good. Thethermal efficiency is low however, because of the large clearance which is necessary in order to make the plant self cranking. The efficiency of the generator as shown in the test is somewhat high because when the overall efficiency was taken the plant was in good condition and when the brake test was made the cylinder was foul with carbon so that the engine did not give quite so high an output as it would otherwise. For the same reason the thermal efficiency is probably low.

RESISTANCES

Shunt Field

I	E	R
1.0	32.0	32.00
0.9	28.5	31.66
0.8	25.0	31.25
0.7	23.0	32.85
0.6	18.9	31.50
0.5	16.0	32.00
	Ave.	31.88

Series Field

I	E	R
0.71	0.16	0.2254
1.00	0.193	0.1930
1.46	0.266	0.1820
1.95	0.366	0.1875
2.61	0.490	0.1875
3.30	0.616	0.1865
4.12	0.763	0.1850
5.00	0.933	0.1865
5.40	0.966	0.1790
6.20	1.160	0.1871
7.55	1.433	0.1900
	Ave.	0.1899

Armature

E	I	R
0.0045	1.05	0.00428
0.00875	2.08	0.0042
0.0110	3.55	0.0031
0.017	5.60	0.00304
0.020	6.80	0.00294
1.027	8.50	0.00318
0.350	10.50	0.00333
0.450	12.20	0.00369
	Ave.	0.00356

Brush

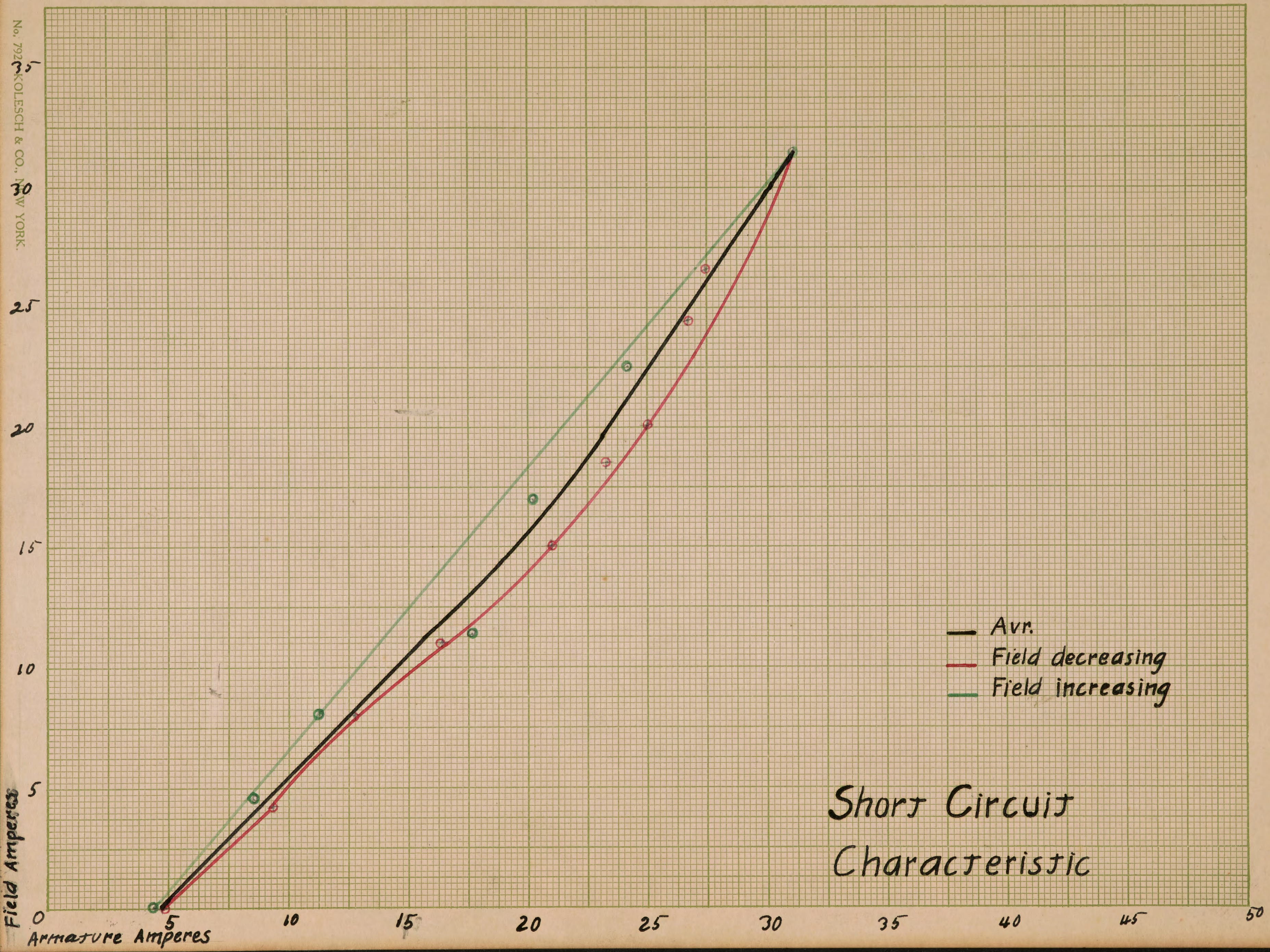
E	I	R
0.0185	1.05	0.0176
0.053	2.90	0.01825
0.086	4.80	0.0179
0.111	6.10	0.0182
0.137	7.6	0.0180
	Ave.	0.01799

