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THESIS

LOSSES AND EFFICIENCIES

MOTOR GENERATOR SET

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1912

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June 1912.

THESIS

A STUDY OF THE LOSSES AND EFFICIENCIES OF A MOTOR GENERATOR SET.

BY

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EAST LANSING, MICHIGAN

SPRING

1912

This thesis was contributed by

Mr. R. A. Warner

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

THESIS OUTLINE

OBJECT

The object of this thesis will be the determination and study of the losses, together with the efficiencies, existing in the motor-generator set in the Large Engineering Labaratory at the Michigan State College. Furthermore to determine a rating of the motor and its capacity for driving the altenator.

PROCEDURE

Bearing in mind that in order to obtain valuable data from any test it is necessary to follow standard methods of procedure, we have decided to determine experimentally all the individual losses and combined efficiencies of the set throughout an operative range of speed, load and field excitation, following the standardization rules (See Standard Hand Book Section 19) as far as possible.

NOTE 1. To avoid confusion and for the sake of brevity, hereafter we will call the generator of the set the altenator, the motor of the set the motor and the outside driving motor the auxiliary.

The losses are:-

1. Bearing Friction and Windage.

Measured by driving the machine unexcited from the auxiliary, the output of which is suitably determined.

2. Commutator Bruch Friction.

Measured by the increase in input to the auxiliary required for driving motor with brushes on and brushes off (The

field being unexcited)

3. Collector Ring Brush Friction.

Measured in a similar manner to the Commutator Brush Friction.

4. Core Losses.

Measured by driving machine with field excited, either as a motor or by an independent motor and determined by subtracting all other losses from the imput to motor.

5. Armature Resistance Loss.

Resistance measured by the Drop of Potential Method.

6. Field Resistance Loss.

Resistance measured by the Queene Acme Testing Set.

The Determination of Efficiencies.

1. Motor- $\frac{\text{Input-losses}}{\text{Input}}$

2. Altenator- $\frac{\text{Output}}{\text{Output+losses}}$

3. Combined

The efficiency of Motor x the Efficiency of Altenator.

Description of the Machines.

To meet the growing need of the Electrical Department at the college for a source of alternating current for testing purposes, a motor-generator set was built up by directly connecting a remodeled D. C. motor to an A. C. generator. The history and description of each machine, as far as was obtainable, is herein given.

The description of the altenator is taken from the thesis of A. P. Pulling and C. H. Ponitz of the class of 1910 " The Machine (#69985) was purchased by the Michigan State College October 24th., 1897 from the Westinghouse Electric and Mfg. Co. at a cost of $2400.00

It is a 75 K. W. , 2200 volt, 3 phase, 10 pole machine to be run at 720 R. P. M.

During the first five years of its operation the alternator supplied the college with electrical energy. After that time up to October, 1909, it served various purposes. In the fall of 1909 the alternator was moved from the Power House at Platt's dam, Lansing, Mich., to the Mechanical Laboratory of the college where it has since been used for testing purposes."

The motor, originally a 500 volt, shunt wound machine of the General Electrical Company's make, was purchased December 1910 from the Capitol Electric Co., of Lansing, Mich. for $200.00. Previous to this time it was the property of the Hugh Lyons Furniture Co. of Lansing. During Christmas vacation of 1911 Mr. Clarence B. Cable, then a special student at the college, was employed by the Electrical Department to make over the machine so as to be used on a 220 volt circuit. This was done by soldering each two consecutive armature segments together and connecting the four field coils in parallel. He aligned up and direct connected the motor and alternator as shown in Fig. 1.

The auxiliary consisted of a 220 volt rotary converter run belt connected for all tests (See Figs. 2 & 3) throughout thesis.

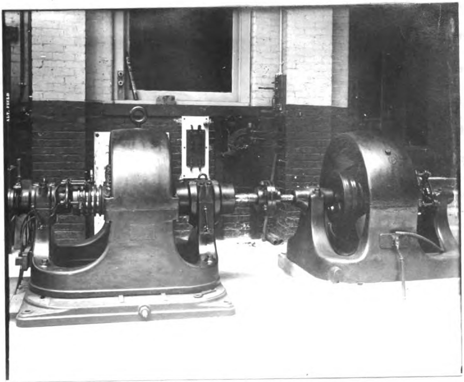


Fig. 1.

PREPARATION FOR TEST.

All meters and tachtometers used were carefully calibrated so that all readings might represent the actual conditions of the tests.

Suitable pulleys were necessary for the auxiliary and motor to give the correct range of speed for the tests. These were found and put in place. The slip ring brushes were then removed from the A. C. side of the auxiliary and all the tests run from the D. C. side. That field current was then found which would give the correct speed with 220 volts across the Armature. This field current was kept constant at 1.1 amperes throughout all tests, thus keeping the core loss of the auxiliary constant. The speed was varied by the booster method* and the following data obtained from which the stray power losses were calculated as shown below and plotted on curve sheet #1. Immediately after this test the resistance of the armature was measured using the Queens Acme Testing set and found to be .37 ohms. The I^2R loss curve of the armature is shown on curve sheet No. 2. From these two curves the total losses of the Auxiliary for any speed and any armature current may be obtained.

Data and Calculations.

R. P. M.	E.	I.	E I	I^2R	S.
1800	222.7	6.36	1420	13	1407
1770	218.9	5.35	1170	9	1161
1750	215.8	6.01	1295	12	1283
1610	200	5.35	1070	9	1061
1600	197	5.35	1053	9	1044
1530	189	4.84	914	7	907

S equals STRAY POWER LOSS IN WATTS

RESTITUTION

We were indebted to Mr. G. A. Kelsall for the calibration of the meters and his time spent in our behalf and to Mr. L. F. Newell of the Power house for his cooperation in the running of the load test.

* The Booster method of changing the speed was used on all tests wherever the speed was varied.

TEST ON MOTOR

The motor was uncoupled from the alternator. Fig. 2 shows the auxiliary belt connected to the motor with its starting box, field rheostat and tachtometers in place. The fields of the auxiliary and motor for all tests were separately excited and provided with rheostats to vary the excitation when deisred. There were ammeters in the field and armature circuits of the auxiliary and the field of the motor. A voltmeter was placed across the armature for all tests.

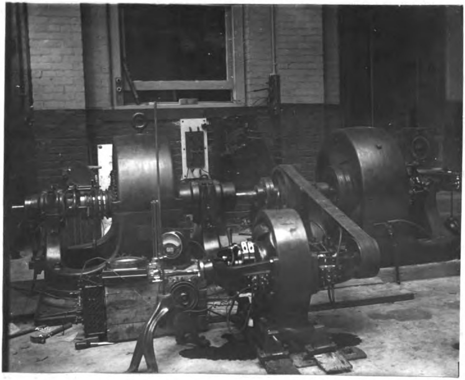


Fig. 2.

Mechanical Losses of Motor.

The mechanical losses of the motor are:

1. Bearing Friction and Windage.
2. Commutator Brush Friction.

The Bearing Friction and Windage losses were obtained for different speeds of the motor by removing its brushes and measuring the input to the auxiliary. This input includes also all the losses of the auxiliary and belt as shown on Curve sheet #3.

Data and Calculations for Bearing Friction and Windage.

A	M	E	I	EI	B	C	D
1811	900	231.1	6.9	159[illegible]	141[illegible]	--	--
1742	870	223.3	6.38	14[illegible]	1309	55	61
1695	841	215.8	6.38	1377	1229	6[illegible]	88
1610	803	208.4	6.38	1330	1084	62	184
1535	765	199	5.87	1168	[illegible]	7[illegible]	141
1511	750	195	5.87	1144	903	76	165
1440	720	189	5.55	1049	793	90	167
1400	699	183	5.3[illegible]	9[illegible]0	740	93	147

A. equals R.P.M. of Auxiliary and M. equals R.P.M. of Motor.

B. " Total Auxiliary losses from Curve sheet #1 and #2.

C. " Belt losses in Watts taken from Curve sheet #4 and transferred to Curve sheet #2.

D. equals Bearing Friction and Windage losses in Watts.

E. " Voltage across armature of auxiliary,

I. " Current input to auxiliary in amperes.

The belt loss was determined by measuring the increased input or power required to run the motor by the auxiliary than was required when run electrically as a motor with the same field excitation for the motor in both cases. When run electrically it must be remembered to subtract the I^2R loss of the motor armature. A 20" diam. split wooden pulley was used on the shaft of the motor and a 9 5/8" diam. on the auxiliary. The width of the belt was 5".

Data and Calculations for the Belt Loss

A.	M.	E.	I.	EI	B.	F.
1750	882	230	14.51	3340	1388	2052
1690	850	222.2	14.51	3230	1284	1946
1655	833	216.8	"	3150	1226	1924
1595	803	208.4	14.01	2920	1113	1807
1525	769	201	"	2820	993	1827
1480	745	195	"	2734	918	1816
1435	722	189	13.72	25.95	843	1752
1400	705	184	"	25.10	783	1727

F equals Power in watts delivered to belt by auxiliary . See Curve A curve sheet No. 4.

For data and calculations when motor is run electrically see Core loss test page 9 for 3.88 Amperes Field excitation, also see curve B. on Curve sheet No. 4.

