THESIS

COMMERCIAL TESTS ON A THREE UNIT MOTOR GENERATOR SET

J. S. HARTT E. F. HOLSER
A. W. BARRON

1915

COMMERCIAL TESTS ON A

THREE UNIT MOTOR GENERATOR SET.

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE

By

J.S.Hartt E.F.Holser

A.W.Barron

Canidates for the Degree of

Bachelor of Science

June,1915.

DEDICATION

As a Mark of Appreciation for the Unfailing Courtesy

and Interest Shown to Each of Us

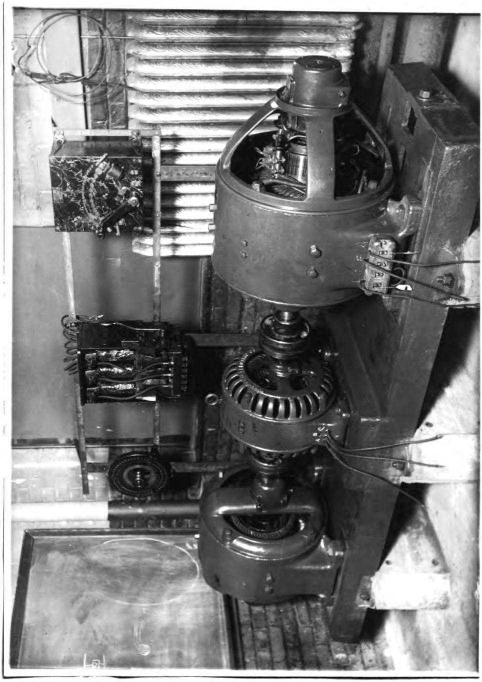
We

Respectfully Dedicate this Thesis

to

MERTON MAINE CORY E.E.

Teacher and Friend.



PREFACE

In accordance with the custom of this college the senior engineering students prepare a thesis during the last term of their course, as a partial fulfillment of the requirements for the degree of Batchelor of Science. The benefits to be derived in carrying out a thesis we believe to be many fold; it gives one an opportunity to outline and do something according to his own ideas and also to meet an engineering problem more nearly as it will be met in actual experience after leaving college.

After a careful investigation of past theses and present subjects available, we decided that many of the problems treated were somewhat beyond the capacity of the ordinary college senior and are capable of being solved only by men of more mature judgment and experience. If some of the solutions offered were to be actually tried out they would doubtless be found impracticable commercially and inconsistent with good engineering practice, which often depends as much upon experience as upon pure theory.

Our reasons for selecting the subject chosen were four fold; First, this is a phase of electrical work in which we were especially interested; Second, the electrical department was reasonably well equipped for carrying on the necessary work; third, we believed that the ~~expense~~ experience gained would be of practical value to us in future work and; Fourth, that previous laboratory experience, classroom work, and available information had qualified us for the work at hand.

It has not been our aim to see how many different tests we could carry out but rather to obtain the best possible results on those tests which we did run. Several of the tests were repeated when it seemed that the results obtained on the first trial were erroneous. In many instances, by retesting, we have been able to eliminate difficulties and sources of error which were encountered during the first run.

TABLE OF CONTENTS.

INTRODUCTION

The object of this thesis is to perform a series of tests upon a three unit motor generator set situated in the College Electircal Laboratory, in order to determine the performance and characteristics of the machines.

The unit comprises three general and distinct types of Electrical Apparatus, namely; A Direct Current Motor, an Induction Motor, and an Alternating Current Generator. The name plate data of the individual machines is as follows:-

(1) General Electric Direct Current Motor.
Shunt Motor Equipped with interpoles.
No. 325698 Volts 220 Amps. 38 H.P. 10.
Speed 700/1.00 4 Poles.
Equipped with a Cutler hammer Combination Starting Box and Speed Regulator.

(2) Western Electrical Squirrel Cage Induction Motor.
No. 39562 Phases 3 Cycles 60 H.P. 10.
Volts 220 Amps. 26 R.P.M. 1800.
The Stator is 4 Pole and delta connected, equipped with a Starting Compensator.

(3) Alternating Current Generator.
No. 163456 Form A K.W. 10 Cycles 60 Phases 1-2-3
Volts 220 Amps. 26 4 Pole R.P.M. 1800
Equipped with a Field Rheostat.

These machines are mounted on a cast iron base and connected together by means of flange couplings with a leather washer between to prevent binding and insure flexibility. The Induction Motor is rigidly bolted to the base in the center with the Direct Current Motor and Alternating Current Generator on the ends. The end machines are each fastened to a screw which is used to separate the machines for testing as single units.

Previous to actual testing we consulted several books on Electrical Testing written by men identified with that line of work. Next we outlined the tests to be performed and the methods to be followed in conducting the tests. In running the tests no attempt was made to perform them in any definite or predetermined order, the governing factor being the running of a test which required the least over-hauling of the machine from the previous test. The results were then worked up and recorded in the following order:-

Section I. Direct Current Motor Experiemts and Results.
Section II. Induction Motor " " "
Section III. Alternating Current Generator Experiments and Results.

References Used:-

The Principal References used during the preparation of this thesis were;

1. Commercial Electric Testing, by E. F. Collins.
2. Notes and Experiments, Direct Current, by H.M. Cory , E.E.
3. " " " , Alternating ", by H.M. Cory , E.E.
4. Experimental Electrical Engineering, by V. Karapetoff.
5. Alternating Current Machinery, by Sheldon & Mason.

Instruments Used

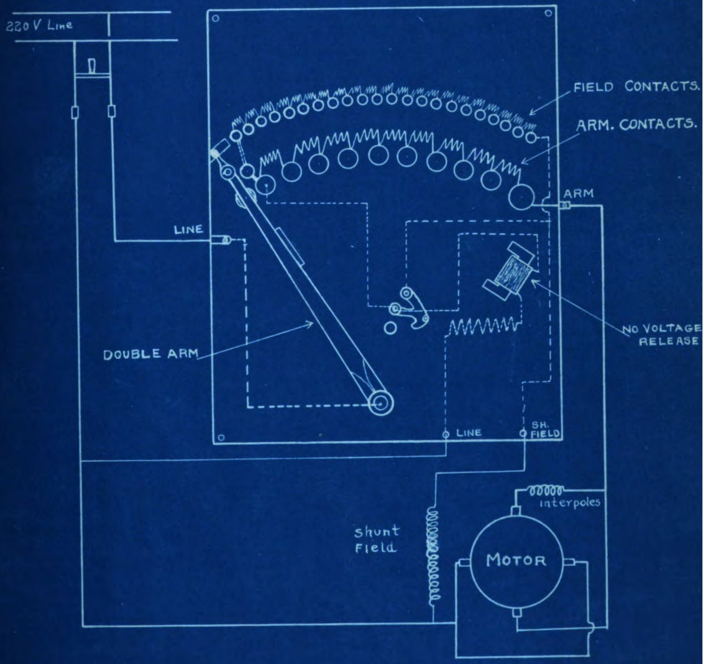
Make	Kind	Mfg. No.	Range	Thesis No.
Weston	D.C. Ammeter	616	0 - 50 Amps.	10
"	" " "	3562	0 -100 "	11
"	" " "	2193	0 - 15 "	12
Weston	D.C. Voltmeter	3414	0 -600 Volts	20
"	" " "	6792	0 -150 "	21
"	" " "	3562	0 -300 "	22
"	" " "	1690	0 -150 "	23
Weston	Wattmeters	207	0 - 3 K.W.	30
"	"	208	0 - 3 " "	31
Weston	A.C. Ammeter	8889	0 - 5 Amps.	110
"	" " "	6188	0 - 5 "	111
"	" " "	6177	0 - 5 "	112
"	" " "	8892	0 - 5 "	113
"	" " "	6978	0,- 2 "	114
Weston	A. C. Voltmeter	6297	0 - 500 Volts	120
"	" " "	4143	0 - 500 "	121
"	" " "	6322	0 - 500 "	122
"	" " "	4547	0 - 500 "	123
Weston	Current Transformer	330	25 - 5 Amps	130
"	" "	325	25 - 5 "	131
"	" "	351	50 - 5 "	132
"	" "	349	50 - 5 "	133
"	" "	124	100 - 5 "	134
Veeder	Tachometer		300- 2000 R.P.M.	140

SECTION ONE

DIRECT CURRENT MOTOR EXPERIMENTS AND RESULTS.

THE COMPOUND D.C. MOTOR STARTER AND SPEED REGULATOR

[CUTLER-HAMMER]



THESIS - H.H. and B.
1915

COLD RESISTANCES OF DIRECT CURRENT MOTOR.

The resistances of the different electrical circuits were measured by the drop of potential method and the values determined. That is by applying Ohm's Law, viz; I= E/R. The temperature of the windings was 20° Centigrade.

TEST DATA
Shunt Field Resistance.

	E	E (corr)	I	I (corr)	R.
Inst. No.	21		11		
Constant	1		0.01		
	64.2	63.2	27	.257	246
	72.1	70.9	30	.286	247.9
	86	84.3	36	.343	246
	95.9	94.1	40	.381	247
	105.5	103.5	44	.419	247
	110	107.8	46	.439	247.5
	120	117.8	50	.478	24[illegible]
	130.9	128.4	54.2	.522	248
	134.8	132.4	56	.539	248
	139.4	137.1	58	.559	247.9
				Average	247.33

Interpole Resistance

	E	E (corr)	I	I (corr)	R.
Inst. No.	22		10		
Constant	.02		1		
	60.6	1.202	20.9	21.1	.057
	73	1.46	25.5	25.6	.057
	76.8	1.536	27	27.05	.0568
	82	1.64	28.8	28.8	.057
	86	1.72	30.5	30.5	.0572
				Average	.057

Terminal Resistance.

	E	E (corr)	I	I (corr)	R.
Inst. No.	21		10		
Constant	.1		1		
	93.1	9.13	23.5	23.6	.387
	109	10.69	27.7	27.8	.3865
	104	10.2	26.5	26.6	.383
	111	10.9	28.5	28.55	.382
	107	10.49	27.5	27.55	.381
	113	11.08	29	29	.382
	120.5	11.83	31	31	.382
	126.2	12.39	32.5	32.5	.381
				Average	.383

Actual Armature Resistance, measured between the brushes.

	E	E (corr)	I	I (corr)	R
Inst. No.	21		10		
Constant	.1		1		
	68	6.69	24	24.1	.278
	72	7.08	25.3	25.4	.279
	77	7.56	27.1	27.15	.279
	90	8.82	31.6	31.6	.279
	93	9.12	32.7	32.7	.279
	94	9.22	33	33	.279
	107	10.5	37.75	37.75	.2783
				Average	.2788

DIRECT CURRENT MOTOR SATURATION TEST.

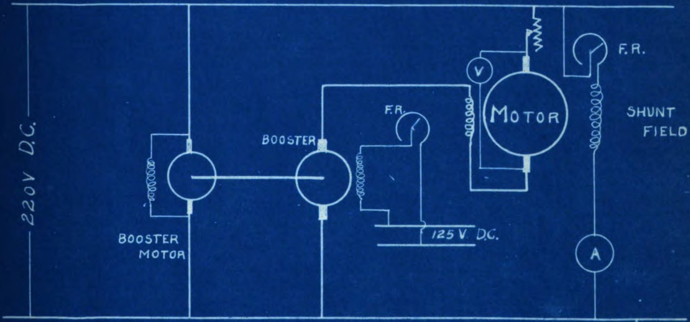
The variable voltage for running the machine was obtained by placing the booster and an iron wire rheostat in series with the 220 volt line. A rheostat was put in the shunt field circuit to vary current, the motor running free. The voltage impressed on the armature was reduced to about 50 percent normal value, and the field current made very low giving the machine a speed of 1200 R.P.M. The voltage was then raised by steps to 15 percent above normal, at the same time increasing the field current to hold the speed constant. Readings were taken at each step of speed, field E and I, and armature E and I.

A curve was then plotted with field amperes as abscissae and armature volts as ordinates.

MOTOR SATURATION TEST.

D.C. MOTOR

CONNECTION DIAGRAM.