Total resistance of armature and brushes =

2 x 0.01799 + 0.00356 = 0.03975

SHORT CIRCUIT CHARACTERISTIC

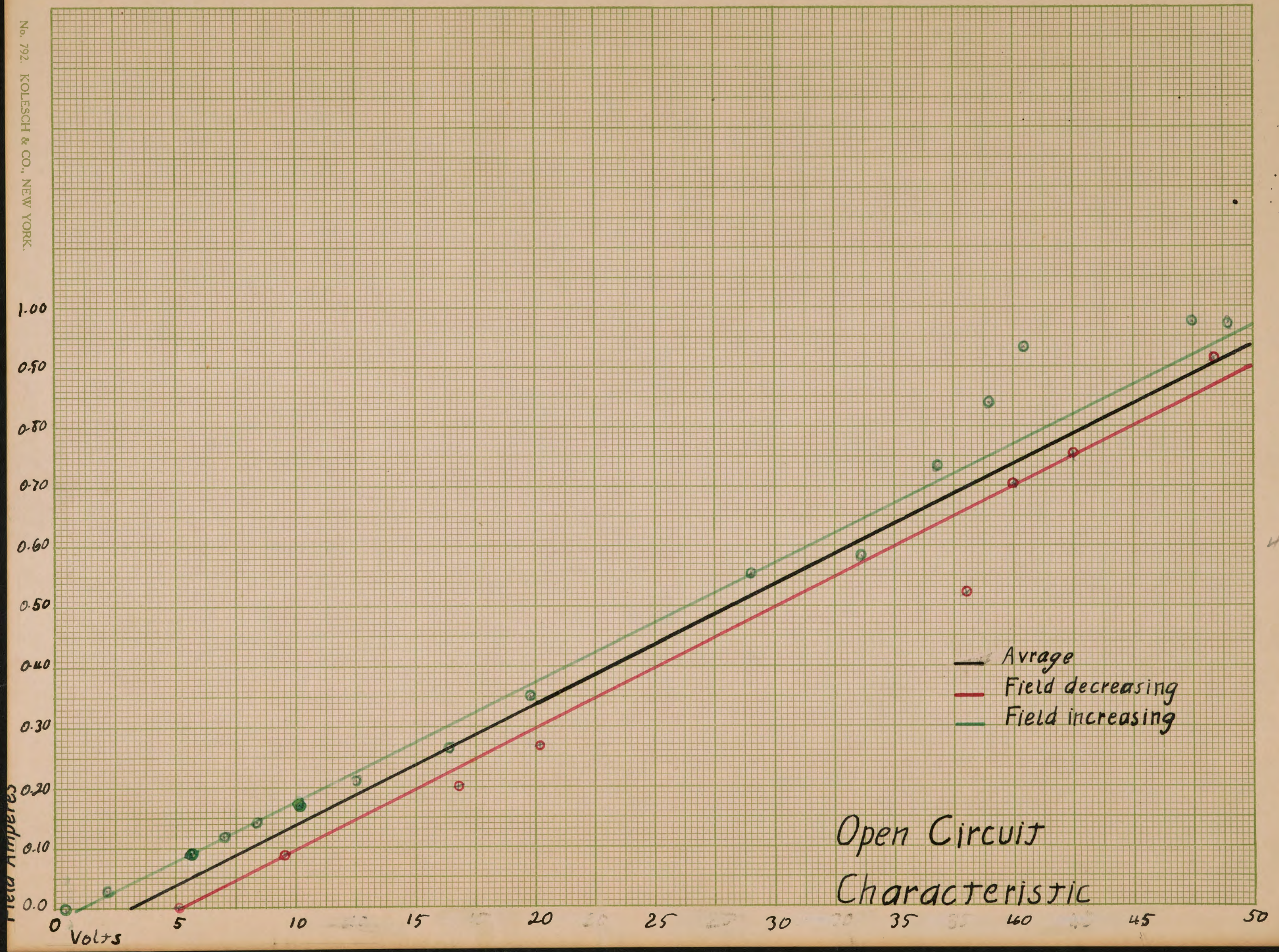
If	I_a	R.P.M.	corrected I_a	corrected R.P.M.
0.00	4.5	1030	4.57	1050
0.045	8.7	1060	8.62	"
0.080	12.0	1110	11.35	"
0.1132	17.7	1052	17.65	"
0.170	20.5	1061	20.28	"
0.225	24.8	1068	24.40	"
0.315	32.2	1060	31.20	"
0.265	28.5	1012	27.50	"
0.245	26.2	964	26.70	"
0.225	25.0	952	27.59	"
0.20	23.5	988	24.99	"
0.185	21.7	976	23.38	"
0.149	20.1	1004	21.00	"
0.110	16.3	1036	16.52	"
0.080	14.4	1024	14.76	"
0.042	9.5	1066	9.35	"
0	4.8	1074	4.69	"



Short Circuit
Characteristic
Avr.
Field decreasing
Field increasing
Field Amperes
Armature Amperes
0
5
10
15
20
25
30
35
40
45
50
No. 792 KOLESCH & CO. NEW YORK.