The Commutator Brush Friction losses were to have been determined by the increased input to auxiliary required to drive motor with the brushes on than with the brushes off (the field being unexcited) but owing to an error discovered in the ammeter reading too late to be corrected, another method was used as follows:

The motor has the commutator brushes arranged in sets of three each. The motor will run idle equally well with one, two or all the brushes of each set in contact with the commutator. A finely reading ammeter in the armature circuit will show the difference in the current necessary to drive the machine under these different conditions. The average data for the three brushes together with the computed power necessary to overcome the brush friction is shown below and the brush friction loss plotted to speed as abscissae on Curve sheet No. 3.

Commutator Brush Friction Data.

M.	E.	I.	3EI
810	235.3	1.4	987
730	210.6	1.4	985
645	188.0	1.366	771

I equals Av. Current in Amp. required to over come 1/3 friction due to brushes.

E. equals Voltage across Armature of Motor.

CORE LOSS

Curves of core losses as functions of speed and exciting current are shown on Curve sheet No. 5. For each value of field current the core loss was obtained at different speeds by measuring the input to the motor, run electrically, and subtracting the I^2R and mechanical losses.

Core Loss Data and Calculations

Field Current 6.78 Amperes.

M.	E.	I.	EI.	I^2R	G.	H.
722	234.2	8.98	2105	29	1011	1065
710	231.1	9.0	2080	"	986	1065
690	224.4	8.98	2015	"	974	1012
670	216.9	8.98	1969	"	961	979

G. equals Mechanical losses of motor in watts.

H. " Core loss in watts .

E. " Voltage across armature of motor.

Field Current 5.79 Amp.

M.	E.	I.	EI.	$I^2R.$	G.	H.
747	233.1	8.98	2090	29	1031	1029
730	228.9	"	2055	"	1014	1012
710	221.1	"	1983	"	986	968
699	217.9	"	1954	"	984	941

Field Current 4.84 A.

M.	E.	I.	EI.	I^2R.	G.	H.
786	233.6	8.98	2095	29	1061	1005
760	226.6	"	2035	29	1036	970
740	221.1	"	1982	29	1026	927
732	218.9	8.98	1965	29	1014	922
686	202	8.78	1774	28	973	773
677	201	8.47	1660	27	962	571

Field Current 3.88 Amperes

M	E	I	EI	I^2R	G	H
855	234.2	8.47	1982	27	----	---
820	244.4	"	1900	"	1096	859
800	207.4	"	1755	"	1081	647
735	201	"	1700	"	1016	657
720	197	"	1668	"	1011	530
680	186	"	1574	"	964	583

Field Current 3.39 Amperes.

M	E	I	EI	I^2R	G	H
900	234.2	7.91	1852	23	----	---
850	222.2	"	1756	"	1136	599
770	202	"	1598	"	1051	524
752	197	"	1558	"	1031	504
733	191	"	1511	"	1014	474
710	185	"	1463	"	986	454

COPPER LOSSES

The resistance of the field was found to be 29.45 ohms, taken with Queene Acme Testing set.

The resistance of the armature was obtained by taking the average resistance from three trials by the drop of potential method, and it was found to be .0[illegible]2 ohms. The drop of potential in this case was measured from the terminals of the machine. Both were taken after machine had been running under load. The drop due to brush contact resistance was afterward taken and found to be .011 ohms for all brushes when the machine was standing still. This resistance will probably change when the machine is running and is a small error that can not be remedied.

For I^2R loss of armature see Curve sheet No. 6.

" " " " field " " " " 7.

TEST ON ALTERNATOR

A similar test to that run on motor was run on the alternator.

MECHANICAL LOSSES

The Bearing Friction and Windage losses were determined by the same method and with the same auxiliary as were those of the motor. The auxiliary is shown belted to the alternator in Fig. 3. This picture was taken after the test was run and shows the auxiliary field rheostat and ammeter, the armature combined volt-ammeter, and the tachtometers.

Bearing Friction and Windage Data

A	M	E	I	EI	B	C	D
1680	830	218.9	9.61	2102	1200	230	652
1612	800	210.5	9.40	1978	1104	240	634
1538	760	201	9.25	1858	967	250	641
1500	742	196	8.98	1762	919	253	590
1453	720	190	8.46	1606	[illegible]26	250	530
1408	698	184.5	8.26	15[illegible]	747	252	524

C equals Belt loss in watts taken from curve sheet No. 3.

D " Bearing friction and windage losses in watts see curve sheet No. 8.

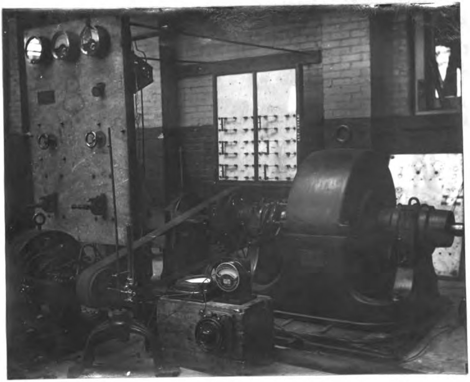


Fig. 3.

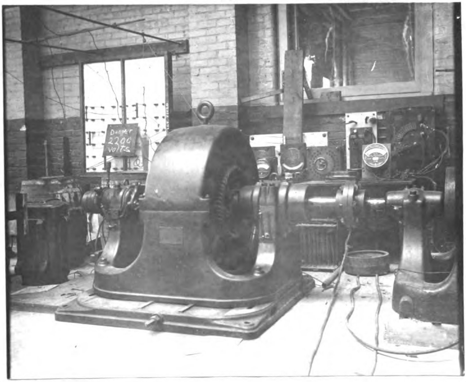


Fig. 4.

The Slip Ring Friction losses were determined by measuring the difference imputs with the brushes up and with the brushes down.

Bearing Friction, Windage and Slip Ring Friction.

A	M	E	I	EI	B	C	G
1675	830	219.4	10.65	2340	1320	230	390
1611	798	210.5	10.34	2180	1110	240	830
1533	760	201	10.02	2011	972	250	789
1505	745	196.5	10.02	1969	925	254	790
1458	720	192	9.71	1863	84[illegible]	230	766
1405	695	185	9.50	17[illegible]5	755	252	748

C is the belt losses taken from Curve sheet No. 9 and transferred to curve sheet No. 8.

G. is the total Mechanical losses of Alternator See Curve sheet No. 8.

The Belt loss was determined by measuring the increased input required to run the alternator by the auxiliary than was required when run direct connected to motor under same conditions.

Data and Calculations.

1. Alternator run by Auxiliary.

A	AL	E	I	EI	B	F
[illegible]	[illegible]	[illegible]	28.86	6650	1538	5112
1650	808	222.2	27.33	6070	1415	4655
1610	790	216.8	26.82	5815	1336	4479
1537	750	207.4	25.6	5308	1183	4125
1460	720	197.5	24.8	4900	1037	3863
1406	692	191.5	24.3	4660	930	3730
1365	672	186	23.8	4430	810	3620

AL equals R.P.M. of Alternator.

F equals Power in watts delivered to belt by auxiliary. (See Curve A. Curve sheet No. 9)

2. Alternator run by Motor

M	E	I	EI	J	K
820	224.4	29.36	6600	1847	4753
800	220	28.86	6350	1762	4588
778	212.6	28.86	6130	1690	4440
732	202.1	25.8	5220	1544	3676
721	198	"	5110	1512	3598
703	194	"	5004	1479	3525
679	188	25.29	4760	1438	3322

J equals total losses of Motor in watts. Field current of motor 3.88 Amperes.

K equals Power in watts to run alternator by direct connection to motor. See curve B. Curve sheet No. 9.

Note! Field current of alternator was kept constant at 8.9 Amperes for both of the above tests.

CORE LOSS

The core loss data for the alternator was obtained with the set connected as in Fig. 1. The core loss of the alternator is equal to the imput to the motor minus all motor losses minus all of the mechanical losses of the alternator. This data together with the calculations are shown below.

The results are plotted to speed as abscissae Curve sheet #10

The core loss-field current curve is shown on Curve sheet #11.

Core Loss Data and Calculations.