APPARATUS USED

NO	KIND	RANGE
1	WESTON D.C. AMMETER	0 - 10 AMPS
1	" " VOLTMETER	0 - 600 VOLTS

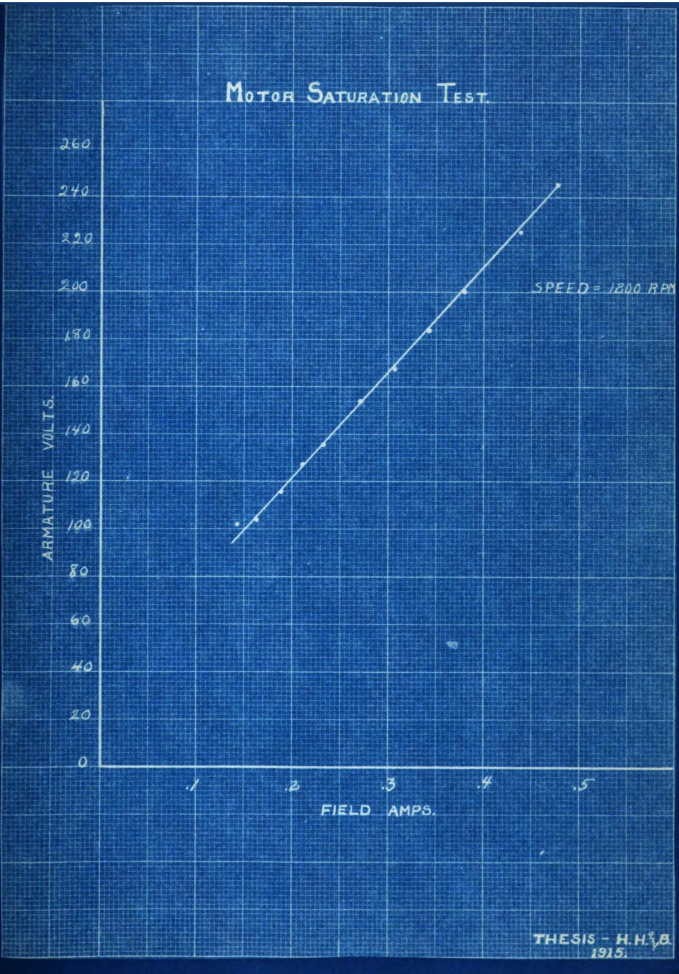
THESIS - H.H.&B.
1915

TEST DATA FOR MOTOR SATURATION TEST.

	Field		Armature		
	E	I	E	I	R.P.M.
Inst. No.	22	11	20	12	140
Constant	2	.01	1	1	1
	19.5	15	105	9.7	1200
	22	17.2	107	6.9	"
	26	20	118	6.12	"
	29.5	22.2	129	6.23	"
	32	24.5	137	5.87	"
	37	28.5	157	5.9	"
	42.2	32.3	170	5.0	"
	47	36	187	5.1	"
	52	40	205	4.35	"
	60	46	230	4.1	"
	66	50	250	3.75	"
	66	50	258	-	"

Corrected data

38.2	.143	102	9.68	1200
42.7	.164	104	6.9	"
49.8	.19	115.6	6.1	"
56.2	.211	127	6.21	"
60.9	.233	134.9	5.65	"
70.2	.271	154	5.78	"
80.0	.307	167	5.0	"
88.8	.343	183.6	5.1	"
98.1	.381	200	4.35	"
112.6	.439	225	4.1	"
114.5	.478	245	3.75	"
114.5	.478	253	--	"


MOTOR SATURATION TEST.
ARMATURE VOLTS.
260
240
220
200
180
160
140
120
100
80
60
40
20
0
.1
.2
.3
.4
.5
FIELD AMPS.
SPEED = 1200 RPM
THESIS - H.H.&B.
1915.

DIRECT CURRENT GENERATOR SATURATION TEST.

The direct current machine was driven as a generator by means of an auxiliary D.C. motor at a constant speed of 1000 R.P.M. Several rheostats were placed in the field and the current was gradually raised from 0 to 200 percent normal current, taking readings of armature E and field I. To show the effect of hysteresis the field current was then reduced to 0 in nine steps. Acurve was plotted with field I as abscissa and armature E as ordinates.

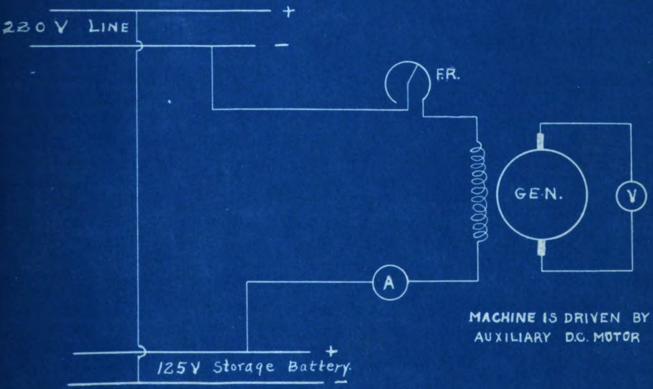
TEST DATA

	Arm. E	Arm. E (corr)	Field I	Field I (corr)	R.P.M.
Inst. No.	21		11		
Constant	1		.01		
	10.1	10.1	19.5	.185	1000
	86.2	84.5	20.3	.193	"
	91	89.2	21.5	.205	"
	95.4	93.5	22.5	.214	"
	101	99.1	24	.228	"
	105.2	103.2	25	.238	"
	110.4	108.2	26	.248	"
	116.4	114.2	27.5	.262	"
	121.9	119.7	29	.276	"
	128	125.6	30.3	.288	"
	135	132.6	32	.305	"
	140.8	138.6	33.7	.321	"
	148	145.6	35.5	.338	"
Inst. No.	20				
Constant	1		.		
	155.5	152.5	37.2	.355	1000
	164	160.5	39	.371	"
	170	166.2	40.5	.386	"
	177.5	173.5	42.7	.407	"
	184.5	180.1	44.2	.422	"
	192	187	46.5	.444	"
	200	195	48	.459	"
	207.5	202.5	50	.478	"
	213	208	52.5	.503	"
	222	217	54.2	.520	"

	Arm. E	Arm. E (corr)	Field I	Field I (corr)	R.P.M.
Inst. No.	20		11		
Constant	1		.01		
	229	224	56	.539	1000
	241.5	236.5	59.5	.575	"
	250	245	62	.6	"
	255	250	64	.62	"
	262	256.5	66	.64	"
	274	268	70	.68	"
	279	273	72	.70	"
	285	278.8	74	.72	"
	290	283.6	76	.74	"
	295	288.5	78.5	.765	"
	304	297.5	81.3	.793	"
	311	304.4	85.5	.835	"
	317	310.2	88	.86	"
	328	321	92	.90"	"
	333	326	94.5	.925	"
	340	333	97	.95	"
Constant			0.1		
	346.5	339.5	9.5	.95	1000
	369	362	10.5	1.05	"
	382	375	11.5	1.15	"
	387	379.5	11.8	1.18	"
Constant			.01		
	300	293.5	73	.71	1000
	272	266	64	.62	"
	236	231	53.5	.513	"
	218	213	48	.459	"
	187	182	41	.39	"
	160	156.5	34.5	.328	"
	135	132	28	.266	"
	113	110	23	.219	"
	95	92	18.5	.176	"
	10.5	10.5	0	0	

GENERATOR SATURATION TEST ON D.C. MOTOR

CONNECTION DIAGRAM

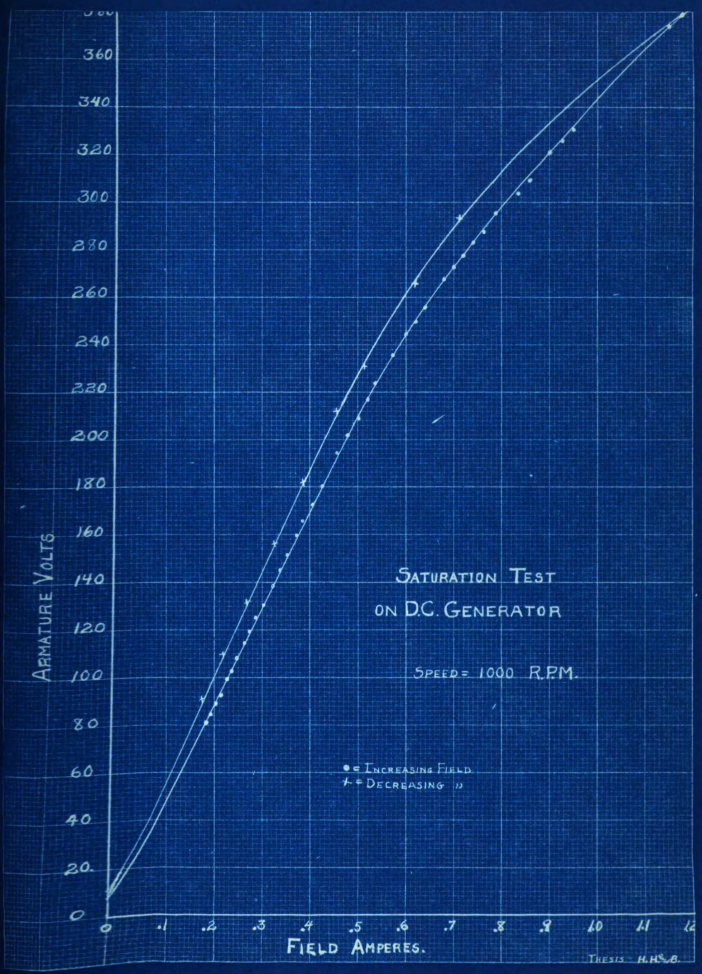


MACHINE IS DRIVEN BY AN AUXILIARY D.C. MOTOR

APPARATUS

NO	KIND	RANGE
1	WESTON D.C. AMMETER	0 – 10 AMPS.
1	" " VOLTMETER	0 – 300 VOLTS.

THESIS – H.-H. & B.
1915.


Saturation Test
on D.C. Generator
Speed = 1000 R.P.M.
• = Increasing Field
+ = Decreasing "
Armature Volts
Field Amperes.
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
Thesis - H.H. & B.

BRAKE TESTS ON DIRECT CURRENT MOTOR.

The motor was connected in series with the booster set and run for about one and one-half hours at nearly full load to warm up the windings and approach, as nearly as possible, normal running conditions.

The load was then thrown off and the speed made as nearly 800 R.P.M. as rheostat on starting box would permit; holding the line voltage constant at exactly 220 volts; readings were taken of line volts, ampers input, R.P.M., and weight in pounds.

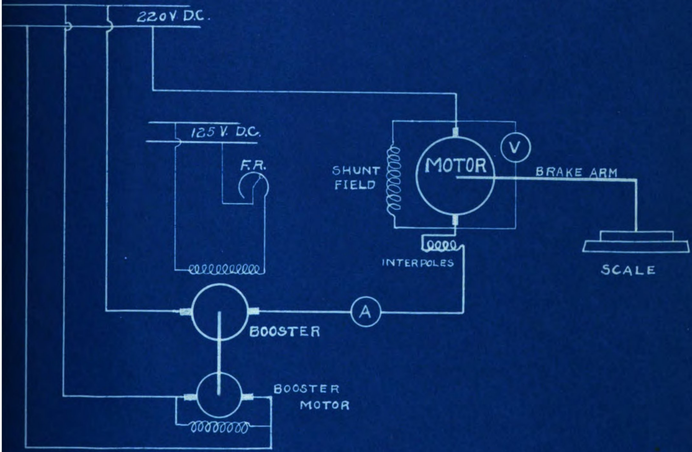
The weight was increased in 1 pound increments from 0 to about 125% overload. The test was repeated at 1300 R.P.M. and 1800 R.P.M. Curves

Curves were then plotted for each speed with horse power output as abscissae and Amps. input, efficiency, R.P.M., and torque as ordinates.

From these curves and from the action of the motor it is seen that the operation of the machine is better and it has a greater efficiency at 800 speed.

BRAKE TEST ON D.C. MOTOR.

CONNECTION DIAGRAM.



APPARATUS USED

NO	KIND	RANGE
1	WESTON D.C. VOLTMETER	0 - 300 VOLTS
1	" D.C. AMMETER	0 - 50 AMPS.
1	SET SCALES AND PRONY BRAKE	
1	BOOSTER SET	

THESIS - H.H. and B.

BRAKE TEST ON DIRECT CURRENT MOTOR (Crigonal)

	E.	I.	R.P.M.	Load lbs.
Inst.No.	20	10	140	
Const.	1	1	1	
	225	3.25	795	0
	"	6.7	793	5
	"	8.05	790	6
	"	9.45	787	7
	"	10.35	785	8
	"	11.8	784	9
	"	12.9	783	10
	"	14.0	780	11
	"	15.6	778	12
	"	16.55	775	13
	"	18.1	774	14
	"	18.85	760	15
	"	20.55	758	16
	"	22.0	762	17
	"	23.1	765	18
	"	24.4	760	19
	"	25.6	755	20
	"	27.25	754	21
	"	28.1	750	22
	"	29.5	752	23
	"	31.2	750	24
	"	31.8	742	25
	"	33.1	740	26
	"	35	735	27
	"	35.6	730	28
	"	37.0	728	29
	"	38.0	730	30
	"	39.5	728	31
	"	41.3	730	32
	"	42.0	720	33
	"	43.5	725	34
	"	44.6	717	35
	"	45.6	717	36
	"	48.0	725	37
	"	48.0	702	38
	"	48.6	710	38
	"			
Inst.No.		11		
Const.		1		
	"	51.0	723	39
	"	52.0	710	40
	"	54.0	718	41
	"	56.0	720	42
	"	57.0	702	43

BRAKE TEST ON DIRECT CURRENT MOTOR. (Corrected Data).