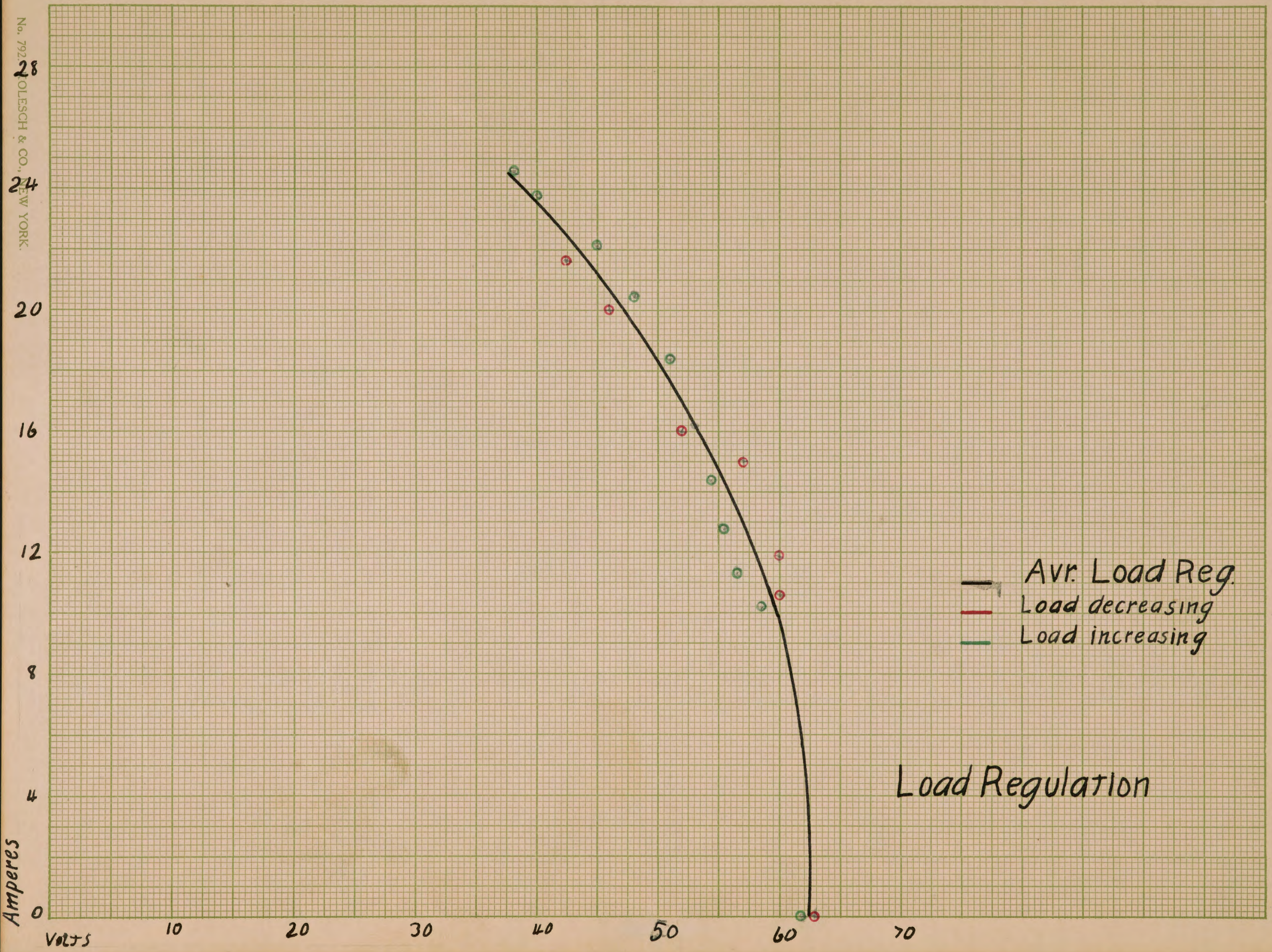
OPEN CIRCUIT CHARACTERISTIC

E	I_f	R.P.M.	corrected E	corrected R.P.M.
0.45	0.00	1040	0.455	1050
2.10	0.03	1040	2.12	"
5.25	0.09	980	5.63	"
6.85	0.12	1030	7.08	"
8.35	0.14	1060	8.27	"
10.85	0.17	1120	10.18	"
12.50	0.21	1050	12.50	"
16.50	0.265	1060	16.35	"
21.50	0.35	1090	19.72	"
24.0	0.41	1060	23.75	"
29.0	0.55	1050	29.00	"
32.0	0.58	1000	33.60	"
36.4	0.73	1040	36.75	"
38.0	0.84	1020	39.10	"
40.0	0.93	1040	40.40	"
49.5	0.97	1000	47.25	"
48.0	0.97	1030	48.90	"
47.0	0.86	1030	47.90	"
42.5	0.75	1050	42.50	"
39.0	0.675	960	42.60	"
37.5	0.59	950	41.50	"
36.5	0.52	910	38.00	"
34.5	0.415	980	37.00	"
23.0	0.37	990	24.40	"
19.0	0.27	1010	20.18	"
16.0	0.20	1000	16.80	"
9.5	0.09	1050	9.5	"
5.0	0.00	1030	5.1	"


No. 792. KOLESCH & CO., NEW YORK.
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.0
0
5
10
15
20
25
30
35
40
45
50
Volts
Avrage
Field decreasing
Field increasing
Open Circuit
Characteristic