Field Current of Alternator equals 11.67

M	E	I	EL	J	G	H
810	223.3	36.6	8170	1862	845	5463
793	216.8	36.1	7830	1841	825	5164
780	213.6	36.1	7720	1820	812	5088
771	211.6	36.1	7640	1802	802	5036
731	201	32.98	6640	1724	774	4142
720	197	32.46	6400	1700	764	3936
702	193	31.94	6170	1672	754	3744
673	186	"	5940	1622	736	3582

Field current equals 9.85

M	E	I	EI	J	G	H
820	224.4	31.94	7170	1882	863	4425
802	218.9	31.94	7000	1850	835	4315
780	213.6	31.94	6825	1810	812	4203
775	212.6	31.42	6680	1800	807	4073
732	204.2	28.35	5790	1722	775	3293
720	198	28.35	5620	1700	764	3156
701	194	27.84	5400	1672	753	2975
673	186	27.33	5080	1620	736	2724

Field current 7.96 amperes

M	E	I	EI	J	G	H
820	225.5	26.82	6050	1867	863	3320
800	220	26.82	5900	1837	832	3231
780	214.7	"	5770	1807	812	3151
736	202.1	23.8	4810	1722	775	2313
720	198.	"	4720	1691	764	2265
702	194	"	4620	1651	754	2215
674	186	22.77	4235	1611	738	1886

Field current equals 6.03 amperes

M	E	I	EI	J	G	H
834	228.9	21.76	4980	1895	904	2181
810	222.2	21.25	4725	1845	845	2025
788	215.8	"	4560	1805	817	1958
731	202	19.7	3960	1701	778	1481
720	198.	"	3900	1683	764	1553
691	191	"	3762	1633	745	1384
675	186	19.18	3570	1602	740	1172

Field current 5.06 amperes

M	E	I	EI	J	G	H
833	227.8	19.7	4480	1893	900	1667
820	222.2	"	4380	1863	863	1654
787	214.7	19.18	4120	1802	815	1503
727	198	18.12	3590	1691	774	1125
720	196	"	3550	1681	764	1105
702	193	"	3500	1651	754	1095
674	186	"	3370	1600	738	1032

E and I refer to the motor

Test of Alternator continued.

COPPER LOSSES

The resistance of the two phases of the armature were measured separately by the drop of potential method immediately after the load test was run and while the armature was warm.

For sake of convenience the phase leading to the two alternate rings nearest the armature of the machine will be designated as Phase 2. The drop of potential was measured across these rings. The average resistances thus obtained for several readings were for Phase #1, 1.84 ohms and for phase #2, 1.76 ohms.

The I^2R losses for both phases are shown on curve sheet #12.

The resistance of the field taken warm by the Queene Acme testing set was found to be 10.15 ohms and the I^2R losses plotted to field current on curve sheet #7.

Load Test on Set.

In order to test the set under load conditions two large water boxes were fixed up and each phase loaded on one of the water boxes. The water box consisted of a large barrel insulated from the floor and filled with clean well water. One terminal led through the bottom of the barrel to a cast iron disk about 5" in diameter and 1" in thickness. The other terminal consisted of an old saw blade suspended in such a manner that it could be raised out or lowered into the water as desired from the table directly back of the machines. See Fig. 4)

Water boxes fixed up for 2200 Volts were necessary because the transformer equipment was not large enough to transform the full load current of the machine. The water box described worked with entire satisfaction at 2200 volts. Considerable heat was evident however. It was also necessary to construct a temporary line from the main feeders, where they came into the Engineering Building under the East stairs, to the machine, as those feeders leading to the motor were not heavy enough to carry full load current. All fuses on the line were taken out and the line connected to run directly from the circuit breakers of a separate generator in the power house.

Owing to an inefficient ammeter in the armature circuit of the motor its imput is not entirely available. All other readings were taken as shown below and the regulation for one phase and for both phases together determined. The motor carried the load without showing any signs of being overloaded up to 3/4 load on the alternator. At full load of alternator the only signs of distress was excessive brush sparking.

Data and calculations for Load Test

Speed constant at 720 R. P. M.

Motor Readings

I_f	I	E	I_1	I_2	E	I_f
8.25	31.9	243.7	0		2200	9.58
7.65	87.9	240.4	5.8		2160	"
7.07	129.2	238.4	10.		2160	"
6.6		236.3	12		2160	"
6.23		234.2	15		2190	"
6.		233.1	17		2160	"
5.75		232.1	20		2160	"
5.5		331.1	23		2150	"
6.23		233.1	17.5		2200	9.85
7.3		243.7	0		2220	"
4.92		333.1	6.8	6.8	2150	9.58
5.5		230	9.2	9.2	2110	"
6.		226.6	12.	12	2070	"
5.15		223.3	15	15	2050	"
5.04		220	17.5	17.5	2010	"
4.92	425*	217.9	17.5	17.5	2200	10.78
6.72		225.5	0	0	2360	"

* At Power House

I_f equals Field current in amperes

I_1 " Armature current on phase 1 in amperes
I_2 " " " " " 2 " "

Regulation for one phase

$$\frac{2220 - 2200}{2200} \text{ equals } .0091 \text{ or } .91$$

Regulation for both phases

$$\frac{2360-2200}{2200} \text{ equals } .0727 \text{ or } 7.27\%$$

Efficiencies from Losses

Efficiency of Motor equals $\frac{\text{Imput-Losses}}{\text{Imput}}$

Efficiency of Alternator equals $\frac{\text{Output}}{\text{Output - Losses}}$

Combined efficiency equals Product of the efficiencies of motor and alternator when the output of motor is equal to the imput to the Alternator.

The separate efficiencies of each machine and their combined efficiency are shown plotted to K. W. output of motor and K. W. imput to alternator on Curve sheet #13.

The Efficiency-Imput curve of motor and the combined Efficiency -Imput curve of set are shown on Curve sheet #14.

The Efficiency-Output curve of Alternator and the combined Efficiency - Output curve of set are shown on Curve sheet #15.

From the Efficiency curves as near an actual rating for the motor as is possible to get would be a 235 volt, 4 pole, 720 R.M.P. 94 H.P., motor as it now stands direct connected to the alternator.

Motor Efficiency Data

The constants are 720 R.M.P., 6.78 amperes field current, 1370 watts field resistance loss, 80 watts bearing friction and windage loss and 1096 watts core loss, taken from curve sheets.

I	I^2R	Total Loss	Input K.W.	Output K.W.	E. %
0	0	1370	1.37	0	0
10	3.2	3409	3.57	16	4.5
25	20	3426	6.87	3.44	39.5
50	80	3486	12.37	8.88	71.8
75	179	3585	17.87	14.29	80
100	320	3726	23.27	19.34	84.1
150	720	4126	34.37	30.24	88
200	1280	4686	47.37	40.68	89.5
250	2000	5606	56.37	50.96	90.3
300	2880	6286	67.37	61.08	90.6
350	3900	7306	78.37	71.06	90.7
400	5120	8526	89.37	80.84	90.5
450	6470	9876	100.37	90.49	90.1
500	8000	11406	111.37	99.96	89.7

Alternator Efficiency Data.

Constants 720 R.P.M., 2200 volts, 746 bearing friction and windage and slip ring friction losses.

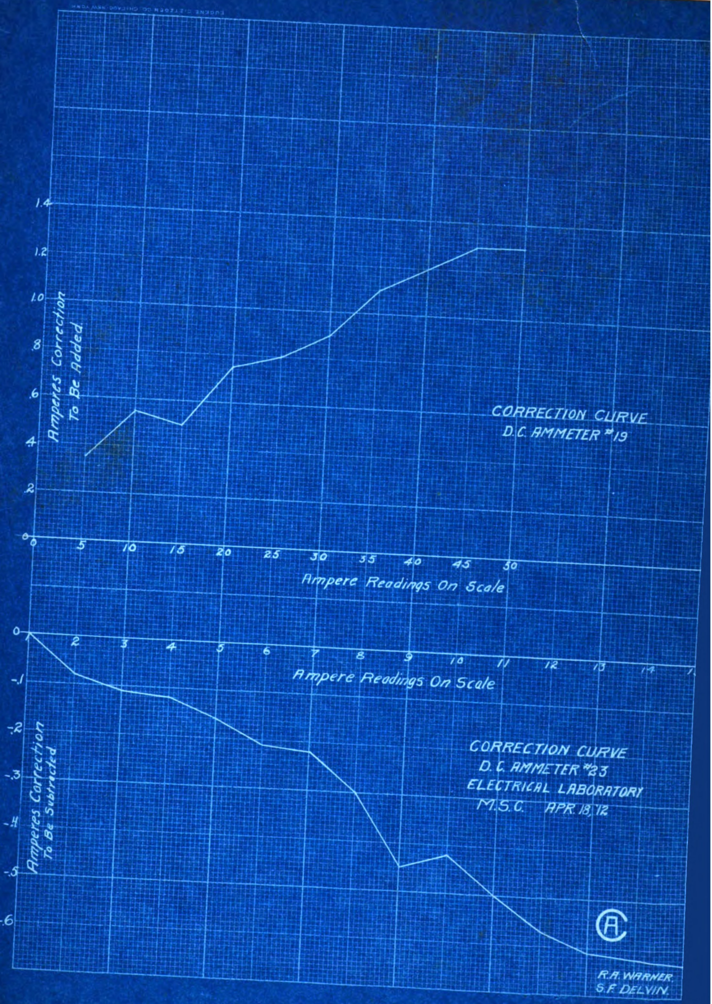
I	I_f	Total Losses	K.W.I.P.	K.W.O.P.	E. %
0	9.58	4690	4.69	0	0
2	9.63	4721	13.53	8.8	65
4	9.69	4812	22.41	17.6	78.4
6	9.75	4934	31.33	26.4	84.3
8	9.82	5075	40.28	35.2	87.7
10	9.9	5295	49.30	44.	89.3
12	10.2	5529	58.33	52.8	90.6
14	10.35	5762	67.36	61.6	91.6