Speed 800 R.P.M.

E	I	R.P.M.	Net Brake Load	H.P. Input	H.P. Output	Torque	% Eff.
220	3.45	779	0	1.02	0	0	0
"	6.85	777	2.75	2.02	1.02	6.88	50.4
"	8.15	774	3.75	2.43	1.38	9.38	56.8
"	9.55	770	4.75	2.82	1.74	11.88	61.8
"	10.45	768	5.75	3.08	2.1	14.38	68.2
"	11.9	767	6.75	3.51	2.46	16.88	70
"	13	766	7.75	3.84	2.83	19.38	73.8
"	14.5	762	8.75	4.28	3.18	21.88	74.3
"	15.7	761	9.75	4.63	3.53	24.38	76.2
"	16.65	758	10.75	4.91	3.88	26.88	79
"	18.25	757	11.75	5.38	4.24	29.38	79
"	19	742	12.75	5.6	4.5	31.88	80.4
"	20.75	739	13.75	6.12	4.82	34.38	79
"	22.2	744	14.75	6.55	5.23	36.88	79.8
"	23.25	747	15.75	6.86	5.6	39.38	81.5
"	24.5	742	16.75	7.22	5.92	41.88	82
"	25.7	736	17.75	7.58	6.23	44.38	82.2
"	27.3	735	18.75	8.05	6.56	46.88	81.6
"	28.1	732	19.75	8.28	6.86	49.38	82.8
v"	29.5	733	20.75	8.7	7.24	51.88	83.2
"	31.2	731	21.75	9.2	7.57	54.38	82.4
"	31.8	722	22.75	9.375	7.82	56.88	83.4
"	33.1	720	23.75	9.76	8.14	59.38	83.4
"	35	715	24.75	10.31	8.425	61.88	81.5
"	35.6	710	25.75	10.5	8.7	64.38	82.8
"	37	708	26.75	10.9	9.02	66.8	82.7
"	38	710	27.75	11.2	9.24	69.38	82.5
"	39.5	708	28.75	11.65	9.69	71.88	83.
"	41.3	710	29.75	12.19	10.01	74.38	82.5
"	42	699	30.75	12.4	10.21	76.88	82.4
"	43.5	705	31.75	12.82	10.66	79.38	83.1
"	44.6	696	32.75	13.15	10.83	81.88	82.4
"	45.6	696	33.75	13.45	11.19	84.38	83.1
"	48.1	705	34.75	14.2	11,65	86.88	82.1
"	48.1	680	35.75	14.2	11.58	89.38	81.5
"	48.7	689	35.75	14.38	11.71	89.38	81.5
"	50.9	702	36.75	15	12.29	91.88	81.8
"	51.9	689	37.75	15.3	12.39	94.38	80.8
"	53.39	697	38.75	15.9	12.85	96.88	80.6
"	55.9	699	39.75	16.48	13.22	99.38	80.3
"	56.9	680	40.75	16.79	13.2	101.88	78.6

BRAKE TEST ON DIRECT CURRENT MOTOR. (Original)

	E	I	R.P.M.	Load lbs.
Inst. No.	20	10	140	
Constant	1	1	1	
	225	4.1	1324	0
	"	9.5	1305	5
	"	12	1290	6
	"	14.5	1270	7
	"	16.5	1273	8
	"	18.75	1270	9
	"	21.25	1260	10
	"	23	1254	11
	"	25	1240	12
	"	27.5	1235	13
	"	29.25	1222	14
	"	31.25	1205	15
	"	33.5	1190	16
	"	35.5	1170	17
	"	36.7	1162	18
	"	39.5	1150	19
	"	41.5	1147	20
	"	44.3	1150	21
	"	45.5	1130	22
	"	47	1110	23
	"	49.5	1080	24
	"	50	1055	25
	"	53	1055	26
	"	57	1060	27
	"	58	1045	28
	"	61	1040	29
	"	61	1025	30
	"	64	1020	31

BRAKE TEST ON DIRECT CURRENT MOTOR. (Corrected data).

Medium Speed.

E	I	R.P.M.	Net Brake Load	H.P. Input	H.P. Output	Torque	% Eff.
220	4.3	1324	0	1.27	0	0	0
"	9.6	1305	2.75	2.83	1.71	6.88	60.4
"	12.1	1290	3.75	3.57	2.3	9.34	64.5
"	14.6	1270	4.75	4.3	2.87	11.88	66.9
"	16.6	1273	5.75	4.9	3.51	14.38	71.5
"	18.9	1270	6.75	5.57	4.08	16.88	73.2
"	21.45	1260	7.75	6.32	4.64	19.38	73.5
"	23.15	1254	8.75	6.81	5.23	21.88	76.7
"	25.1	1240	9.75	7.4	5.76	24.38	77.8
"	27.55	1235	10.75	8.11	6.31	26.88	77.9
"	29.25	1222	11.75	8.62	6.85	29.38	79.4
"	31.25	1205	12.75	9.22	7.31	31.88	79.5
"	33.5	1190	13.75	9.88	7.79	34.38	79
"	36.7	1161	15.75	10.81	8.7	39.38	80.4
"	39.5	1149	16.75	11.66	9.16	41.88	78.6
"	41.5	1146	17.75	12.25	9.67	44.38	78.8
"	44.3	1149	18.75	13.08	11.24	46.88	78.4
"	45.5	1129	19.75	13.41	10.6	49.38	79
"	47.05	1108	20.75	13.9	10.91	51.88	78.5
"	49.7	1077	21.75	14.68	11.13	54.38	76
"	50.2	1051	22.75	14.8	11.39	56.88	76.9
"	52.9	1051	23.75	15.6	11.9	59.38	76.3
"	56.9	1056	24.75	16.78	12.42	61.88	74.2
"	57.9	1041	25.75	17.1	12.77	64.38	74.5
"	60.9	1036	26.75	17.97	13.18	66.88	73.3
"	63.9	1015	28.75	18.85	13.9	71.88	73.6

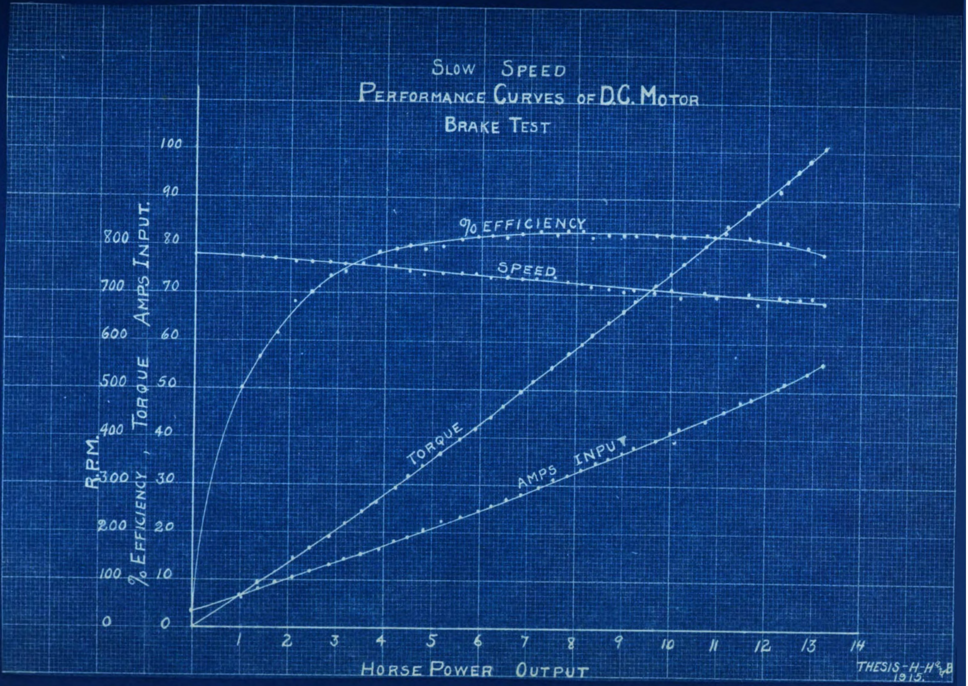
BRAKE TEST ON DIRECT CURRENT MOTOR (Origonal)

	E.	I.	R.P.M.	Load lbs.
Inst.No.	20	10	140	
Const.	1	1	1	
	225	5.4	1827	0
	"	13.5	1779	5
	"	16.5	1745	6
	"	19.0	1730	7
	"	22.5	1660	8
	"	24.5	1675	9
	"	27.0	1615	10
	"	29.5	1600	11
	"	31.5	1525	12
	"	34.5	1490	13
	"	36.5	1450	14
	"	37.5	1450	15
	"	38.5	1390	16
	"	40.5	1340	17
	"	42.5	1320	18
	"	45.5	1328	19
	"	49.0	1370	20
	"	54.0	1340	21
	"	58.0	1325	22
	"	60.0	1240	23
	"	59.0	1270	23
	"	62.0	1235	24
	"	62.5	1220	25

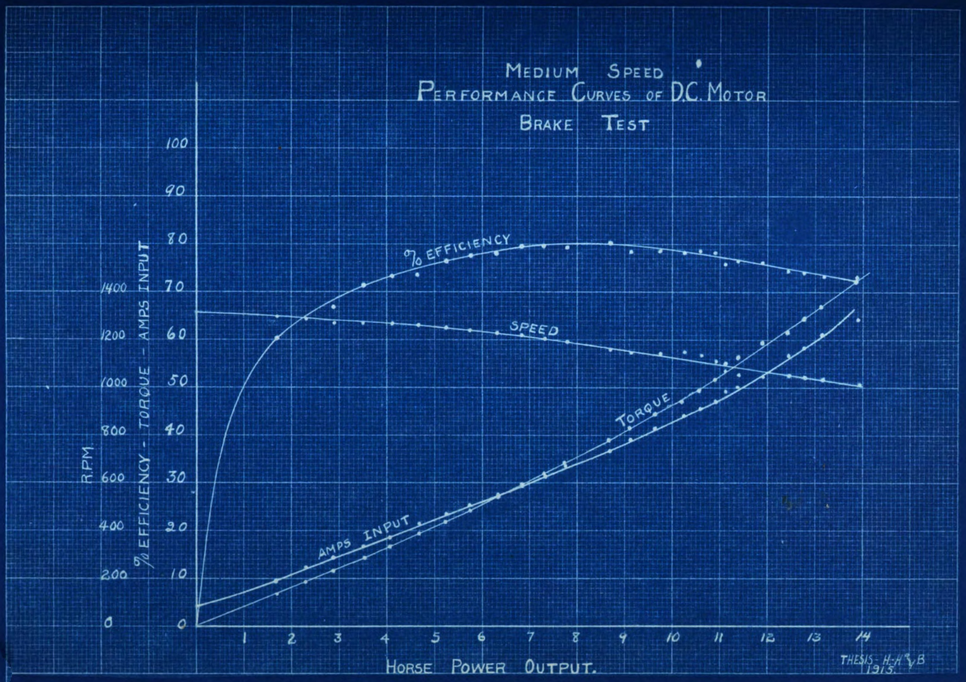
BRAKE TEST ON DIRECT CURRENT MOTOR. (Corrected Data).

Speed 1800 R.P.M.