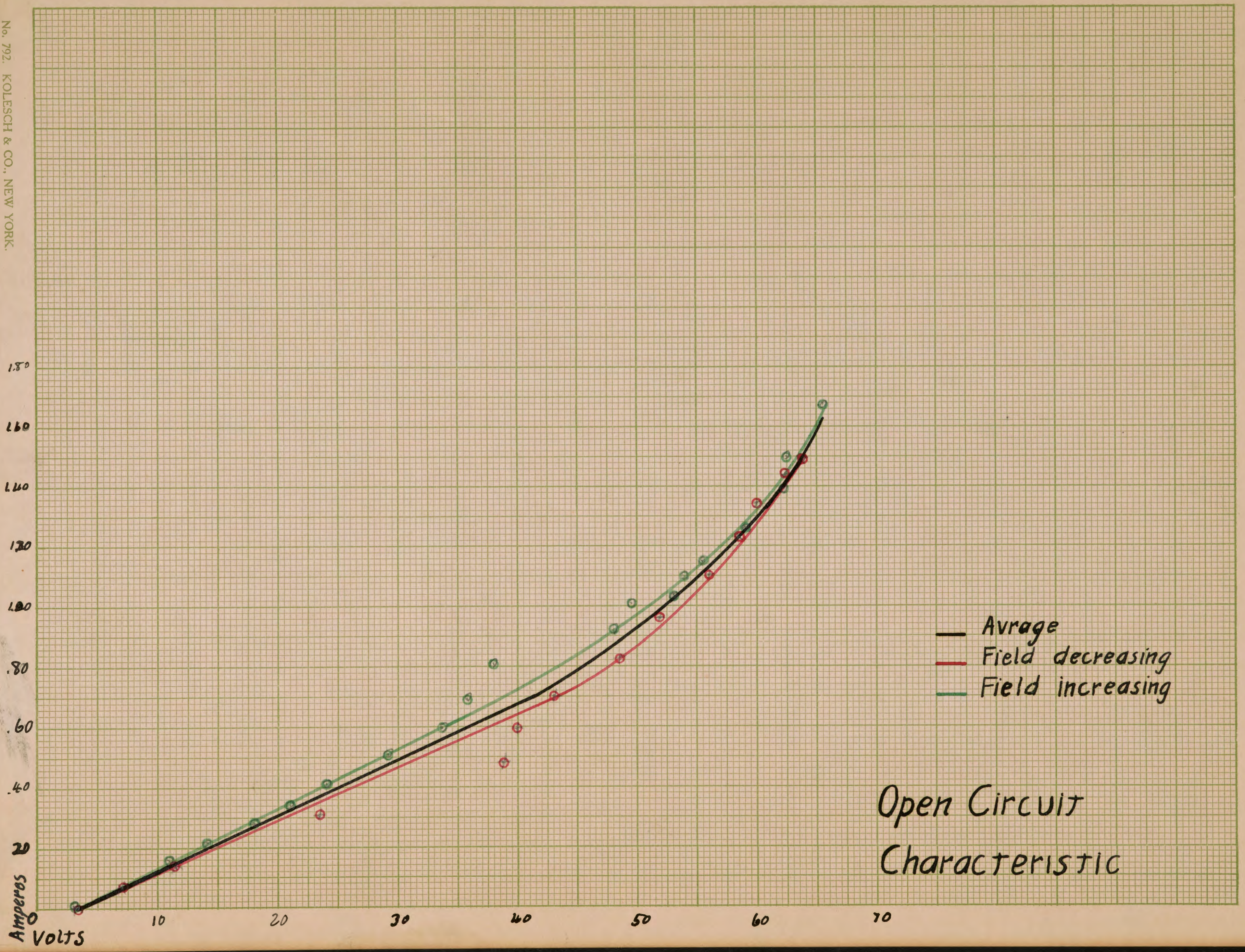
LOAD REGULATION

E	Ia	If	R.P.M.
62.0	0.0	1.7	1052
58.5	10.2	1.65	1056
56.5	11.4	1.65	1056
55.8	12.8	1.60	1050
54.5	14.4	1.56	1050
53.0	16.15	1.48	1050
51.0	18.4	1.43	1040
48.0	20.5	1.35	1048
45.0	22.1	1.25	1054
40.0	23.7	1.15	1056
38.0	24.6	1.95	1052
42.5	21.6	1.20	1050
46.0	20.0	1.32	1054
52.0	16.00	1.50	1054
57.0	15.0	1.64	1044
59.5	11.9	1.70	1050
60.0	10.6	1.70	1056
63.0	6.0	1.70	1050


No. 792 KOLESCH & CO., NEW YORK.
28
24
20
16
12
8
4
0
Amperes
Volts
10
20
30
40
50
60
70
Avr. Load Reg.
Load decreasing
Load increasing
Load Regulation