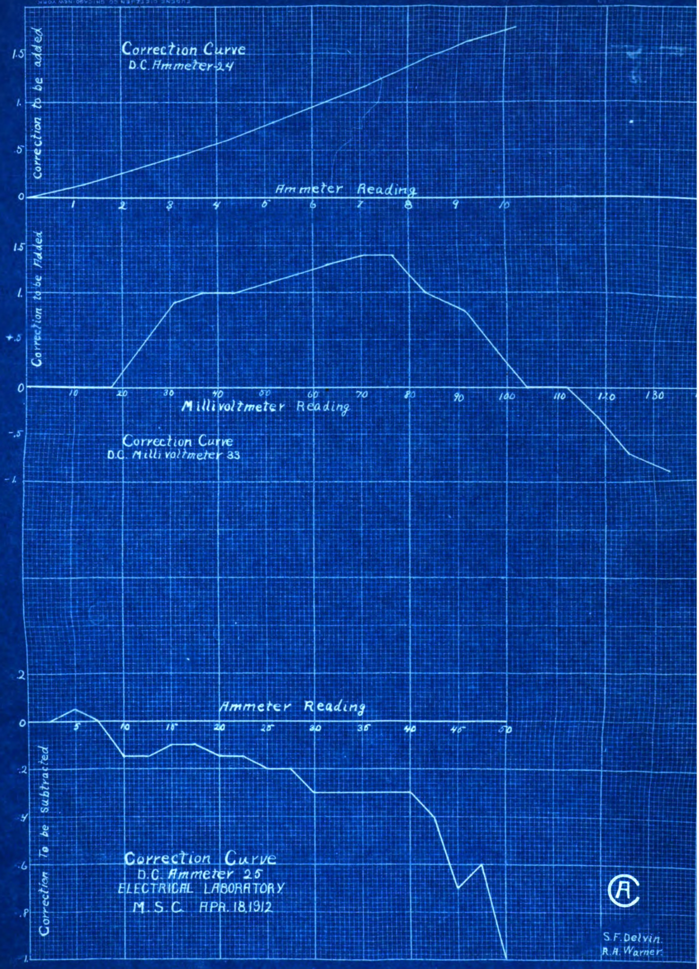
Alternator Efficiency Data Continued.

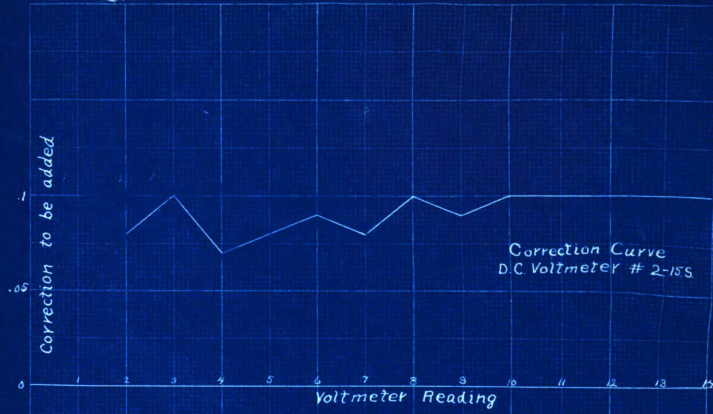
I	I_f	Total Losses	K. .I.P.	K.W.O.P.	E. %
16	10.65	6335	76.74	70.4	91.9
17.5	10.78	6795	83.80	77	92.1
20	10.9	7002	95.00	88	92.6
22	11.1	7454	104.25	96.8	92.8
24	11.3	7915	112.52	105.6	92.3

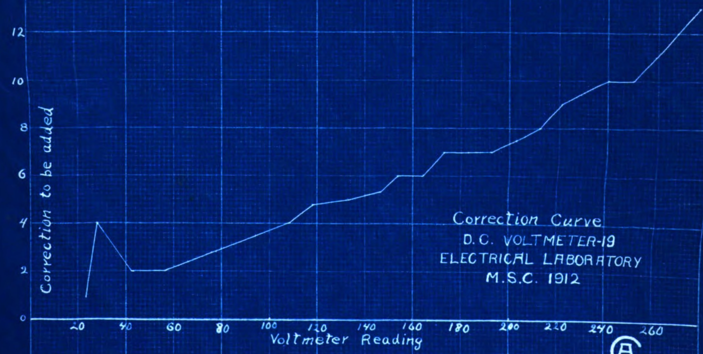
Combined Efficiency Calculations

O.P.M I.P.A.	E.M.	E.A.	C.E.	I.P.M.	O.P.A.
10 KW	75.5	47	35.5	13.34	4.7
20	84.	75.6	63.5	23.8	16.8
34	87	83.7	72.8	34.5	25.11
40	88.6	87.5	77.6	45.2	35.
60	90.6	91.	82.5	66.2	54.6
80	90.6	92.2	83.5	88.3	73.76
100	89.7	92.7	83.1	111.6	92.7

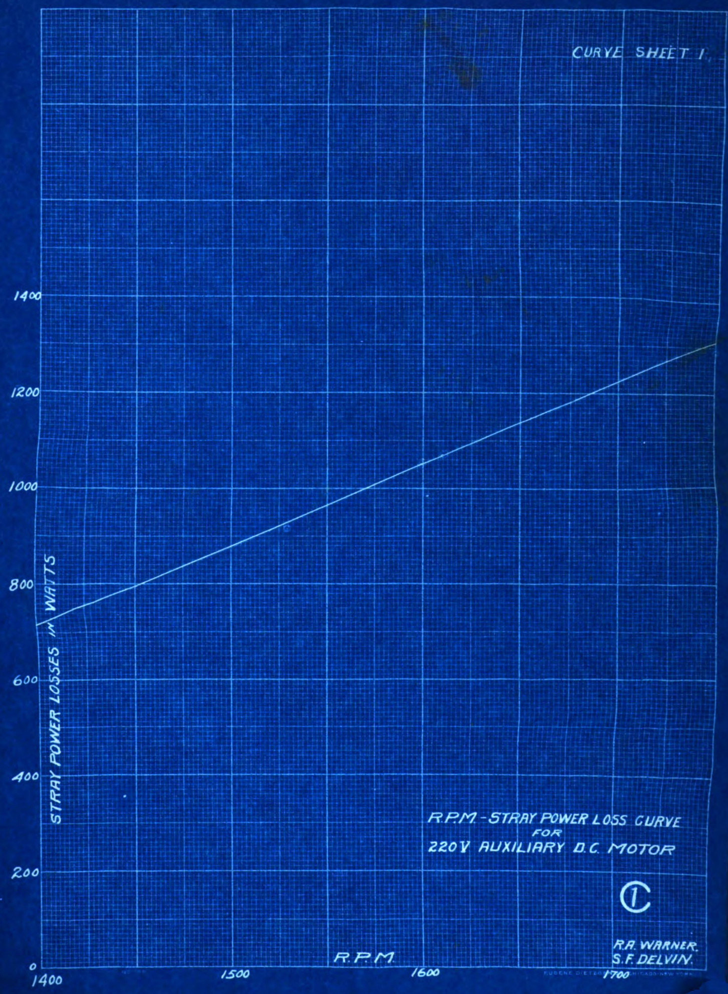

CORRECTION CURVE
D.C. AMMETER #19
Amperes Correction
To Be Added
1.4
1.2
1.0
.8
.6
.4
.2
0
0 5 10 15 20 25 30 35 40 45 50
Ampere Readings On Scale
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Ampere Readings On Scale
-.1
-.2
-.3
-.4
-.5
-.6
Amperes Correction
To Be Subtracted
CORRECTION CURVE
D.C. AMMETER #23
ELECTRICAL LABORATORY
M.S.C. APR. 18, '12
R.A. WARNER
S.F. DELVIN