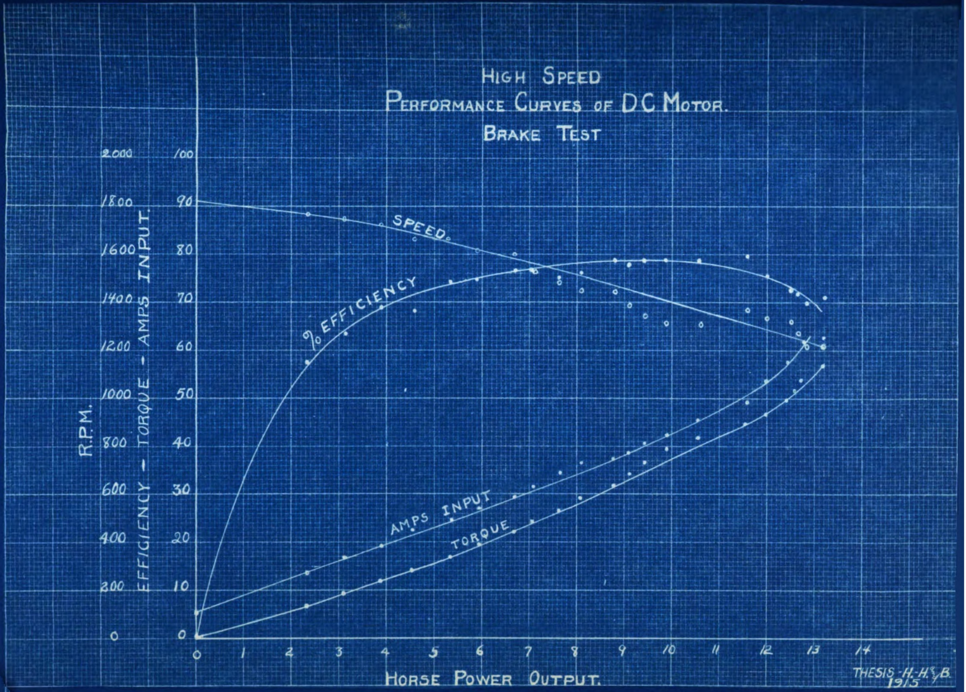
E	I	R.P.M.	Net Brake Load	H.P. Input	H.P. Output	Torque	% Eff.
220	5.6	1827	0	1.65	0	0	0
"	13.6	1778	2.75	4.01	2.32	6.88	57.9
"	16.6	1745	3.75	4.9	3.11	9.38	63.5
"	19.2	1730	4.75	5.66	3.9	11.88	69
"	22.65	1660	5.75	6.67	4.55	14.38	68.2
"	24.6	1675	6.75	7.26	5.39	16.88	74.5
"	27.05	1615	7.75	7.97	5.96	19.38	74.7
"	29.5	1600	8.75	8.7	6.66	21.88	76.5
"	31.5	1525	9.75	9.29	7.07	24.38	76.3
"	34.5	1490	10.75	10.17	7.64	26.88	75
"	36.5	1450	11.75	10.77	8.1	29.38	75.2
"	37.5	1450	12.75	11.05	8.81	31.88	79.7
"	38.5	1390	13.75	11.62	9.1	34.38	78.1
"	40.5	1340	14.75	11.94	9.41	36.88	78.7
"	42.5	1320	15.75	13.52	9.9	39.38	78.9
"	45.55	1328	16.75	13.4	10.59	41.88	79
"	49.15	1370	17.75	14.5	11.6	44.38	80
"	53.9	1340	18.75	15.9	11.97	46.88	75.3
"	57.9	1325	19.75	17.1	12.45	49.38	72.8
"	58.9	1270	20.75	17.39	12.52	51.88	72.2
"	61.9	1235	21.75	18.29	12.76	54.38	69.9
"	62.4	1220	22.75	18.41	13.2	56.88	71.6



SLOW SPEED
PERFORMANCE CURVES OF D.C. MOTOR
BRAKE TEST
% EFFICIENCY
SPEED
TORQUE
AMPS INPUT
R.P.M.
% EFFICIENCY , TORQUE AMPS INPUT.
0
100
200
300
400
500
600
700
800
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
HORSE POWER OUTPUT
THESIS-H-H & B
1915.



MEDIUM SPEED
PERFORMANCE CURVES OF D.C. MOTOR
BRAKE TEST
% EFFICIENCY
SPEED
TORQUE
AMPS INPUT
R.P.M.
% EFFICIENCY - TORQUE - AMPS INPUT
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
HORSE POWER OUTPUT.
THESIS - H-H & B
1915.


High Speed
Performance Curves of DC Motor.
Brake Test
SPEED
% EFFICIENCY
AMPS INPUT
TORQUE
R.P.M.
EFFICIENCY - TORQUE - AMPS INPUT.
2000
1800
1600
1400
1200
1000
800
600
400
200
0
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Horse Power Output.
THESIS - H.-H. & B.
1915

MOTOR REGULATION.

From data obtained from brake test we figured the speed regulation of the diredt current motor by means of the following formula,

$$\text{speed regulation} = \frac{\text{no load speed} - \text{full load speed}}{\text{full load speed}}$$

From the data, it is apparent that the machine gives the best regulation at 800 R.P.M.

Regulation data

$$\frac{779 - 710}{710} = \frac{69}{710} = 9.72\%$$

$$\frac{1324 - 1123}{1123} = \frac{201}{1123} = 17.87\%$$

$$\frac{1827 - 1400}{1400} = \frac{427}{1400} = 30.45\%$$

DIRECT CURRENT GENERATOR REGULATION.

We tried to get a "Saw Toothed" regulation curve by running the direct current machine as a shunt generator. With rheostats in the field circuit adjust the field current to give 220 volts at no load, then put on one-fourth load current, note terminal voltage. Then the field current and load are adjusted to give 220 volts at one-fourth load, and one-half load was thrown on, repeating this operation until the machine was carrying full load then open the field switch and determine the rise in voltage. From this data the curve can be plotted between armature volts and amperes load showing the voltage regulation.

When we attempted to perform this test we found we found that from 0 to ¼ load and at 1485 R.P.M., the voltage would drop from 220 to 50 volts, then after raising the voltage to 220 we found that the machine would carry only a little over ¼ load before the voltage would drop to 0, also, when the load was thrown off the voltage would rise to about 1000 volts and flash over the commutator. At higher speeds the generator would not carry ¼ load. Not being able to get a low enough frequency to run the induction motor below 1450 R.P.M. as a driving motor, we had to abandon the test.

From the above results it is evident that the direct current machine was built as a low speed motor.

D.C. BAR-TO-BAR VOLTAGE TEST.

The motor is so designed that it has four sets of double brushes around the commutator. One brush from each set was raised and a band of fish paper about 2 inches wide was fastened around the commutator by means of strings tied to the brush holders. The fish paper had holes drilled in it a distance apart equal to the width of one commutator bar, and the holes extending over more than 360 electricl degrees, the first hole placed about midway between two brushes. Then by taking two soft lead pencils attached to the voltmeter leads, the voltage between the first hole and each succeeding one was measured, the machine running under the following conditions;- (a) compensating winding in, induction motor and A. C. generator running free; (b) compensating winding in, A. C. generator loaded; (c) same as (b) with compensating winding cut out.

Then by plotting voltage against electrical degrees we have the wave form. The number of commutator bars being expressed in electrical degrees, that is

1 commutator bar $= 720/97 = 7.42$ electrical degrees

The curves show that the neutral point shifts for different loads. This is due to the fact that at no load there is greater fringing because at full load there is less local field due to greater armature current which neutralizes some of the lines. Or in other words this is due to armature reaction.

D.C. BAR-TO-BAR VOLTAGE TEST DATA.

Compensating winding in, Induction Motor and A. C. generator running free.

	Bar	E	E (corr)	Armature E	Armature I
Inst. No.		21		22	10
Constant		1		2	1
	1	13	13	114	3
	2	25	24.8	"	"
	3	36.3	35.6	"	"
	4	52	51	"	"
	5	60.5	59.5	"	"
	6	71.	69.8	"	"
	7	87	85.2	"	"
	8	96	94.2	"	"
	9	103	101	"	"
	10	102.5	101.5	"	"
	11	103	101	"	"
	12	103	101	"	"
	13	101	99.1	"	"
	14	100	98.1	"	"
	15	99	97.1	"	"
	16	98.5	96.6	"	"
	17	92	90.2	"	"
	18	84	82.4	"	"
	19	75	73.7	"	"
	20	63	62	"	"
	21	49	48	"	"
	22	36	35.3	"	"
	23	21	20.8	"	"
	24	9.5	9.5	"	"
	25	- 6	-6	"	"
	26	-18	-17.9	"	"
	27	-32	-31.5	"	"
	28	-42.5	-41.5	"	"
	29	-57	-56	"	"
	30	-69	-68	"	"
	31	-80	-78.4	"	"
	32	-90	-88.2	"	"
	33	-99.5	-97.6	"	"
	34	-103	-101	"	"
	35	-103.5	-101.5	"	"
	36	-105	-103	"	"
	37	-104	-102	"	"
	38	-103.5	-101.5	"	"
	39.	-101	- 99.1	"	"
	40	-100	-98.1	"	"
	41	-99	- 97.1	"	"
	42	-93	-91.2	"	"
	43	-83	-81.4	"	"
	44	-71	-69.8	"	"
	45	-60	-59	"	"
	46	-47	-46	"	"
	47	-33.5	-32.9	"	"

Bar	E	E (corr)	Armature E	Armature I
48	-20	-19.8	114	3
49	-7	-7	"	"
50	6	6	"	"
51	19.	18.8	"	"
52	30	29.5	"	"
53	45	44	"	"

Compensating winding in, A. C. Generator loaded

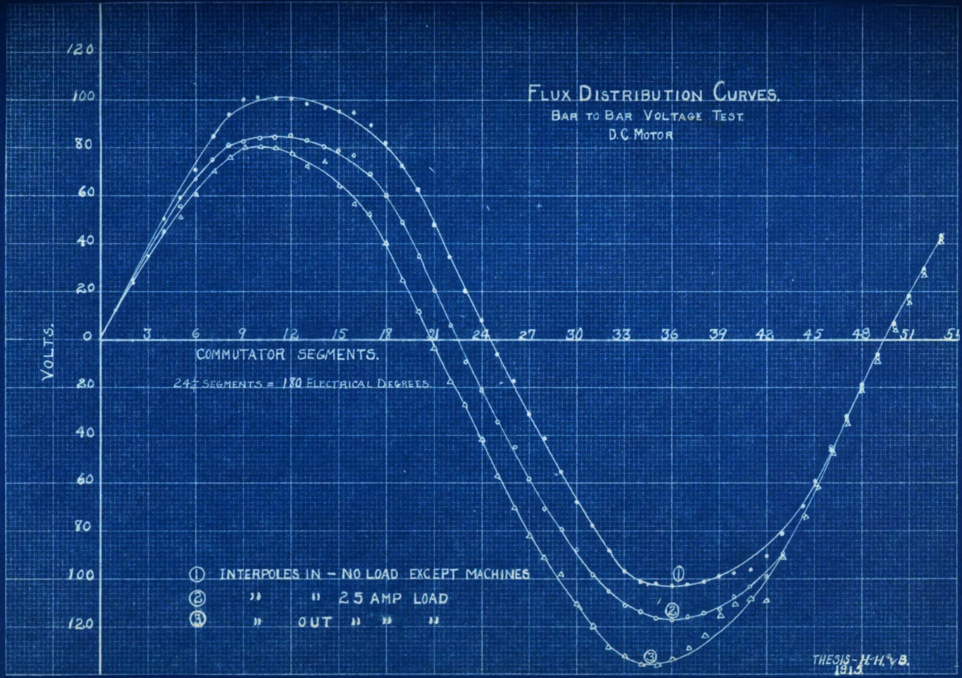
	Bar	E	E (corr)	Armature E	Armature I
Inst. No.		21		22	10
Constant		1		2	1
	1	12.5	12.5	114	25
	2	24	23.7	"	"
	3	36	35.3	"	"
	4	46.5	45.5	"	"
	5	57	56	"	"
	6	68	67	"	"
	7	76	74.6	"	"
	8	82	80.4	"	"
	9	84	82.4	"	"
	10	86	84.3	"	"
	11	86	84.3	"	"
	12	87.5	85.8	"	"
	13	85	83.3	"	"
	14	82	80.4	"	"
	15	81	79.4	"	"
	16	79	77.5	"	"
	17	70.5	69.3	"	"
	18	61	60	"	"
	19	50.5	49.5	"	"
	20	35	34.3	"	"
	21	20.5	20.3	"	"
	22	6	6	"	"
	23	- 9.5	-9.5	"	"
	24	-21	-20.8	"	"
	25	-35	-34.3	"	"
	26	-46	-45.	"	"
	27	-59.5	-58.5	"	"
	28	-72	-70.8	"	"
	29	-81	-79.5	"	"
	30	-90	-88.2	"	"
	31	-100	-98.1	"	"
	32	-108	-105.8	"	"

Bar	E	E (corr)	Armature E	Armature I
33	-114	-111.8	114	25
34	-116	-113.8	"	"
35	-120	-117.8	"	"
36	-120	-117.8	"	"
37	-119	-116.8	"	"
38	-118	-115.8	"	"
39	-116	-113.8	"	"
40	-110	-107.8	"	"
41	-107	-104.9	"	"
42	-101	-99	"	"
43	-91.5	-89.7	"	"
44	-75	-73.6	"	"
45	-61.5	-60.5	"	"
46	-43.5	-42.5	"	"
47	-33	-32.5	"	"
48	-20	-19.8	"	"
49	-7	-7	"	"
50	7	7	"	"
51	19	18.9	"	"
52	31	30.5	"	"
53	44	43	"	"

Compensating winding cut out, A.C. generator loaded.