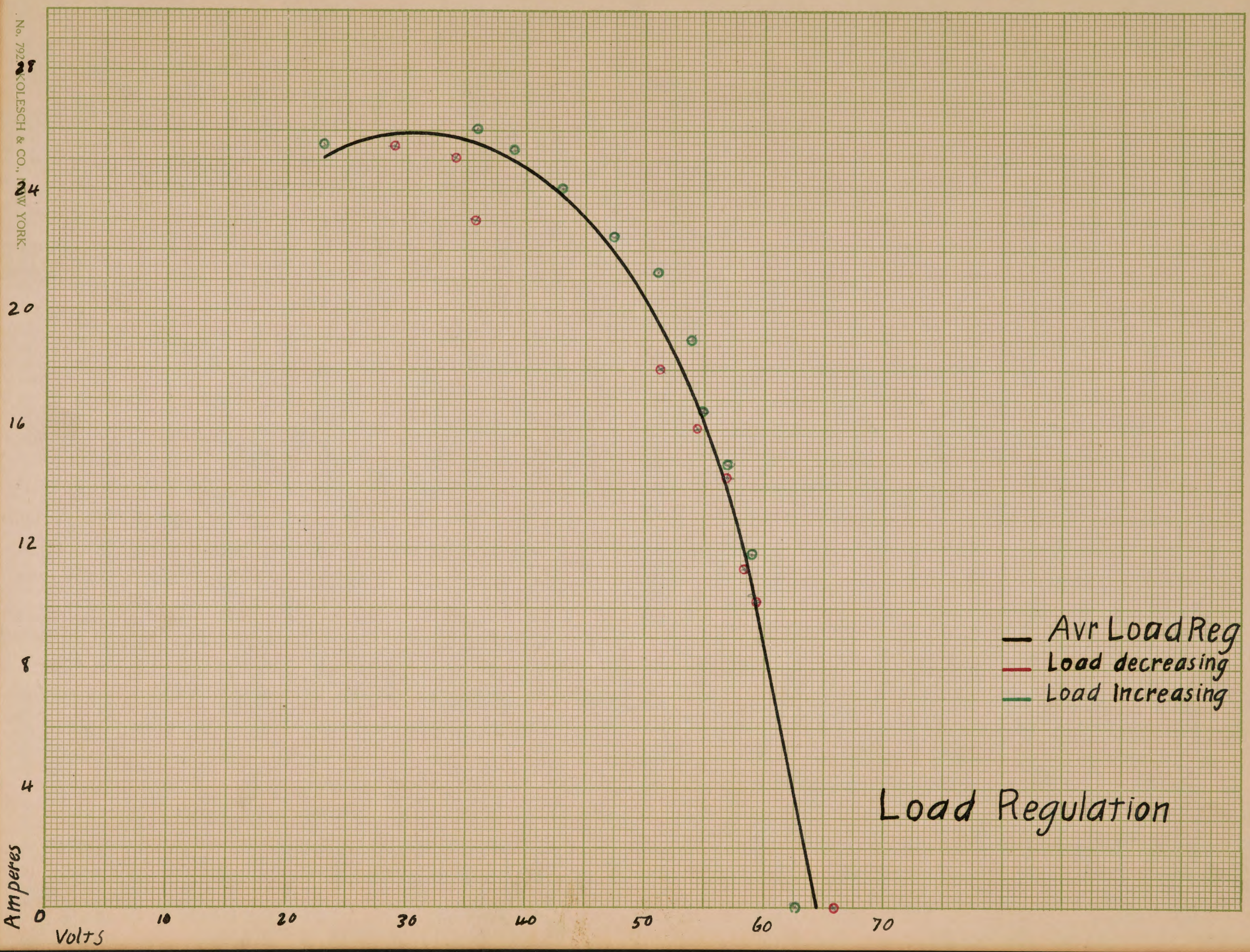
OPEN CIRCUIT CHARACTERISTIC

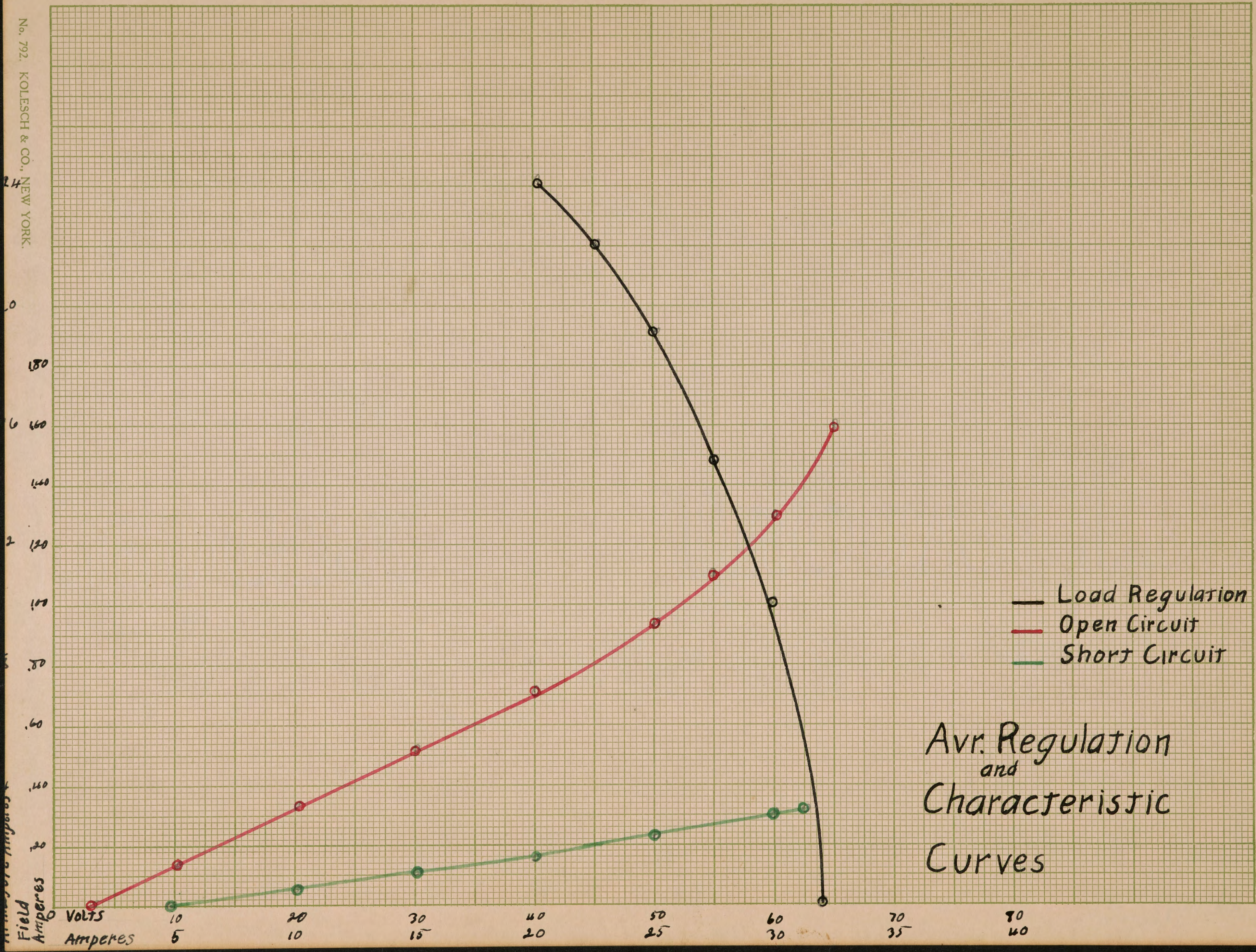
E	If	R.P.M.	corrected E	corrected R.P.M.
3.7	0	1056	3.68	1050
11.0	0.6	1056	10.94	"
14.0	0.22	1050	14.0	"
18.0	0.28	1044	18.10	"
21.0	0.34	1056	20.9	"
24.0	0.41	1056	23.9	"
29.0	0.50	1054	29.30	"
34.0	0.60	1056	33.85	"
36.0	0.70	1056	35.80	"
38.0	0.81	1052	37.90	"
47.0	0.92	1058	47.20	"
50.0	1.01	1060	49.60	"
51.5	1.03	1020	53.00	"
53.0	1.10	1030	54.00	"
54.5	1.15	1032	55.40	"
56.5	1.22	1028	57.80	"
57.5	1.26	1040	68.10	"
61.0	1.40	1030	62.20	"
62.5	1.50	1050	62.50	"
64.5	1.625	1036	65.40	"
65.0	1.68	1040	65.60	"
63.5	1.50	1040	64.10	"
62.0	1.44	1040	62.60	"
60.0	1.35	1024	61.50	"
58.0	1.23	1044	58.40	"
54.5	1.10	1024	55.9	"
51.0	0.96	1032	51.8	"
47.0	0.87	1020	48.40	"
42.0	0.70	1022	43.05	"
39.0	0.59	1028	39.90	"
37.0	0.48	1036	37.50	"
23.0	0.31	1040	23.21	"
11.0	0.14	1036	11.15	"
6.9	0.08	1020	7.10	"
3.9	0.00	1040	3.94	"


1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
Amperes
0
10
20
30
40
50
60
70
Volts
Avrage
Field decreasing
Field increasing
Open Circuit
Characteristic

LOAD REGULATION

E	I_a	I_f	R.P.M.
63.0	00.0	1.70	1048
59.0	10.4	1.70	1040
59.0	11.8	1.70	1040
57.0	14.8	1.70	1040
55.0	16.6	1.60	1040
54.0	19.0	1.55	1052
51.0	21.2	1.48	1040
47.5	22.4	1.35	1040
43.0	24.0	1.20	1048
39.0	25.3	1.05	1040
37.0	26.0	0.90	1042
23.0	24.5	0.65	1056
29.0	24.5	0.82	1056
34.0	24.1	1.00	1040
36.0	23.0	1.20	1040
38.0	21.65	1.30	1040
51.5	18.10	1.50	1040
57.5	16.00	1.55	1040
57.0	14.0	1.60	1050
58.5	42.5	1.65	1042
59.5	10.2	1.65	1054
66.0	00.0	1.70	1052