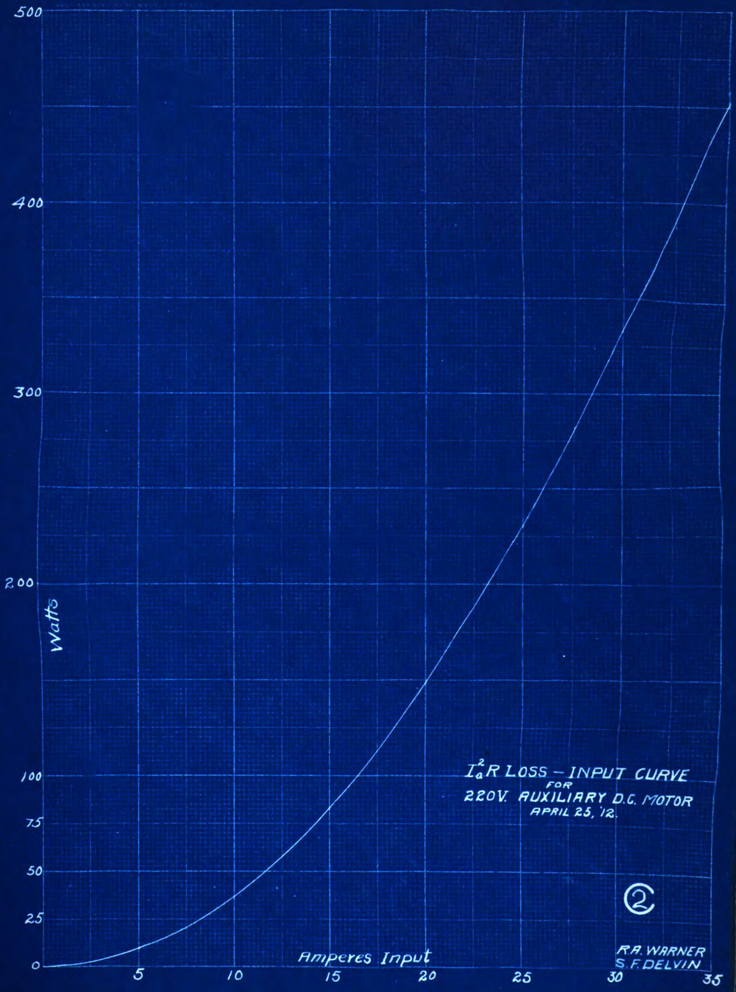

Correction Curve
D.C. Ammeter-24
Correction to be added
1.5
1.
.5
0
Ammeter Reading
1
2
3
4
5
6
7
8
9
10
Correction to be Added
1.5
1.
+.5
0
-.5
-1.
10
20
30
40
50
60
70
80
90
100
110
120
130
Millivoltmeter Reading
Correction Curve
D.C. Millivoltmeter 33
.2
0
Ammeter Reading
5
10
15
20
25
30
35
40
45
50
Correction To be Subtracted
.2
.4
.6
.8
1.
Correction Curve
D.C. Ammeter 25
ELECTRICAL LABORATORY
M.S.C. APR. 18, 1912
S.F. Delvin
R.A. Warner

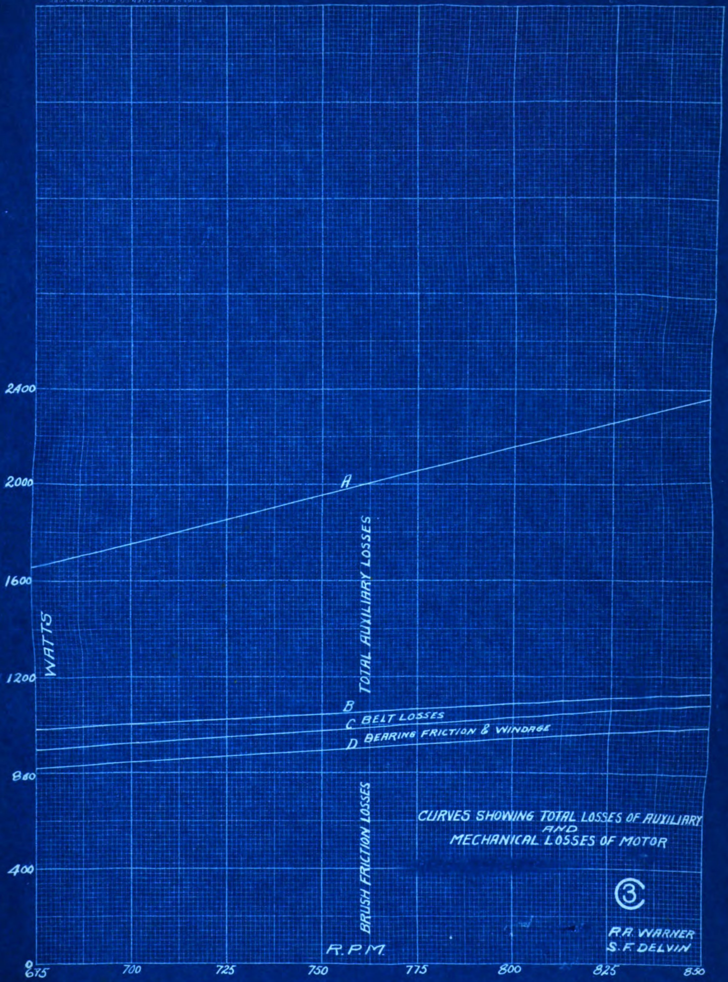




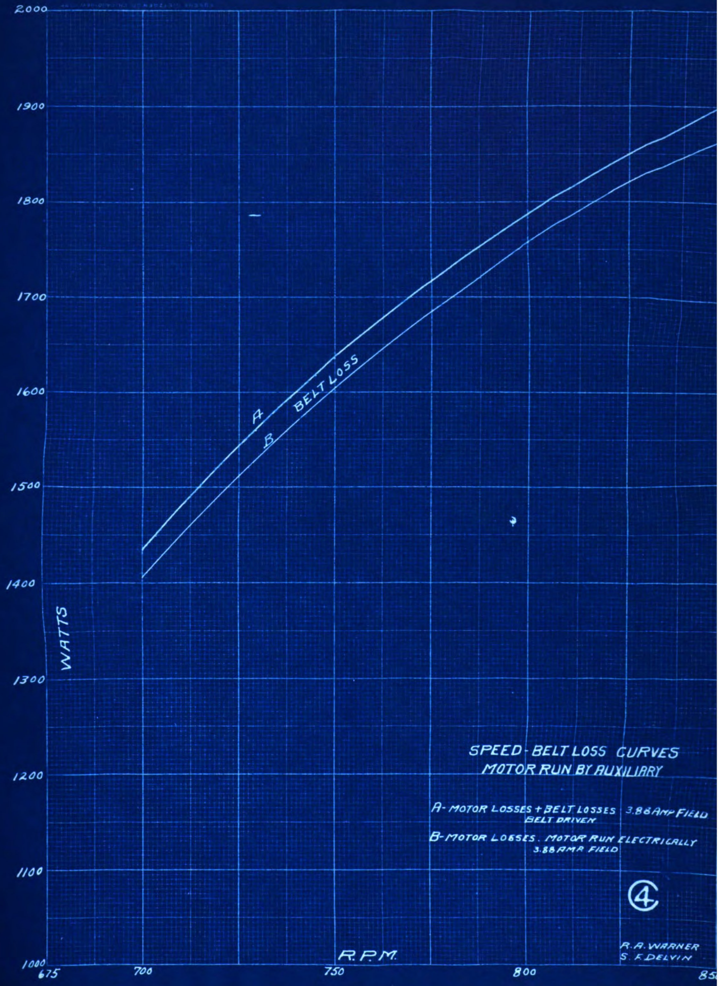
S.F. Delvin
R.A. Warner

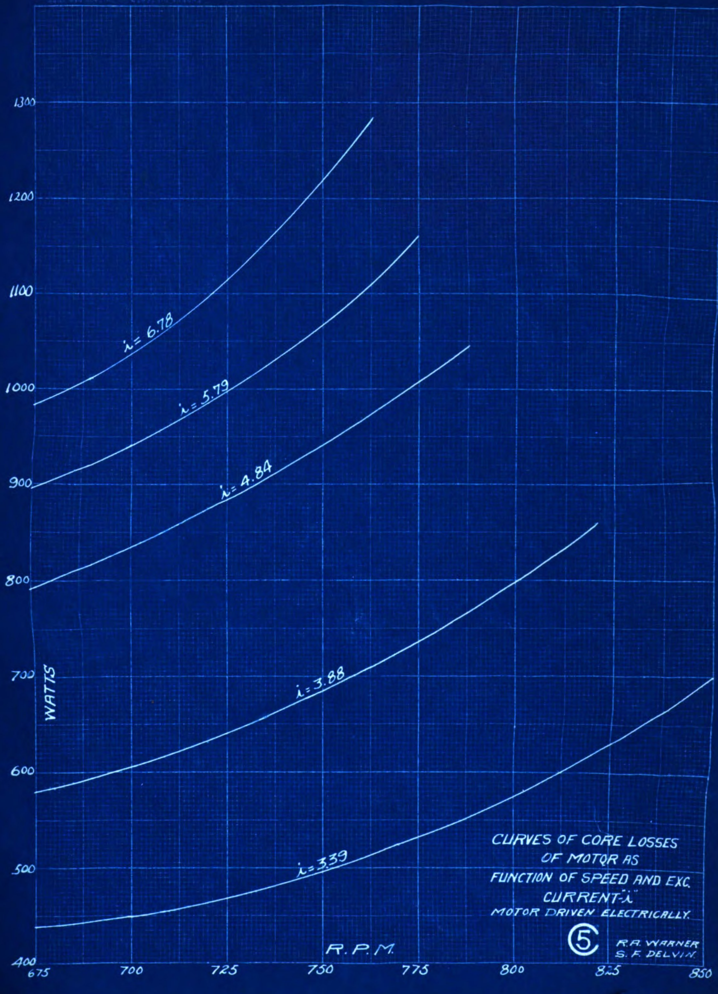

CURVE SHEET I.
1400
1200
1000
800
600
400
200
0
STRAY POWER LOSSES IN WATTS
R.P.M - STRAY POWER LOSS CURVE
FOR
220V AUXILIARY D.C. MOTOR
R.A. WARNER.
S.F. DELVIN.
R.P.M.
1400
1500
1600
1700


I_a^2R LOSS – INPUT CURVE
FOR
220V. AUXILIARY D.C. MOTOR
APRIL 25, '12.
Watts
Amperes Input
500
400
300
200
100
75
50
25
0
5
10
15
20
25
30
35
2
R.A. WARNER
S.F. DELVIN