Bar	E	E (corr)	Armature E	Armature I
Inst. No.	21		22	10
Constant	1		2	1
1	12.7	12.7	114	25
2	25	24.7	"	"
3	36	35.3	"	"
4	46	45	"	"
5	52	51	"	"
6	62.5	61.5	"	"
7	72	70.8	"	"
8	78	76.6	"	"
9	83	81.7	"	"
10	83	81.7	"	"
11	82	80.4	"	"
12	80	78.5	"	"
13	74	72.7	"	"
14	76	74.7	"	"
15	65	64	"	"
16	57.5	56.5	"	"
17	53	52	"	"
18	41	40	"	"
19	25	24.7	"	"
20	12.5	12.4	"	"

Bar	E	E (corr)	Armature E	Armature I
21	- 3.5	- 3.5	114	25
22	-18	-17.8	"	"
23	-26.5	-26.2	"	"
24	-42	-41	"	"
25	-58	-57	"	"
26	-71.5	-70.3	"	"
27	-83	-81.5	"	"
28	-93	-91.2	"	"
29	-99	-97.1	"	"
30	-113	-110.8	"	"
31	-121.5	-119.3	"	"
32	-131	-128.5	"	"
33	-135	-132.6	"	"
34	-139	-136.8	"	"
35	-139	-136.8	"	"
36	-136	-133.6	"	"
37	-132	-129.5	"	"
38	-126.5	-124.1	"	"
39	-116	-113.8	"	"
40	-113	-110.8	"	"
41	-111	-108.8	"	"
42	-112	-109.8	"	"
43	-90	-88.2	"	"
44	-75	-73.7	"	"
45	-62	-61	"	"
46	-44	-43	"	"
47	-34	-33.3	"	"
48	-20	-19.8	"	"
49	-7	-7	"	"
50	7	7	"	"
51	18.5	18.3	"	"
52	29	28.5	"	"


FLUX DISTRIBUTION CURVES.
BAR TO BAR VOLTAGE TEST.
D.C. MOTOR
VOLTS.
120
100
80
60
40
20
0
20
40
60
80
100
120
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51
COMMUTATOR SEGMENTS.
24½ SEGMENTS = 180 ELECTRICAL DEGREES.
① INTERPOLES IN – NO LOAD EXCEPT MACHINES
② " " 25 AMP LOAD
③ " OUT " " "
THESIS - H.H. & B.
1913.

CORE LOSS TESTS ON DIRECT CURRENT MACHINE.

A 2 H.P. Direct Current motor was used to drive the D.C. machine thru a flange coupling. The cold resistance of the driving motor was first taken, then it was separately excited and connected so that readings of armature volts and amperes, and speed could be taken.

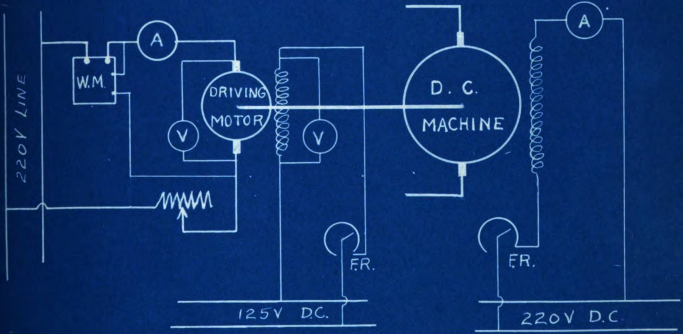
The test was then carried out as follows:- The field current of the driving motor was adjusted to about normal value and held constant throughout the test. The motor to be tested was driven first without any field excitation and readings taken of input to the driving motor at several speeds; third, starting with the brushes down and 0 field excitation readings of input into the driving motor were taken as the field current was increased from 0 to 125% normal at the following speeds, 800, 1300, and 1800 R.P.M. The driving motor was then disconnected and its input measured while running free.

The difference between the input to the driving motor when the brushes were down and when raised gives the brush friction. By subtracting the I^2R loss and input to the driving motor at 0 load from its input at each different field strength the core loss was figured for each point.

Curves were plotted with field amperes as abscissae and core loss as ordinates, also with R.P.M. as abscissae and bearing, brush, and windfriction as ordinates.

CORE LOSS TEST.

CONNECTION DIAGRAM



APPARATUS USED

NO	KIND	RANGE	
2	D.C. AMMETERS (WESTON)	0-50 AMPS	0-10 AMPS
2	D.C VOLTMETERS "	0-150 V.	
1	WATTMETERS "		
5	FIELD RHEOSTATS.		
2	LINE "		

THESIS - H.H.&B
1915.

CORE LOSS TEST (Origonal)

Driving Motor Running Free. (With the Brushes)

	Arm. KW.	Arm. I.	Arm. E.	Field E.	R.P.M.
Inst.No.	30	10	21	23	140
Const.	1	1	1	1	1
	.079	2.0	36.5	45	795
	.11	2.2	46.0	"	1000
	.135	2.3	55.5	"	1200
	.166	2.45	55.4	"	1400
	.20	2.5	74.9	"	1605
	.215	2.55	79.9	"	1705
	.235	2.6	83.2	"	1800
Inst.No.	30	12			
Const.	.5	1			
	.15	2.0	35.1	"	800
	.20	2.1	45.0	"	1000
	.258	2.29	54.0	"	1200
	.32	2.4	63.5	"	1400
	.381	2.55	73.2	"	1600
	.41	2.59	78.0	"	1700
	.438	2.61	81.5	"	1800

Driving Motor Running Free. (Against the Brushes)

	Arm. KW.	Arm. I.	Arm. E.	Field E.	R.P.M.
Inst.No.	30	12	21	23	140
Const.	.5	1	1	1	1
	.188	2.0	45.0	45	1000
	.24	2.18	54.0	"	1200
	.29	2.32	63.0	"	1400
	.354	2.415	72.0	"	1600
	.429	2.61	80.5	"	1800
	.429	2.61	81.0	"	1800
	.398	2.59	76.0	"	1700
	.362	2.5	71.5	"	1600
	.29	2.25	62.5	"	1400
	.237	2.12	53.5	"	1200
	.184	1.99	45.1	"	1000
	.13	1.75	36.0	"	800

CORE LOSS TEST DATA. (Origonal)

Brushes out, 0 field, of D.C.Machine; input to driving Motor.

	Arm. KW.	Arm. I.	Arm. E.	Field E.	R.P.M.
Inst.No.	30	10	21	23	140
Const.	2	1	1	1	1
	.11	6.0	37.5	45	800
	.16	6.5	46.0	"	1000
	.228	7.5	57.0	"	1200
	.278	8.0	66.5	"	1400
	.330	8.25	76.5	"	1600
	.345	8.2	81.0	"	1700
	.373	8.4	86.3	"	1800

Brushes Down, 0 field, of D.C.Machine; input to driving motor.

	Arm. KW.	Arm. I.	Arm. E.	Field E.	R.P.M.
Inst.No.	30	10	21	23	140
Const.	2	1	1	1	1
	.191	9.2	39.5	45	800
	.251	9.8	49.3	"	1000
	.310	10.25	58.7	1200	1200
	.3795	10.6	68.5	"	1400
	.43	10.9	77.3	"	1600
	.479	11.3	83.0	"	1705
	.51	11.9	87.4	"	1805

CORE LOSS TEST (Origonal)

Brushes down, field excited, of D.C. Machine.

	Driving Motor				D.C. Machine			
	Arm. KW.	Arm. I.	Arm. E	Field E	Arm. E	Field E	Field I	R.P.M.
Inst.	30	10	21	23	20	22	11	140
Const.	2	1	1	1	1	1	.01	1
	.185	8.7	40.3	45	8.5	0	0	800
	.19	9.25	39.7	"	20.0	12	5	"
	.19	9.25	39.8	"	28.0	18	7.5	"
	.195	9.4	39.6	"	53.0	34.5	14.5	"
	.20	9.6	39.4	"	54.0	40	16.5	"
	.202	9.7	39.5	"	68	50	20.7	"
	.215	10.25	40.0	"	96	70	29	"
	.221	10.65	39.8	"	108	80	33	"
	.235	11.4	40.0	"	133	100	41	"
	.245	11.75	40.3	"	145	110	45	"
	.25	11.9	40.5	"	156	120	49	"
	.26	12.35	40.7	"	168	130	52.8	"
	.37	11.1	63.7	45	14	0	0	1300
	.375	11.4	63.9	"	30	10	4	"
	.376	11.5	63.6	"	45.2	19	8	"
	.39	11.85	64.0	"	80	35	14.5	"
	.391	11.9	63.7	"	89	40	16.5	"
	.40	12.15	64.0	"	112	50	20.5	"
	.421	12.8	64.3	"	155	70	28.7	"
	.48	13.25	65.0	"	178	80	33	"
	.477	14.2	64.9	"	218	99	40.2	"
	.485	14.45	65.1	"	237	110	44.8	"
	.51	15.1	65.6	"	257	120	49	"
	.54	15.8	66.0	"	280	130	53	"

CORE LOSS TEST (Calculated).

Driving Motor Running Free. (With the Brushes)

Watts (Corr)	Arm. I. (Corr)	Arm. E. (Corr)	Field E. (Corr)	ExI. Input	
79	2.1	36.4	45	76.4	(1)
75	2.1	35.0	"	73.5	
110	2.3	45.9	"	105.8	(2)
100	2.2	44.9	"	98.8	
135	2.4	55.4	"	133.0	(3)
129	2.39	53.9	"	128.9	
166	2.46	55.3	"	136.0	(4)
160	2.5	63.4	"	158.3	
200	2.6	74.8	"	194.5	(5)
191	2.55	73.1	"	193.5	
215	2.65	79.7	"	211.0	(6)
205	2.69	77.8	"	209.0	
235	2.7	83.0	"	224.0	(7)
219	2.71	81.3	"	220.0	

Arm. Res.	I^2R Loss	Watts - I^2R	Av. of 2 Read's	R.P.M.	
.59	2.59	76.4	74.4	795	(1)
.59	2.59	72.4		800	
.585	3.1	106.9	107.0	1000	(2)
.59	2.9	107.1		1000	
.58	3.3	131.7	128.7	1200	(3)
.58	3.3	125.7		1200	
.58	3.45	162.6	159.5	1400	(4)
.58	3.6	156.4		1400	
.575	3.9	196.1	191.5	1600	(5)
.573	4.0	197.0		1600	
.573	4.0	211.0	206.0	1700	(6)
.571	4.1	201.0		1700	
.571	4.2	230.8	222.8	1800	(7)
.571	4.2	214.8		1800	

CORE LOSS TEST (Calculated).

Driving Motor Running Free.(Against the Brushes).

Watts (Corr)	Arm. I. (Corr)	Arm. E. (Corr)	Field E. (Corr)	E.x I. Input	
65	1.75	35.3	45	61.7	(1)
--	--	--	--	--	
94	2.0	44.0	"	88.0	(2)
92	1.99	44.1	"	87.8	
120	2.18	53.0	"	115.4	(3)
119	2.12	52.5	"	111.4	
145	2.22	63.0	"	140.0	(4)
145	2.25	61.5	"	138.4	
177	2.415	70.8	"	171.0	(5)
181	2.5	70.3	"	175.5	
199	2.59	74.8	"	194.0	(6)
--	--	--	--	--	
214	2.61	79.0	"	206.0	(7)
214	2.61	79.5	"	207.5	

Arm. Res.	I^2R Loss	Watts $- I^2R$	Av. of 2 Rdgs.	R.P.M.	
.6	1.8	63	63	800	(1)
--	--	--		--	
.6	2.4	92.5	91	1000	(2)
.6	2.38	90.0		1000	
.59	2.8	117.0	116.5	1200	(3)
.59	2.7	116.0		1200	
.59	2.9	142.0	142	1400	(4)
.58	2.9	142.0		1400	
.58	3.5	173.5	175.5	1600	(5)
.57	3.5	177.5		1600	
.56	3.75	195.0	195	1700	(6)
--	--	--		--	
.56	3.8	210.0	210	1800	(7)
.56	3.8	210.0		1800	

CORE LOSS TEST (Calculated).

Brushes Raised, 0 Field, of D.C.Machine.

Driving Motor					
Watts (Corr)	Arm. I. (Corr)	Arm. E. (Corr)	Field E. (Corr)	E x I Input	
220	6.15	36.7	45	225	(1)
320	6.65	45.0	"	300	(2)
456	7.63	56.0	"	426	(3)
556	8.12	65.4	"	539	(4)
660	8.36	75.1	"	629	(5)
690	8.31	79.4	"	660	(6)
746	8.5	84.6	"	720	(7)

Arm. Res.	I^2R Loss	Watts - I^2R	Windage & Bearing Loss	R.P.M.	
.465	17.6	202.4	128	800	(1)
.455	20.1	299.9	192.9	1000	(2)
.440	25.6	430.4	301.7	1200	(3)
.430	28.4	527.6	366.1	1400	(4)
.425	29.7	630.3	432.8	1600	(5)
.430	29.7	660.3	454.3	1700	(6)
.425	31.1	714.9	492.1	1800	(7)

Brushes Down, 0 Field, of D.C.Machine.