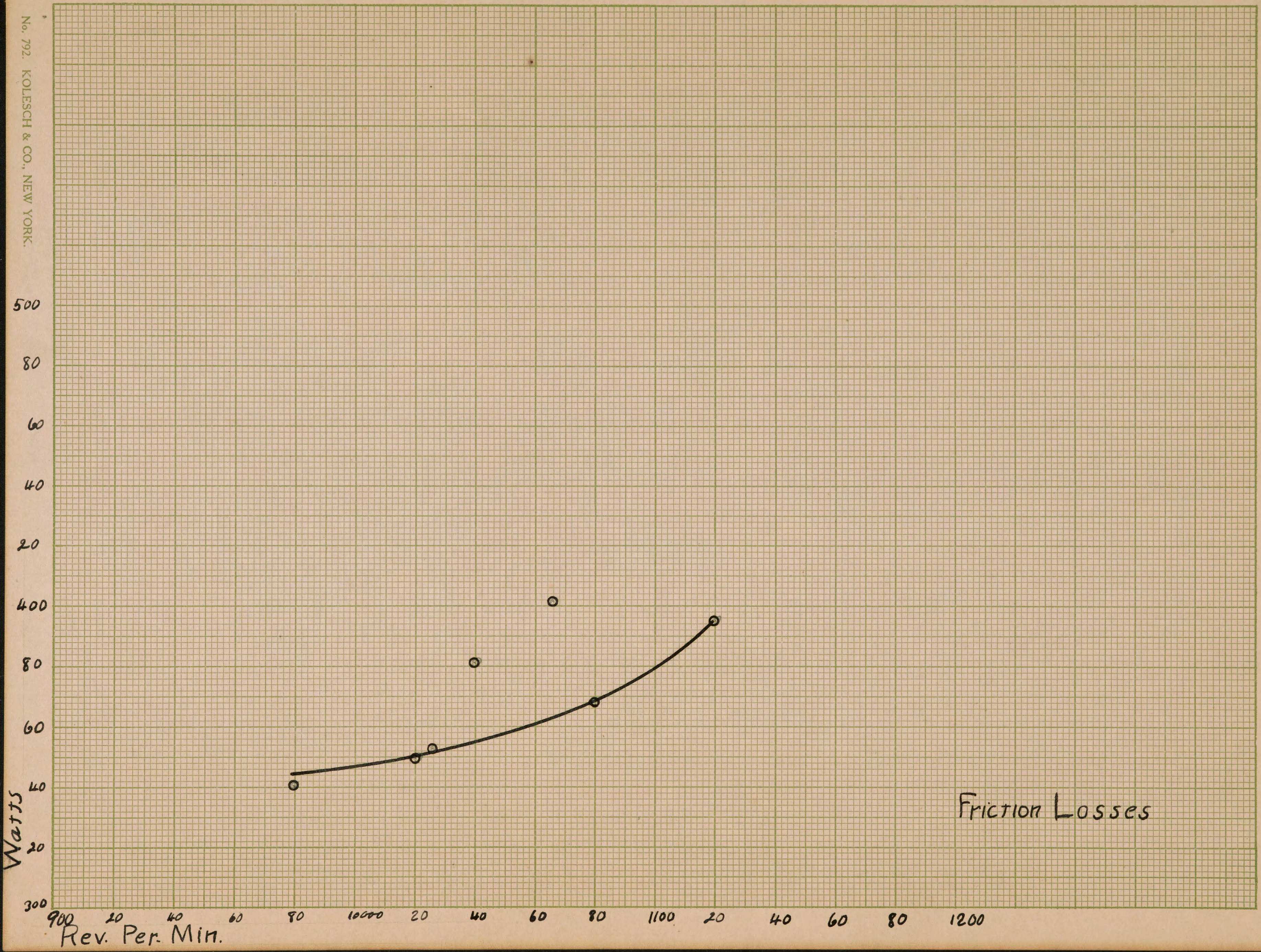

No. 792 KOLESCH & CO. NEW YORK.
28
24
20
16
12
8
4
0
Amperes
Volts
10
20
30
40
50
60
70
Avr Load Reg
Load decreasing
Load Increasing
Load Regulation


No. 792. KOLESCH & CO., NEW YORK.
Avr. Regulation and Characteristic Curves
Load Regulation
Open Circuit
Short Circuit
Field Amperes
Volts
Amperes
0
10
20
30
40
50
60
70
80
5
10
15
20
25
30
35
40
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
24

GENERATOR OPERATING AS SHUNT MOTOR

E_f	E_a	I_f	I_a	R.P.M.	W_f	W_a
39.5	67.0	1.2	7.0	1020	47.5	469
39.5	63.2	1.2	6.93	1080	47.5	442
40.0	61.0	1.2	6.93	1026	48.0	426
40.0	59.0	1.2	6.8	980	48.0	413
40.0	60.5	1.19	6.95	1020	48.0	423
44.0	69.0	1.19	7.1	1066	52.75	482
45.5	65.0	1.2	7.0	1040	54.60	455

Total W	Arm RI^2	Total Copper loss	Friction + iron loss	Friction loss
516.5	10.45	57.95	458.55	395.0
489.5	9.90	57.40	432.10	368.6
474.0	9.54	57.54	416.60	353.1
461.0	9.24	57.24	403.76	340.3
471.0	9.48	57.48	413.52	350.0
534.75	10.40	63.15	471.60	409.1
509.60	10.08	64.68	444.92	381.4


No. 792. KOLESCH & CO., NEW YORK.
500
80
60
40
20
400
80
60
40
20
300
Watts
900
20
40
60
80
1000
20
40
60
80
1100
20
40
60
80
1200
Rev. Per. Min.
Friction Losses

9

PLANT OPERATING ON KEROSENE

	Time	R.P.M.	E	I	W
	9:45	1004	38.0	26.5	
	9:50		38.0	25.6	
	9:55	1034	38.0	26.0	
	10:00		38.0	21.0	
	10:05	940	38.0	21.0	
	10:10		39.0	25.6	
	10:15	1050	39.5	24.8	
	10:20		39.5	24.5	
	10:25	1058	40.0	24.5	
	10:30		40.0	24.0	
	10:35	1050	40.0	23.8	
	10:40		40.0	23.8	
	10:45		40.0	23.2	
Ave			39.	24.15	9425

Kerosene used = 1.674#

B.T.U. per Lb. 20000 (assumed)

B.T.U. input = 33480

Output = 9425 watt hour = 3218 B.T.U.