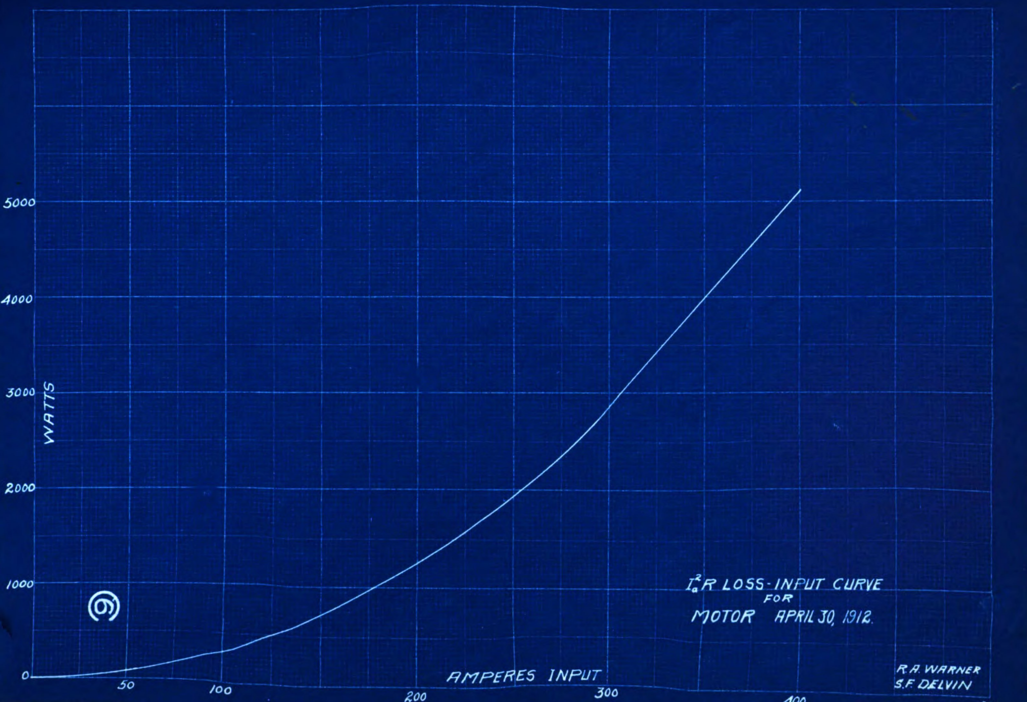


2400
2000
1600
1200
800
400
0
WATTS
A
TOTAL AUXILIARY LOSSES
B
C BELT LOSSES
D BEARING FRICTION & WINDAGE
BRUSH FRICTION LOSSES
CURVES SHOWING TOTAL LOSSES OF AUXILIARY
AND
MECHANICAL LOSSES OF MOTOR
3
R.P.M.
675
700
725
750
775
800
825
850
R.A. WARNER
S.F. DELVIN

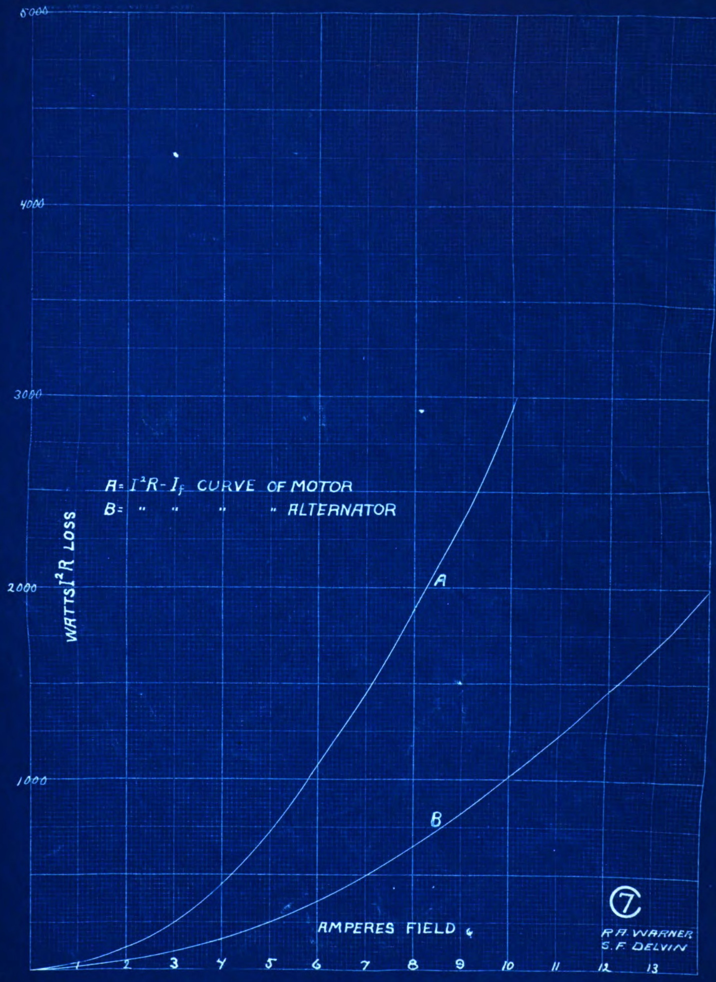

2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
WATTS
A
B
BELT LOSS
SPEED-BELT LOSS CURVES
MOTOR RUN BY AUXILIARY
A- MOTOR LOSSES + BELT LOSSES 3.88 AMP FIELD
BELT DRIVEN
B- MOTOR LOSSES. MOTOR RUN ELECTRICALLY
3.88 AMP FIELD
4
R.A. WARNER
S. F. DELVIN
675
700
750
800
R.P.M.



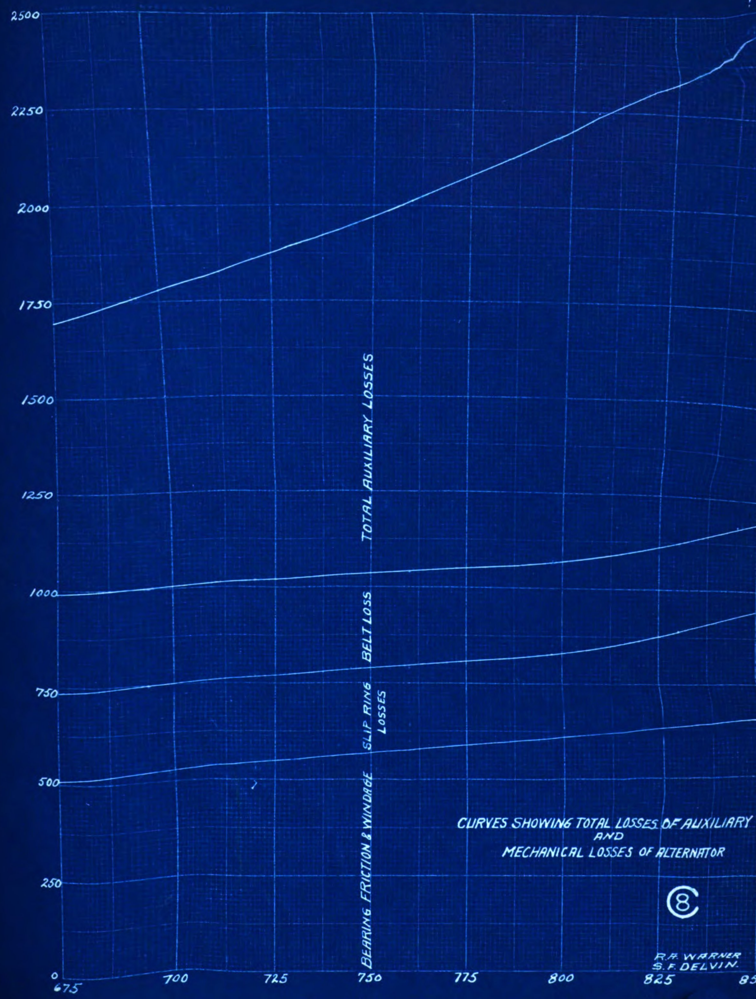
1300
1200
1100
1000
900
800
700
600
500
400
WATTS
i = 6.78
i = 5.79
i = 4.84
i = 3.88
i = 3.39
675
700
725
750
775
800
825
850
R. P. M.
CURVES OF CORE LOSSES
OF MOTOR AS
FUNCTION OF SPEED AND EXC.
CURRENT "i"
MOTOR DRIVEN ELECTRICALLY.
5
R. A. WARNER
S. F. DELVIN.