Driving Motor					
Watts (Corr)	Arm. I. (Corr)	Arm. E. (Corr)	Field E. (Corr)	E x I Input	
382	9.3	38.5	45	358	(1)
502	9.9	48.3	"	478	(2)
620	10.35	57.7	"	597	(3)
759	10.7	67.4	"	720	(4)
860	11.0	75.9	"	835	(5)
958	11.4	80.4	"	916	(6)
1020	12.0	85.7	"	1029	(7)

CORE LOSS TEST (Calculated).

Arm. Res.	I^2R Loss	Watts - I^2R	Windage, Bearing & Brush Loss	R.P.M.	
.415	35.9	346.1	271.7	800	(1)
.41	40.1	461.9	354.9	1000	(2)
.40	42.9	577.1	448.4	1200	(3)
.40	45.9	713.1	553.6	1400	(4)
.40	48.4	811.6	620.1	1600	(5)
.40	52.0	906.0	700.0	1700	(6)
.39	56.5	963.5	740.7	1800	(7)

Brushes Down, Field Excited, of D.C. Machine. (800 R.P.M.)

Driving Motor						
Watts (Corr)	Arm. I. (Corr)	Arm. E. (Corr)	Field E. (Corr)	E x I Input	R.P.M.	
382	9.3	38.5	45	358	800	(1)
380	9.25	38.7	"	358	"	(2)
380	9.25	38.8	"	359	"	(3)
390	9.4	38.8	"	365	"	(4)
400	9.6	38.4	"	369	"	(5)
404	9.7	38.5	"	373	"	(6)
430	10.25	39.0	"	400	"	(7)
442	10.65	38.8	"	414	"	(8)
470	11.4	39.0	"	445	"	(9)
490	11.75	39.3	"	462	"	(10)
500	11.9	39.4	"	469	"	(11)
520	12.35	39.7	"	490	"	(12)

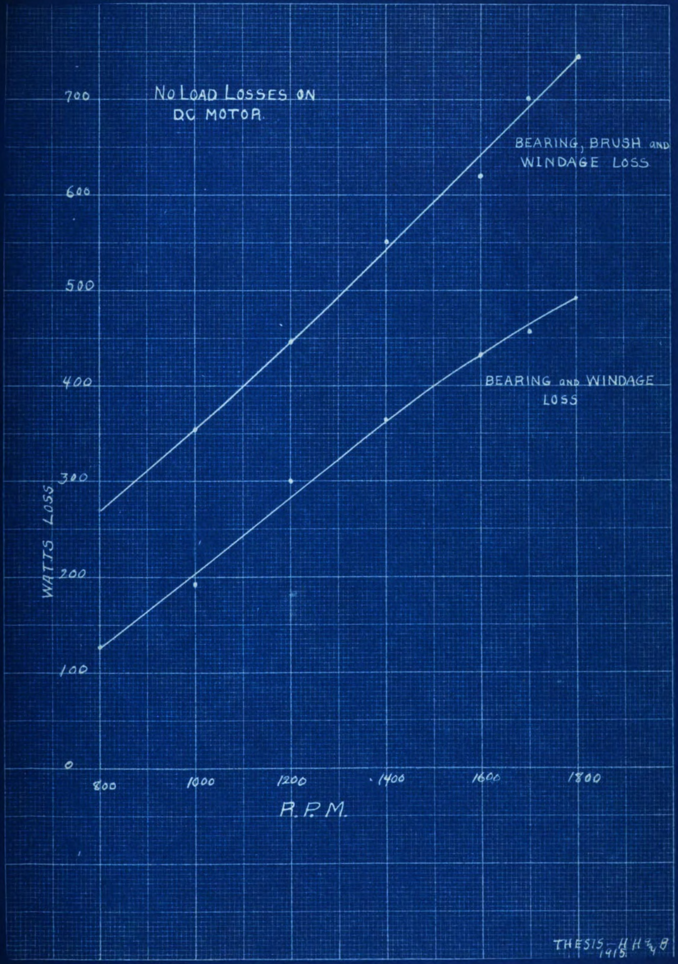
Arm. Res.	I2R Loss	Watts - I^2R	Total Loss (Watts)	Field I (Corr)	Core Loss (Watts)	
.415	35.9	346.1	271.7	0	0	(1)
.415	35.6	344.4	273.6	.05	1.9	(2)
.415	35.6	344.4	273.6	.075	1.9	(3)
.415	36.7	353.3	282.5	.145	10.8	(4)
.412	38.0	362.0	291.2	.165	19.5	(5)
.411	38.7	360.9	290.1	.207	18.4	(6)
.41	43.1	386.9	316.1	.29	44.4	(7)
.405	46.0	396.0	325.2	.33	53.5	(8)
.40	52.0	418.0	347.2	.41	75.5	(9)
.40	55.2	438.8	368.0	.45	96.3	(10)
.40	56.6	443.4	372.60	.49	100.9	(11)
.40	61.0	459.0	388.2	.528	116.5	(12)

CORE LOSS TEST (Calculated).

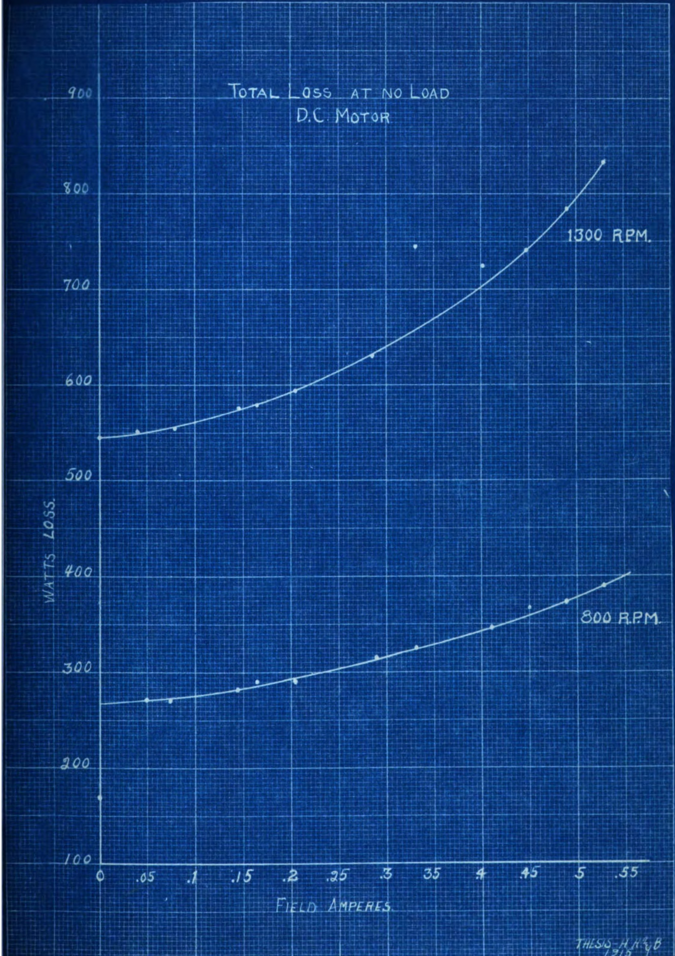
Brushes Down, Field Excited, of D.C. Machine. (1300 R.P.M.)

Driving Motor Watts (Corr)	Arm. I. (Corr)	Arm. E. (Corr)	Field E. (Corr)	E x I Input	R.P.M.	
740	11.2	62.7	45	702	1300	(1)
750	11.6	62.9	"	730	"	(2)
752	11.7	62.6	"	734	"	(3)
780	12.05	63.0	"	760	"	(4)
782	12.1	62.7	"	758	"	(5)
800	12.35	63.0	"	777	"	(6)
842	13.0	63.3	"	824	"	(7)
960	13.45	63.9	"	860	"	(8)
954	14.4	63.9	"	920	"	(9)
970	14.65	64.0	"	945	"	(10)
1020	15.1	64.5	"	975	"	(11)
1080	16.0	64.9	"	1038	"	(12)

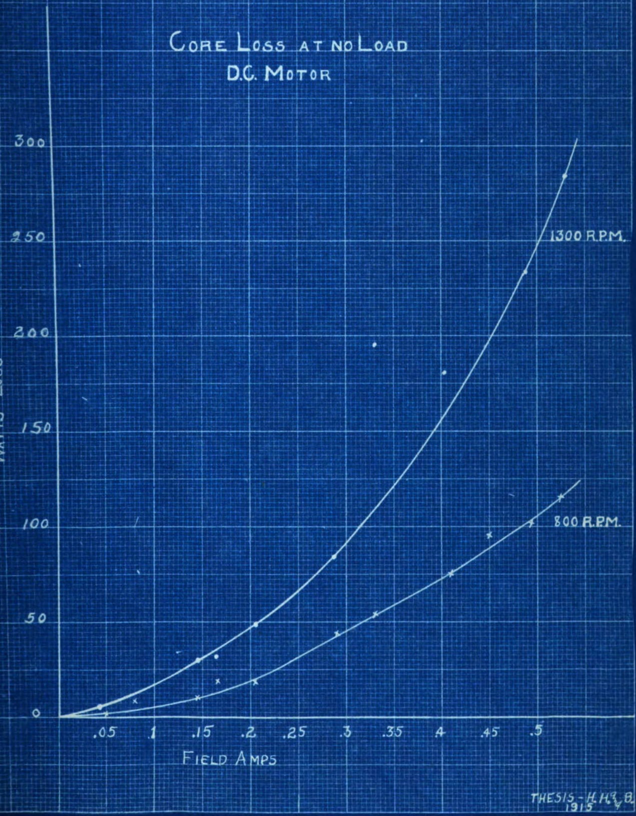
Driving Motor Arm. Res.	I^2R Loss	Watts - I^2R	D.C. Machine. Total Loss (Watts)	Field I. (Corr)	Core Loss (Watts)	
.40	50.2	689.8	545.8	0	0	(1)
.40	54.0	696.0	552.0	.04	6.2	(2)
.40	55.0	697.0	553.0	.08	7.2	(3)
.40	58.0	722.0	578.0	.145	32.2	(4)
.40	58.5	723.5	579.5	.165	33.7	(5)
.40	61.0	739.0	595.0	.205	49.2	(6)
.40	67.5	774.5	630.5	.287	84.7	(7)
.40	72.7	889.3	745.3	.330	199.5	(8)
.40	83.0	871.0	727.0	.402	181.2	(9)
.40	86.0	884.0	740.0	.448	194.2	(10)
.40	91.0	929.0	785.0	.490	234.2	(11)
.40	103.8	978.2	834.2	.530	288.4	(12)



NO LOAD LOSSES ON
DC MOTOR
BEARING, BRUSH AND
WINDAGE LOSS
BEARING AND WINDAGE
LOSS
WATTS LOSS
0
100
200
300
400
500
600
700
800
1000
1200
1400
1600
1800
R.P.M.
THESIS - H H & B
1915



TOTAL LOSS AT NO LOAD
D.C. MOTOR
1300 R.P.M.
800 R.P.M.
WATTS LOSS.
900
800
700
600
500
400
300
200
100
0
.05
.1
.15
.2
.25
.3
.35
.4
.45
.5
.55
FIELD AMPERES.
THESIS-H.H.&B


CORE LOSS AT NO LOAD
D.C. MOTOR
WATTS LOSS
300
250
200
150
100
50
0
.05
.1
.15
.2
.25
.3
.35
.4
.45
.5
FIELD AMPS
1300 R.P.M.
800 R.P.M.
THESIS - H.H.& B.
1915

GENERAL CONCLUSIONS DRAWN FROM TESTS MADE ON THE DIRECT CURRENT MACHINE.

That the direct current machine was designed as a slow speed motor is clearly shown by the motor and generator regulation tests, brake tests, and saturation tests.

While running at a slow speed we could see that the machine did not heat appreciably and the commutation was good when over full load current was flowing, whereas at the higher speeds the machine did not seem to run stable when full load was applied, that is, it began to heat, and arcing at the brushes was excessive.

Apparently normal current is flowing in the field when at the speed of 800 R.P.M., while at 1800 R.P.M. the field is necessarily so weakened that it permits another reaction to shift the neutral and thus cause the difficulty. The compensating windings are intended to remedy this fault, but the range of speed is so large that it is impossible to secure as good a performance on the high speeds as the slow speeds.