Eff. of plant = $\frac{3218}{33480}$ = 9.6 %

PLANT OPERATING ON GASOLINE

	Time	E	I	W
	3:20	36	27.0	972
	3:25	38	28.0	1064
	3:30	38	27.5	1045
	3:35	38	27.5	1045
	3:40	38	27.5	1045
	3:45	38	27.5	1045
	3:50	38	27.5	1045
	3:55	38	27.5	1045
	4:00	37	26.5	955
	4:05	35	26.0	911
	4:10	35	26.0	911
	4:15	37	27.0	999
	4:20	38	27.5	1045
Ave				1009

Gasoline used = 1.622 #

B.T.U. per Lb. = 20000 (assumed)

B.T.U. input = 32440

Output = 1009 watt hour

Output = 3460 B.T.U.

Eff. of plant = $\frac{3460}{3244}$

Eff. of plant = 10.65 %

ENGINE TEST - BRAKE LOAD

OPERATING ON KEROSENE

Time	R.P.M.	Wf
4:45	1060	3.5 #
4:50	1064	"
4:55	1014	"
5:00	1050	"
5:05	1020	"
5:10	1030	"
5:15	1060	"
5:20	1020	"
5:25	970	"
5:30	1040	"
5:35	980	"
5:40	1020	"
5:45	940	"
Ave	1018	"

Brake arm 2 ft.

Load 3.5 lbs.

Time 60 min.

Kerosene used = 1.46 lbs.

B.T.U. per lb. = 20000 (assumed)

B.T.U. input = 29200

B.T.U. output = 3490

Overall Eff. = 11.69 %

IRON LOSSES AND EFFICIENCIES

Net eff. of engine and generator = 10.17 %

Eff. of engine = 11.69 %

Eff. of generator = 87.1 %

1. 942.5 watts = output of generator

   $\frac{942.5}{0.871}$ = 1080 input of generator

   1080 - 942.5 = 137.5 watts lost in generator

   copper loss = 71.8 watts

   137.5 - 71.8 = 65.7 watts iron loss

2. 1009 watts = output of generator

   $\frac{1009}{0.871}$ = 1158 input of generator

   1158 - 1009 = 149 watts lost in generator

   copper loss = 87.8 watts

   iron loss = 149 - 87.8 = 61.2 watts

   $\frac{61.2 + 65.7}{2}$ = 63.5 watts iron loss (average)

Friction loss per 1050 R.P.M. = 356 watts

" " " " " = 121.5 B.T.U. per hour

B.T.U. input = 29200

Output of engine = friction loss + brake power

" " " = 121.5 + 3490 = 3611.5

$\frac{3611.5}{29200}$ = 12.37 % thermal efficiency of engine

$\frac{11.69}{12.37}$ = 94.5 % mechanical efficiency of engine

ENDURANCE TEST.

The object of the endurance test was to determine what difficulties would be met with in the practical operation of the engine and generator. The machine was to be kept running for 24 hours, or until it stopped of its own accord, a supply of oil and fuel being kept in the tank. The 24 hour run could not be made without stopping from 11 P.M. until the next morning, so on the first day the engine was run continuously for 14 hours and stopped at 11 P.M. The next morning it was started at 8:40 A.M. and allowed to run 10 hours more.

The fuel used was kerosene and the load 21 amperes. The machine ran smoothly throughout the time without stopping or showing any sign of trouble from over heating or from any other cause.

Later after the engine had been run as much perhaps as the average person would use it in six months, the engine became so foul with carbon that it would not run. The trouble was probably caused by burning kerosene without injecting water into the cylinder with the fuel. ? X

X Kerosene is the fuel most highly recommended by the manufacturer but there is no means provided by which water can be used with it.

operate on leaner mixture

EFFICIENCY OF BATTERIES.

The batteries were tested for efficiency at their discharge ratie; 4 amperes, 8 amperes, and 12 amperes. The battery was discharged at the given rates and the time and voltage recorded, the amperes discharged being kept constant in each case. After each discharge the battery was charged and a record made of the time, the watts and the changing current. The battery was discharged from a specific gravity of 1.225 to a specific gravity of 1.985.

Test at 4 ampere discharge rate.

Discharge:

Time	10 hours
Amperes	40
Average volts	335
Ampere hours	40
Watt hours	1340

Charge:

Time	2 hours, 30 minutes.
Average amperes	21
Average volts	42.8
Ampere hours	52.8
Watt hours	2260.5
Efficiency	59.3 %

Test at 8 ampere discharge rate.

Discharge:

Time . . . . 4 hours, 45 minutes.

Amperes 8

Average volts 33.6

Ampere hours 38.0

Watt hours 1278

Charge:

Time . . . . 2 hours, 45 minutes.

Average amperes 21.22

Average volts 43.4

Ampere hours 58.4

Watt hours 2532

Efficiency . . . . 50.4 %

Test at 12 ampere discharge rate.

Discharge:

Time . . . . 3 hours, 5 minutes.

Amperes 12

Average volts 32.5

Ampere hours 36.1

Watt hours 1172

Charge:

Time . . . . 3 hours

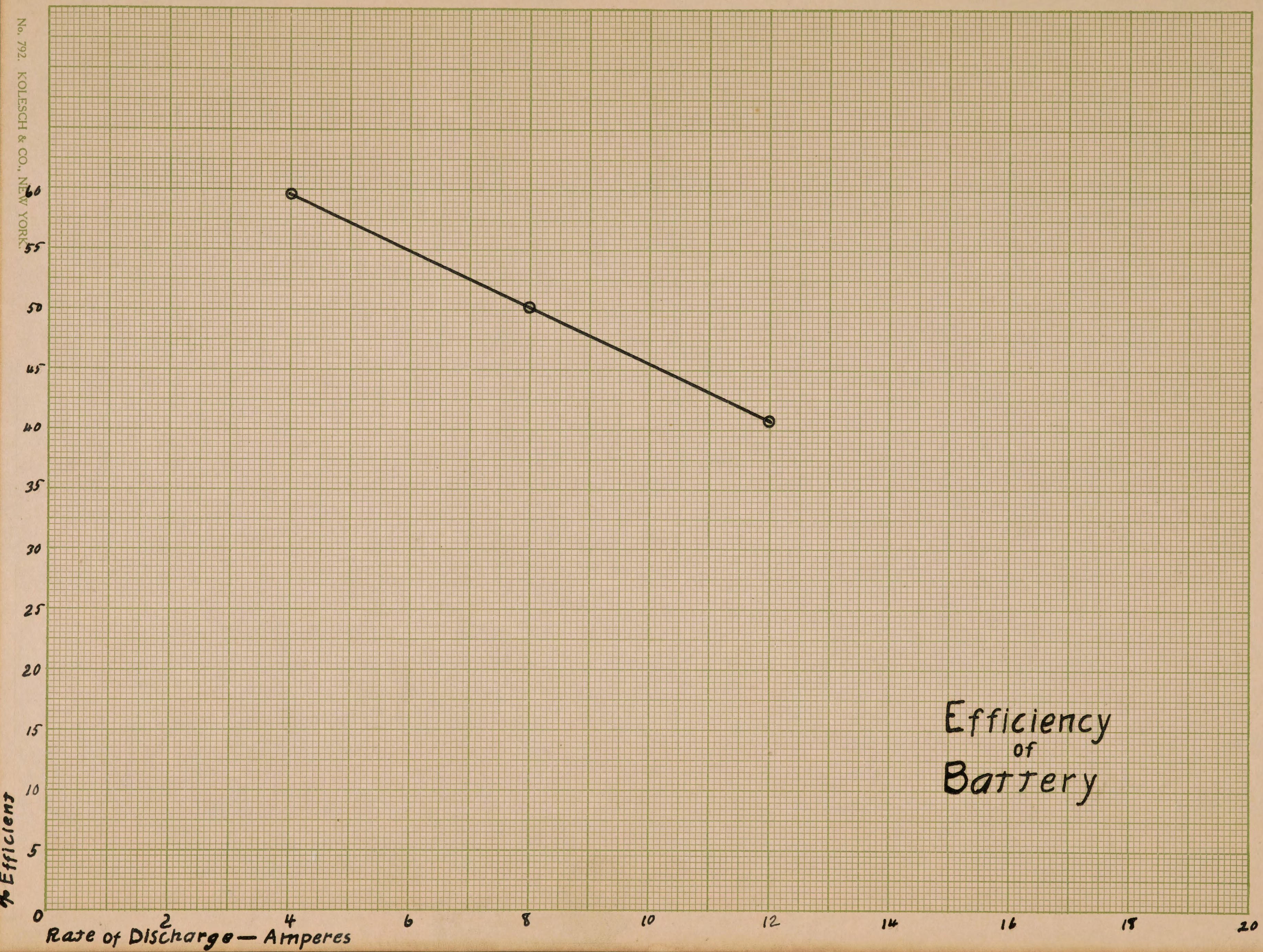
Average amperes 21.65

Average volts 43.42

Ampere hours 65.1

Watt hours 2823

Efficiency . . . . 41.5 %



No. 792. KOLESCH & CO., NEW YORK.
Efficiency of Battery
% Efficient
0
5
10
15
20
25
30
35
40
45
50
55
60
2
4
6
8
10
12
14
16
18
20
Rate of Discharge — Amperes

From the data of the 8 ampere discharge rate it is seen that the battery has a capacity of 38 ampere hours. Eight amperes is the standard discharge rate for rating batteries. ?

? Ask A.I.E.E., S.A.E. or N.G.E.A.

The manufacturer rates the battery at 80 ampere hours, this however, is not at the standard discharged rate, but is based on a discharge rate of one ampere. The manufacturers gave in their discharge chart 6 hours and 45 minutes or the time 8 amperes can be discharged continuously from the battery. According to the standard for rating such batteries this would give the battery a capacity of 54 ampere hours then the battery is 48.2 % over rated according to the manufacturers discharge chart and 110.5 % over rated according to the data of their test. ?

The manufacturer does not state what the specific gravity for the electrolyte was at full charge and at discharge for the data given by the chart furnished with the machine, but they recommend that the charged and discharged specific gravity of the electrolyte be between the limits of 1.220 and 1.185.

COST OF OPERATING AND MAINTAINING PLANT.

The cost of operating and maintaining the plant will depend principally upon the cost of fuel and the amount and quality of the mixing.

From the test of the plant it was found that the efficiency of the batteries is 59.3 % and that the net efficiency of the engine and generator is 10.17 %. Then the net efficiency of the whole plant is 6.04 %.

Weight of kerosene per gallon = 6.75 lbs.
" " gasoline " " = 5.46 "
One watt hour = 341 B.T.U.

B.T.U. contained per gallon of kerosene = 135000
" " " " " gasoline = 105200
K W hours contained per gallon kerosene = 39.6
" " " " " gasoline = 30.9
Output per gallon kerosene = 2.39 K W hours
" " " gasoline = 1.87 K W hours
Cost of kerosene per gallon = 12 cents
" " gasoline " " = 25 cents
Cost per K W hour for kerosene = 5.2 cents
" " " " " gasoline =13.4 cents
" " " " " oil = 1.2 cents

One engine and generator will probably last ten ? years and a battery will last about five years so that ? the depreciation will be 13 per cent. Interest on the investment will be 6 per cent. The cost per year of maintaining the plant will be 19 per cent of the selling price or $52.25. The cost of wiring and of small motors etc., will be about $125.00 for the average plant, the depreciation for this will be about 2 per cent and the interest on money invested will be 6 per cent, making the maintenance of this plant $10.00 and the total maintenance cost will be $62.25 per year.

About 25 K.W. hours per month or 300 K.W. hours per year will be used. The maintenance cost per K.W. hour will be $62.25 divided by 300 which is 20.7 cents. The cost of operating the plant is 5.4 cents per K.W. hour for kerosene and 14.6 cents per K.W. hour for gasoline. The total cost per K.W. hour delivered by the batteries will be 26.1 cents for kerosene and 35.3 cents for gasoline.

Too high