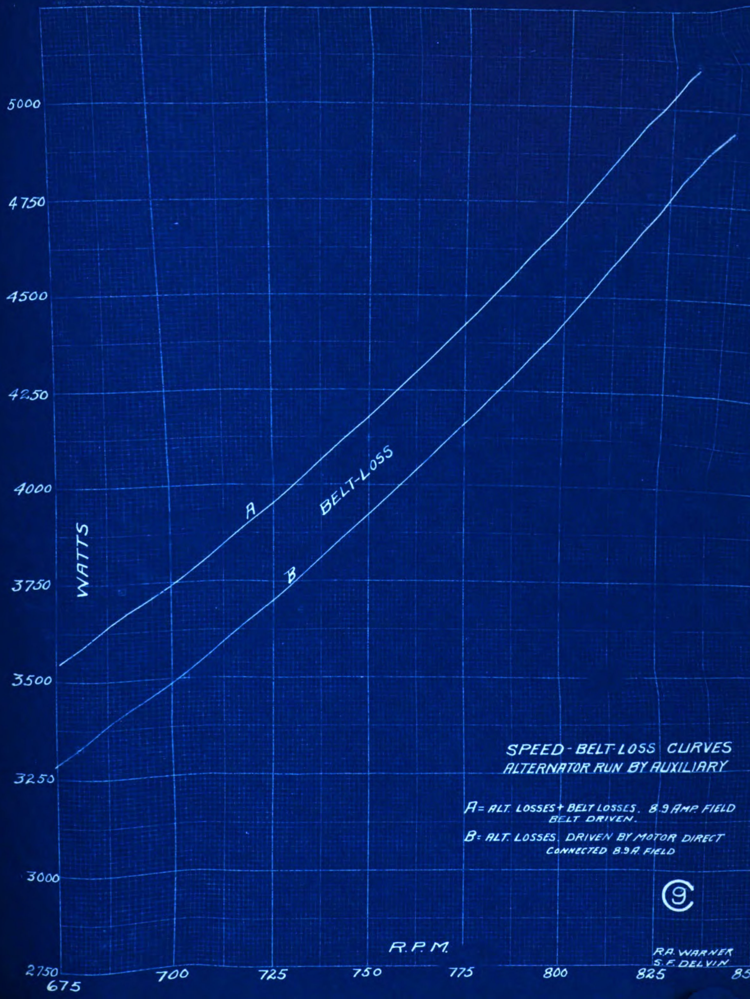


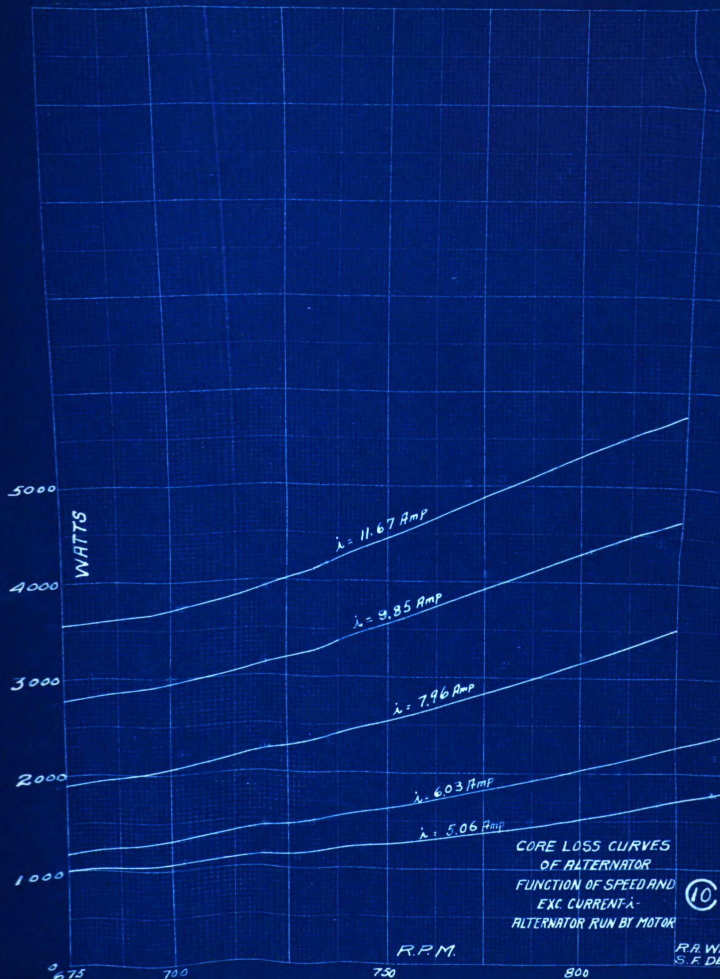
I_a^2R LOSS-INPUT CURVE
FOR
MOTOR APRIL 30, 1912.
WATTS
AMPERES INPUT
0
1000
2000
3000
4000
5000
50
100
200
300
400
R.A. WARNER
S.F. DELVIN
6



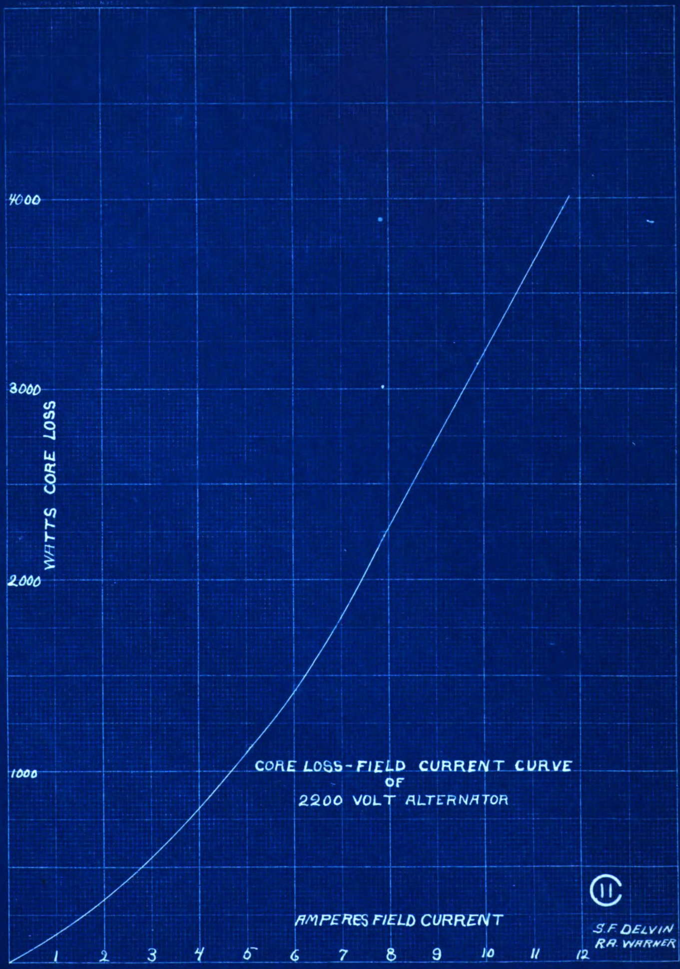
5000
4000
3000
2000
1000
A = $I^2R - I_f$ CURVE OF MOTOR
B = " " " " ALTERNATOR
WATTS I^2R LOSS
A
B
AMPERES FIELD
1 2 3 4 5 6 7 8 9 10 11 12 13
7
R.A. WARNER
S.F. DELVIN


2500
2250
2000
1750
1500
1250
1000
750
500
250
0
675
700
725
750
775
800
825
TOTAL AUXILIARY LOSSES
BELT LOSS
SLIP RING LOSSES
BEARING FRICTION & WINDAGE
CURVES SHOWING TOTAL LOSSES OF AUXILIARY AND MECHANICAL LOSSES OF ALTERNATOR
8
R.A. WARNER
S.F. DELVIN.

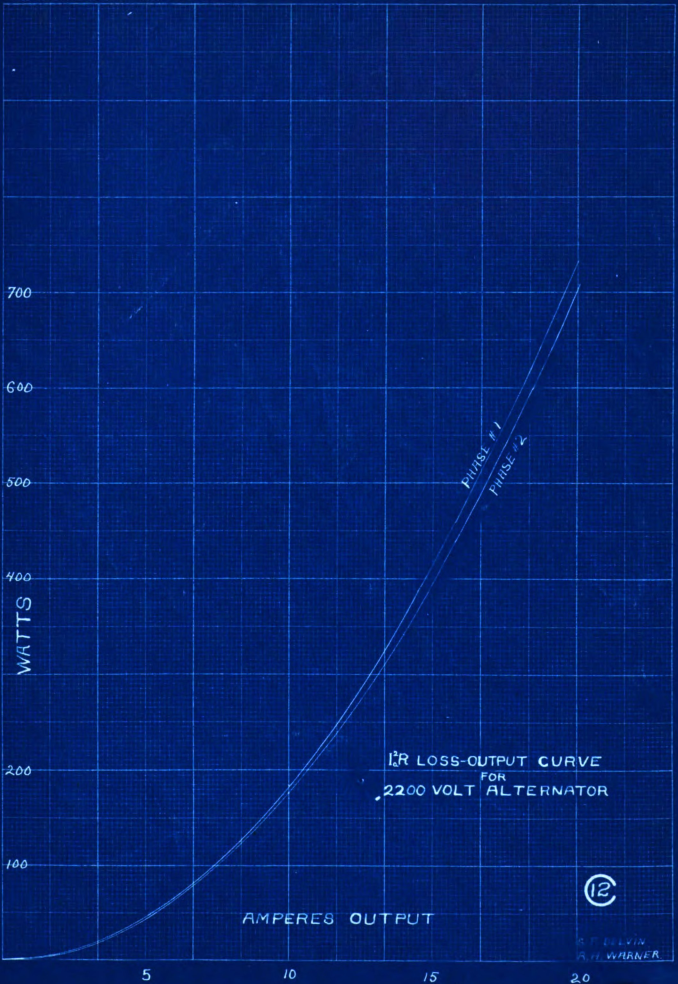

5000
4750
4500
4250
4000
3750
3500
3250
3000
2750
WATTS
A
B
BELT-LOSS
675
700
725
750
775
800
825
R.P.M.
SPEED-BELT-LOSS CURVES
ALTERNATOR RUN BY AUXILIARY
A= ALT. LOSSES + BELT LOSSES. 8.9 AMP. FIELD
BELT DRIVEN.
B= ALT. LOSSES. DRIVEN BY MOTOR DIRECT
CONNECTED 8.9 A. FIELD
9
R.A. WARNER
S.F. DELVIN