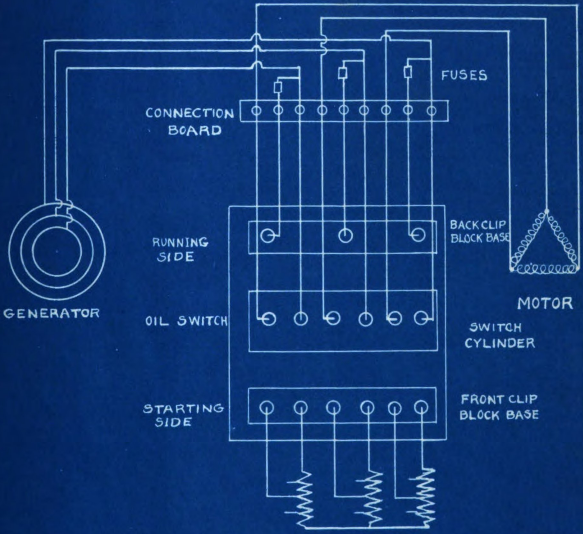
SECTION TWO

INDUCTION MOTOR EXPERIMENTS AND RESULTS.

AUTO STARTER.

FOR 3 PHASE INDUCTION MOTOR - SQUIRREL CAGE SECONDARY.

CONNECTION DIAGRAM.



THESIS

INDUCTION MOTOR RESISTANCES

At 20° Centigrade, by the drop of potential method.

PHASE A - B

	E	E (Corr)	I	I (Corr)	R
Inst. No.	21		10		
Const.	.1		1		
	55	5.4	23.0	23.1	.234
	59.0	5.8	24.75	24.85	.2335
	62	6.1	26.15	26.2	.233
	70	6.88	29.5	29.5	.2335
	74	7.27	31.2	31.2	.233
	76	7.46	31.85	31.85	.234
	80	7.84	33.5	33.5	.234
	86	8.43	36.0	36.0	.234
				Average	.2336

PHASE A - C

	E	E (Corr)	I	I (Corr)	R
	31	3.05	13.0	13.1	.2335
	35.7	3.5	14.9	15.0	.2335
	55	5.4	23.0	23.1	.234
	59	5.8	24.6	24.75	.234
	62	6.1	25.85	25.95	.234
	73	7.17	30.5	30.5	.235
	75	7.36	31.4	31.4	.234
				Average	.234

PHASE B - C

	E	E (Corr)	I	I (Corr)	R
	26	2.57	10.85	10.95	.2345
	31.1	3.06	12.9	13.0	.235
	40	3.9	16.7	16.8	.232
	47	4.6	19.5	19.7	.2335
	55	5.4	22.9	23.05	.234
	59	5.8	24.6	24.7	.2345
	66	6.5	27.5	27.55	.234
				Average	.234

PREDETERMINATION OF PERFORMANCE OF THE INDUCTION MOTOR.

The following tests were necessary for predetermining the performance of the induction motor:

1. Resistance of the stator winding.
2. Excitation with the motor running idle.
3. Impedance with the rotor locked.

It may seem at first that these tests, together with the necessity of constructing a diagram, and other calculations, should take more time than an ordinary brake test. Experience shows, however, that better results are obtained by the indirect method, than is possible with a brake test.

RESISTANCE OF THE STATOR WINDING.

The resistance was measured by the drop of potential method, direct current being applied between pairs of terminals. If the motor is Y-connected the resistance (r), of one phase will be one half of the resistance of (R), between two terminals, and the copper loss of the stator is

$$3\ I^2r \text{ or } 3/2\ I^2R.$$

If the motor is delta-connected, the resistance (r), is 3/2 or (R) and the copper loss is $3/2\ I^2R$. From this it is seen that in performing the task it is not necessary to ascertain the character of connections in the motor.

THE CIRCLE DIAGRAM.

Excitation Test or No-load Characteristics of the Induction Motor.

The purpose of this test was to determine the watts and amperes taken by the induction motor at no load, and the data was used in the construction of the circle diagram, together with the data from the impedance and resistance tests. The alternator in the engine laboratory, which is a ten pole machine, was run at a speed of 720 R.P.M. during the test to keep a constant frequency of 60 cycles. A rheostat was placed in the field of the alternator in order to vary the voltage. Starting with 115% rated voltage, the voltage was decreased in steps of about 10 volts each until the current reached a minimum and began to increase, taking simultaneous readings of volts, amperes, and watts. The power input was measured by the two watt meter method. Curves were plotted with terminal volts as abscissae to amperes per phase and total watts as ordinates.

Impedance Test or Short-Circuit Characteristics of the Induction Motor.

The purpose of this test was to determine watts and amperes taken by the induction motor with the rotor locked, and the data was also used in constructing the circle diagram. The set up was the same as for the excitation test. Starting with about 20% rated voltage, readings of watts, amperes, and volts were taken, gradually increasing the voltage until rated current was reached. Curves were plotted with terminal volts as abscissae to amperes per phase and total watts as ordinates. The ampere curve is a straight line and the watt curve is a parabola.

Construction of the Circle Diagram.

(1) <u>Power Factor Quadrant</u>. Reference axes Ox and OE were selected. Op was taken equal to 100% power factor to a convenient scale. With Op as a radius the quadrant prq was drawn. For any factor of primary current, such as OI the power factor is represented by Ot, the ordinate of the point r where the vector intersects the quadrant.

(2) <u>Input</u>. The apparent horse power input with the rotor locked was then figured which is equal to

$$\frac{i_s E \sqrt{3}}{746} \text{ H.P.}$$

and this value plotted to a convenient scale as the vector OI_s, at a power factor equal to

$$\frac{100\ W_s}{i_s E \sqrt{3}} \text{ per cent.}$$

We then plotted the apparent horse power input at no load

$$OI_o = \frac{i_o E \sqrt{3}}{746} \text{ horse power.}$$

The power factor being $\frac{100\ W_o}{i_o E \sqrt{3}}$ per cent.

A semi circle was then drawn thru the points I_o and I_s, having its center on the horizontal line I_oK. For any point such as I, the vecotr OI represents the apparent horse power input, and the ordinate Id represents the true horse power input.

(3) Primary Current. The vector of the primary current coincides with the vector OI of apparent input. OI is measured in horse power, and the primary current per phase $i_1 = \frac{746\ OI}{E\ \sqrt{3}}$ amperes.

(4) Output. A line was drawn connecting I_oI_s. The portion of any ordinate of the circle above the line I_oI_s as Ia, measures the horse power output.

(5) Torque. The horse power loss was figured from the formula:

$$\frac{3\ (i_s\ \frac{I_oI_s}{OI_s})^2\ \times 1/2\ R}{746} = \text{horse power loss.}$$

This was plotted, as fg, and the line I_og was drawn. For any input, such as Id, the ordinate Ib measures torque in synchronous horse power.

$$\text{Torque in ft. lbs.} = \frac{\text{torque in synchron. h.p.} \times 5252}{\text{synchron. rev. per min.}}$$

(6) True Efficiency. The true efficiency of the motor is equal to the ratio Ia to Id. The efficiency is measured directly by producing I_oI_s to 1 and the vertical line 1N drawn. The efficiency scale NN' was then drawn at such a distance from the axis Ox as to get the length NN' easily divisible by 100. The efficiency corresponding to the input Id was then obtained by laying a straight edge between the points 1 and I and the efficiency read directly in per cent at the point n on the same line.

(7) Apparent Efficiency. This is calculated as the ratio of Ia to IO.

(8) <u>Slip.</u> Per cent slip may be calculated as the ratio of ab to Ib. The slip scale was constucted by drawing the line S'S parallel to the line $I_o g$ at such a distance as to have it easily divisible by 100. The slip for a point, such as I, was found by laying a straight edge between the points I_o and I, S's measured the slip.

Maximum Values from Circle Diagram.

(1) Maximum input corresponds to the point at which the tangent to the circle is parallel to the axis Ox.

(2) Maximum torque corresponds to the point at which the tangent to the circle is parallel to the line $I_o g$.

(3) Maximum output corresponds to thepoint at which the tangent to the circle is parallel to the line $I_o I_s$.

(4) Maximum efficiency corresponds to the point at which the tangent from 1 touches the cirle.

(5) Maximum power factor corresponds to the point at which the tangent from O touches the circle.

CALCULATIONS.

Data taken from the Excitation Test.

i_o = 11 amperes at 220 volts.

W_o = 462 watts at 220 volts.

Data taken from the Impedance Test.

The ampere curve being a straight line we calculated the current input at 220 volts by direct proportion, as

$\frac{i_s}{35.3} = \frac{220}{40}$ $\quad i_s = 194.0$ amperes

$\frac{i_s}{31} = \frac{220}{35}$ $\quad i_s = 194.2$ "

$\frac{i_s}{26.5} = \frac{220}{30}$ $\quad i_s = 194.2$ "

Average 194.13 amperes

In as much as the watt input curve takes the form of a parabola, the total power input at normal voltage can be obtained from the following; $W_s : W_{220} = E^2 : 220^2$, where E is any voltage and W_s is the input at that voltage. Therefore:

$\frac{W_s}{1315} = \frac{220^2}{40^2}$ $\quad W_s = 39,800$ watts

$\frac{W_s}{990} = \frac{220^2}{35^2}$ $\quad W_s = 39,100$ "

$\frac{W_s}{730} = \frac{220^2}{30^2}$ $\quad W_s = 39,300$ "

Average 39,400 watts.

Apparent Horse Power input equals

$$\frac{i_o E \sqrt{3}}{746} = \frac{11 \times 220 \sqrt{3}}{746} = 5.6 \text{ horse power}$$

$$\text{Power Factor} = \frac{100\ W_o}{I_o E \sqrt{3}} = \frac{100 \times 462}{11 \times 220 \sqrt{3}} = 11.05\%$$

Apparent horse power input with rotor locked equals

$$\frac{i_s E \sqrt{3}}{746} = \frac{194.13 \times 220 \sqrt{3}}{746} = 99 \text{ horse power}$$

$$\text{Power Factor} = \frac{100\ W_s}{I_s E \sqrt{3}} = \frac{100 \times 39{,}400}{194.13 \times 220 \sqrt{3}} = 53.3\%$$

The stator copper loss equals $3/2\ I^2 R$ where R is the resistance between terminals. This resistance is based on a maximum temperature of 65° C. (or allowing 40° C. rise in temperature) and is determined by means of the following formulas

$$R_T = R_t \left(\frac{1 + aT}{1 + at} \right)$$ where t is the initial, and T the final temperatures.

$$R_{65} = R_{24} \left(\frac{1 + 0.0042 \times 65}{1 + 0.0042 \times 24} \right) = 0.234\ (1.156) = 0.2705\ \text{o.}$$

From the diagram $I_o I_s$ = 94 horse power

OI_o = 99 horse power.

$$\text{Horse power loss} = \frac{3 \times \left(i_s \dfrac{I_o I_s}{OI_s} \right)^2 \times 1/2\ R}{746}$$

$$= \frac{3 \times \left(\dfrac{194.13 \times 94}{99} \right)^2 \times 1/2 \times 0.2705}{746}$$

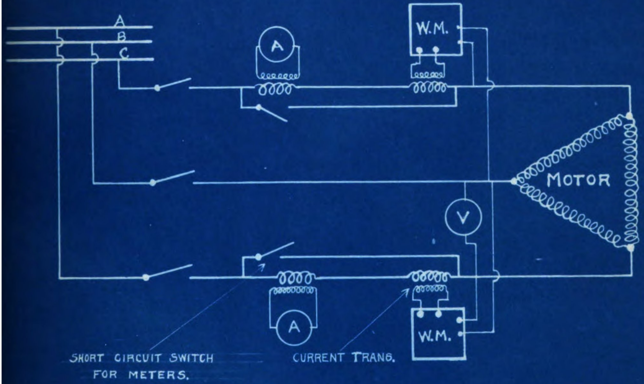
= 18.5 horse power

Impedance:-

$$Z = \frac{E}{I}$$

Induction Motor
Impedance and Excitation Test
TO OBTAIN DATA FOR CONSTRUCTING THE CIRCLE DIAGRAM.

CONNECTION DIAGRAM



APPARATUS USED

NO	KIND	RANGE
2	WESTON WATTMETERS	0-3 KW 0-20 AMPS 0-300 VOLTS
2	WESTON AMMETERS-A.C.	0-5 AMPS
2	CURRENT TRANSFORMERS	25-5 AMPS USED WITH W.M.
2	" "	50-5 AMPS " " AMMETER.
1	WESTON A.C. VOLTMETER	0-500 VOLTS.

THESIS - H.-H. and B.
1915.

EXCITATION TEST ON INDUCTION MOTOR. (Original).