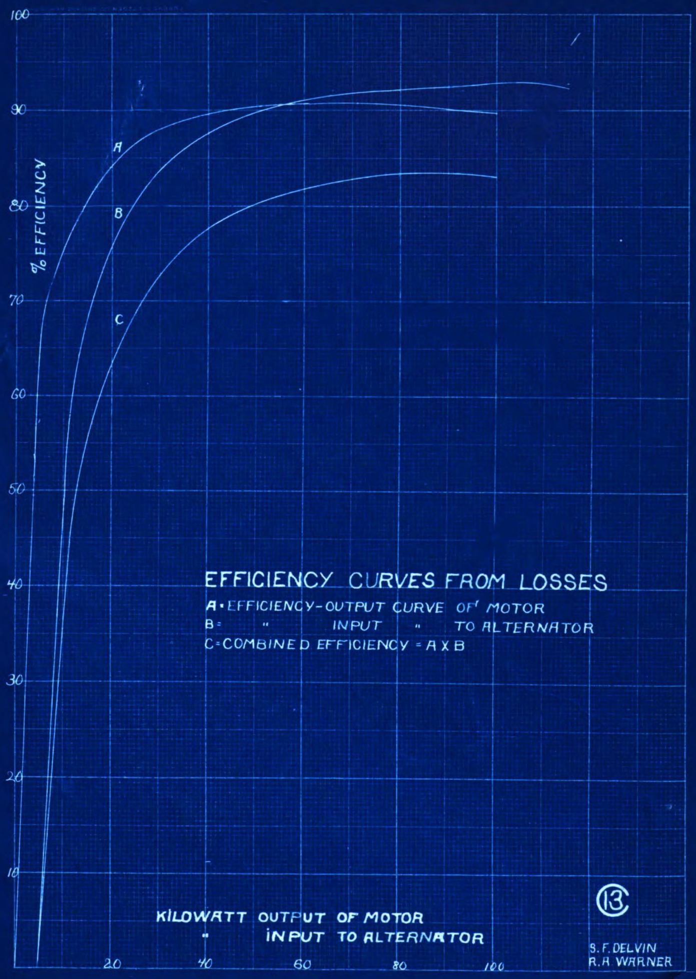


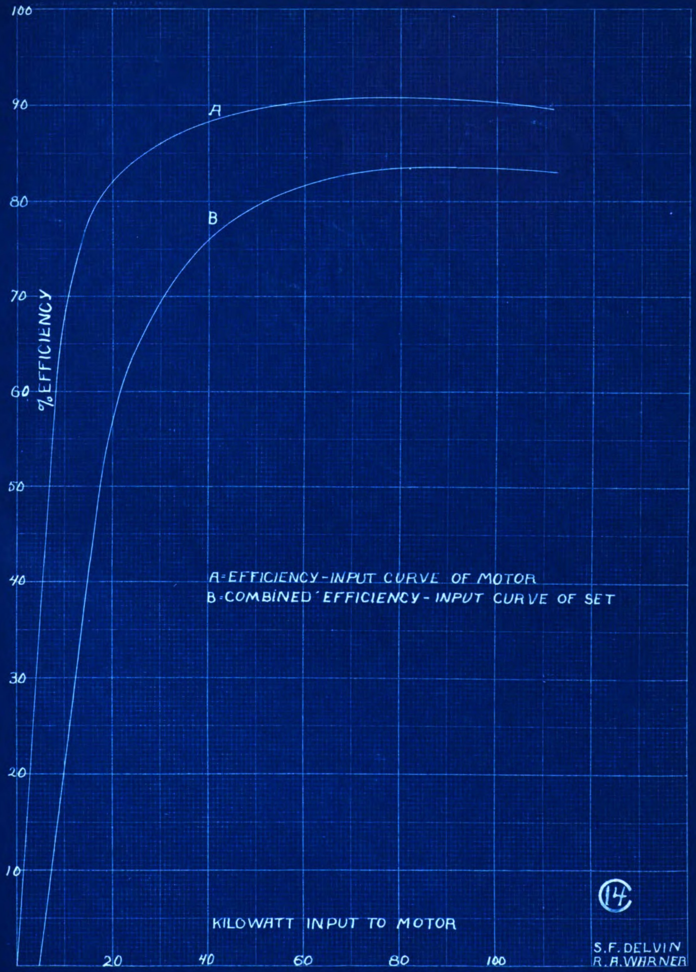
5000
4000
3000
2000
1000
0
WATTS
i = 11.67 Amp
i = 9.85 Amp
i = 7.96 Amp
i = 6.03 Amp
i = 5.06 Amp
CORE LOSS CURVES
OF ALTERNATOR
FUNCTION OF SPEED AND
EXC. CURRENT-i-
ALTERNATOR RUN BY MOTOR
10
R.P.M.
675
700
750
800

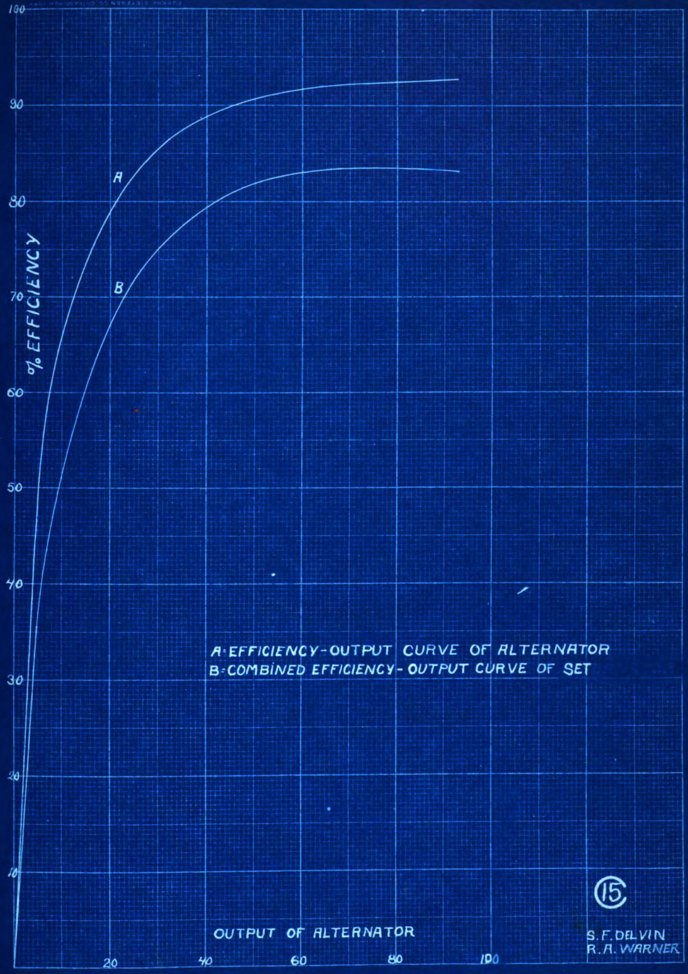


4000
3000
2000
1000
WATTS CORE LOSS
CORE LOSS-FIELD CURRENT CURVE
OF
2200 VOLT ALTERNATOR
AMPERES FIELD CURRENT
1
2
3
4
5
6
7
8
9
10
11
12
11
S.F. DELVIN
R.A. WARNER


700
600
500
400
WATTS
200
100
PHASE #1
PHASE #2
I_a^2R LOSS-OUTPUT CURVE
FOR
2200 VOLT ALTERNATOR
12
AMPERES OUTPUT
R. H. WARNER.
5
10
15
20


EFFICIENCY CURVES FROM LOSSES
A = EFFICIENCY-OUTPUT CURVE OF MOTOR
B = " INPUT " TO ALTERNATOR
C = COMBINED EFFICIENCY = A X B
% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
A
B
C
KILOWATT OUTPUT OF MOTOR
" INPUT TO ALTERNATOR
20
40
60
80
100
13
S. F. DELVIN
R. A. WARNER


100
90
80
70
60
50
40
30
20
10
% EFFICIENCY
A
B
A=EFFICIENCY-INPUT CURVE OF MOTOR
B=COMBINED EFFICIENCY-INPUT CURVE OF SET
(14)
KILOWATT INPUT TO MOTOR
20
40
60
80
100
S.F. DELVIN
R.A. WARNER


% EFFICIENCY
100
90
80
70
60
50
40
30
20
10
A
B
A=EFFICIENCY-OUTPUT CURVE OF ALTERNATOR
B=COMBINED EFFICIENCY-OUTPUT CURVE OF SET
15
OUTPUT OF ALTERNATOR
20
40
60
80
100
S. F. DELVIN
R. A. WARNER

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