	PHASE A		PHASE C		
	KW.	I	KW.	I	E
Inst. No.	30	110	31	111	120
Constant	2	5	2	5	1
	-.65	2.61	.94	2.68	250
	-.565	2.5	.835	2.49	240
	-.475	2.26	.72	2.25	225
	-.45	2.18	.68	2.18	220
	-.405	2.07	.62	2.06	212
	-.35	1.91	.545	1.91	200
	-.3	1.78	.485	1.78	189
	-.27	1.71	.45	1.7	180
	-.235	1.59	.395	1.58	170
	-.205	1.5	.35	1.5	160
	-.16	1.3	.28	1.3	140
	-.125	1.24	.25	1.24	132
	-.1	1.1	.22	1.1	120
	-.08	1.04	.185	104	110
	-.06	.9	.16	.9	100
	-.04	.8	.135	.8	90
	-.032	.75	.12	.75	81
	-.01	.65	.095	.65	69
Constant	2	1	2	1	
	-.008	.31	.075	0305	60
	0	.292	.07	.29	55
	.01	.275	.06	.27	50
	.018	.27	.05	.26	39.5
	.109	.27	.05	.26	35
	.02	.275	.045	.27	31
	.021	.312	.04	.3	25
	.023	.35	.04	.34	20
	.02	.42	.035	.41	15

EXCITATION TEST ON INDUCTION MOTOR. (Corrected Data).

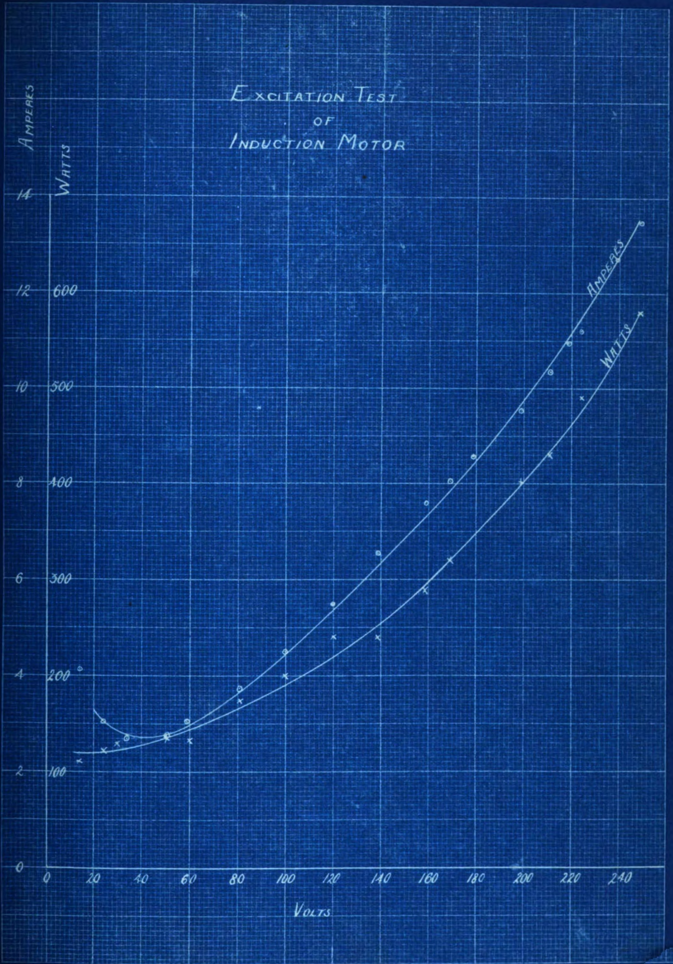
PHASE A KW.	PHASE A I	PHASE C KW	PHASE C I	E	Total KW.	Av. I
-1.3	13.3	1.88	13.65	249	.58	13.5
-1.13	12.75	1.67	12.7	239	.54	12.725
- .95	11.05	1.44	11.35	224	.49	11.2
-.9	10.9	1.36	10.95	219	.46	10.925
-.81	10.35	1.24	10.3	211	.43	10.325
-.7	9.55	1.09	9.55	199	.39	9.55
-0.6	8.9	.97	8.9	188	.37	8.9
-.54	8.6	.9	8.55	179	.36	8.575
-.47	8.05	.79	8.0	169	.32	8.025
-.41	7.6	.7	7.6	159	.29	7.6
-.32	6.55	.56	6.55	139	.24	6.55
-.25	6.25	.5	6.25	131	.25	6.25
-.2	5.5	.44	5.5	119.5	.24	5.5
-.16	5.2	.37	5.2	109.5	.21	5.2
-.12	4.5	.32	4.5	99.5	.2	4.5
-.08	40	.27	4.0	89.5	.19	4.0
-.064	3.75	.24	3.75	80.5	.176	3.75
-.02	3.25	.19	3.25	68.5	.17	3.25
.016	3.12	.15	3.07	59	.134	3.18
0	2.94	.14	2.92	54	.14	2.93
.02	2.79	.12	2.75	49	.14	2.77
.036	2.75	.10	2.65	38.5	.136	2.7
.038	2.75	.10	2.65	34	.138	2.7
.04	2.79	.09	2.75	30	.13	2.77
.042	3.14	.08	3.02	24	.122	3.08
.046	3.51	.08	3.41	19	.126	3.46
.04	4.2	.07	4.1	14	.11	4.15

IMPEDANCE TEST OF INDUCTION MOTOR. (Original).

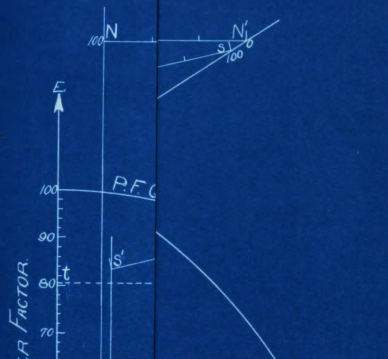
	PHASE A		PHASE C		
	KW.	I	KW.	I	E
Inst.No.	30	110	31	111	120
Constant	5	10	5	10	1
	.003	1.16	.03	1.2	12.5
	.005	1.38	.038	1.4	15
	.005	1.48	.045	1.49	18
	.008	1.87	.072	1.87	20
	.009	2.08	.09	2.07	25
	.01	2.38	.115	2.37	28
	.01	2.5	.128	2.5	30
	.01	2.67	.143	2.66	31
	.011	2.84	.160	2.8	33
	.012	2.94	.171	2.88	34
	.013	3.08	.189	3.02	36
	.0135	3.2	.202	3.15	37.5
	.015	3.35	.222	3.31	39
	.016	3.53	.247	3.5	41

Corrected data.

PHASE A		PHASE C			Total	Av.	
KW.	I	KW.	I	E	KW	I	Z
.015	11.6	.15	12	12.5	.165	11.8	1.06
.025	13.9	.19	14	15	.215	13.95	1.075
.025	15	.225	14.9	18	.25	14.95	1.205
.04	18.8	.36	18.6	20	.40	18.7	1.07
.045	20.8	.45	20.6	25	.495	20.7	1.205
.05	24.3	.575	23.8	28	.625	24.05	1.16
.05	25.5	.64	25.3	28.8	.69	25.4	1.085
.05	27.1	.715	26.9	29.8	.765	27	1.105
.055	28.7	.80	28.3	31.9	.855	28.5	1.12
.06	29.6	.855	29.1	32.9	.915	29.35	1.12
.065	31	.945	30.6	34.9	1.01	30.8	1.132
.0675	32.2	1.01	31.8	36.5	1.078	32	1.14
.075	33.7	1.11	33.3	38	1.185	33.5	1.135
.08	35.4	1.235	35.1	40	1.315	35.25	1.135



Excitation Test
of
Induction Motor
Amperes
Watts
14
12
10
8
6
4
2
0
600
500
400
300
200
100
0
20
40
60
80
100
120
140
160
180
200
220
240
Volts
Amperes
Watts



N
N'
100
S
100
E
P.F.
PERCENT POWER FACTOR
100
90
80
70
60
50
40
30
20
10
0
t
S'
H.P. OUTPUT
SECONDARY COPPER LOSS
PRIMARY COPPER LOSS
K
l

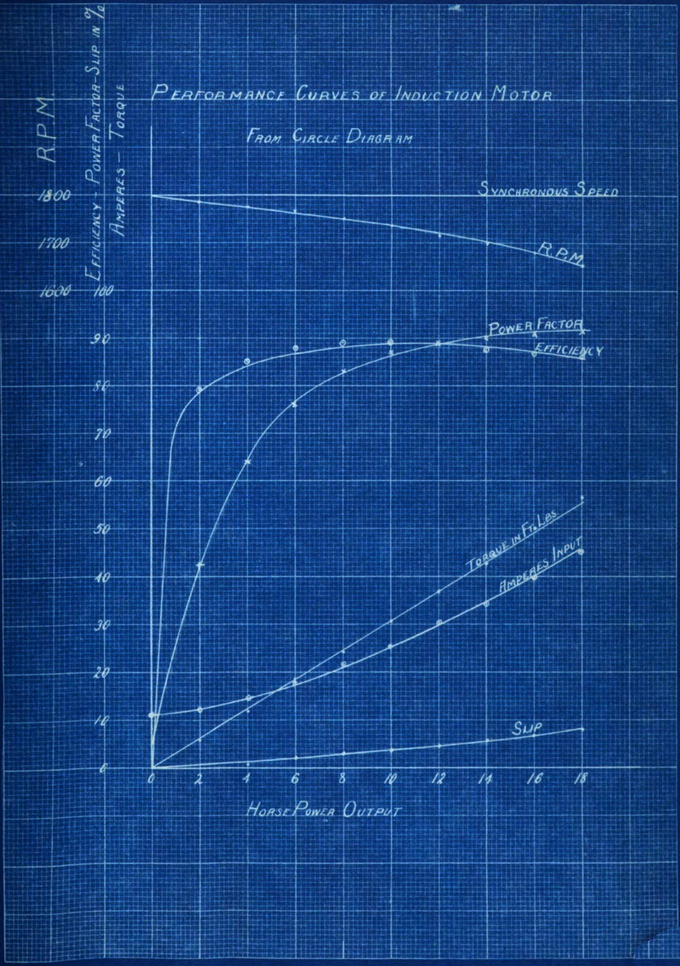
.M.

PERFORMANCE DATA DETERMINED FROM CIRCLE DIAGRAM.

H.P. Out.	Syn. H.P.	Torque	OI	I	% Eff.	% Slip	% P.F.	R.P.M.
2	2.0	5.84	6.2	12.15	79.0	1.0	42.3	1785
4	4.0	11.7	7.4	14.5	85.2	1.5	64.0	1775
6	6.2	18.1	9.0	17.65	88.0	2.1	76.0	1765
8	8.3	24.2	11.0	21.55	89.1	2.7	83.0	1750
10	10.5	30.65	13.0	25.4	89.1	3.6	87.0	1735
12	12.6	36.8	15.4	30.2	88.7	4.6	89.0	1715
14	14.6	42.65	17.4	34.1	87.6	5.5	90.0	1700
16	17.1	49.9	20.3	39.8	86.8	6.7	91.0	1680
18	19.4	56.16	23.0	45.02	86.0	8.0	91.5	1655

$$I = \frac{746 \times OI}{220 \times \sqrt{3}}$$

$$\text{Torque in Ft.Lbs.} = \frac{\text{Syn.h.p.} \times 5252}{\text{Syn.Speed.}}$$



Performance Curves of Induction Motor
From Circle Diagram
R.P.M.
Efficiency - Power Factor - Slip in %
Amperes - Torque
1800
1700
1600
100
90
80
70
60
50
40
30
20
10
0
Synchronous Speed
R.P.M.
Power Factor
Efficiency
Torque in Ft. Lbs
Amperes Input
Slip
0
2
4
6
8
10
12
14
16
18
Horse Power Output

BRAKE TEST ON INDUCTION MOTOR.

The purpose of this test was to obtain performance curves of the induction motor. The motor was run for about one hour carrying nearly rated load, before readings were taken, to warm up the windings and approach, as nearly as possible, normal running conditions.

Starting with 0 load readings were taken of volts, amperes per phase, watts input, R.P.M., and weight in pounds; gradually increasing the load on the brake arm in 25% increments from 0 to 150% overload.

Curves were then plotted with horse power output as abscissae to the following ordinates:- efficiency, slip, and power factor, in per cent; torque, in foot pounds; speed; and amperes per phase.

The calculations were made as follows:-

$$\text{Power Factor} = \frac{W}{\sqrt{3}\,EI}$$

$$\%\ \text{slip} = \frac{\text{Synchronous speed} - \text{Motor speed}}{\text{Synchronous speed}}$$

Torque = length of brake arm x net weight.

$$\text{H.P. input} = \frac{\text{Watts}}{746}$$

$$\text{H.P. output} = \frac{2\pi r NW}{33{,}000}$$

BRAKE TEST ON INDUCTION MOTOR (Original).

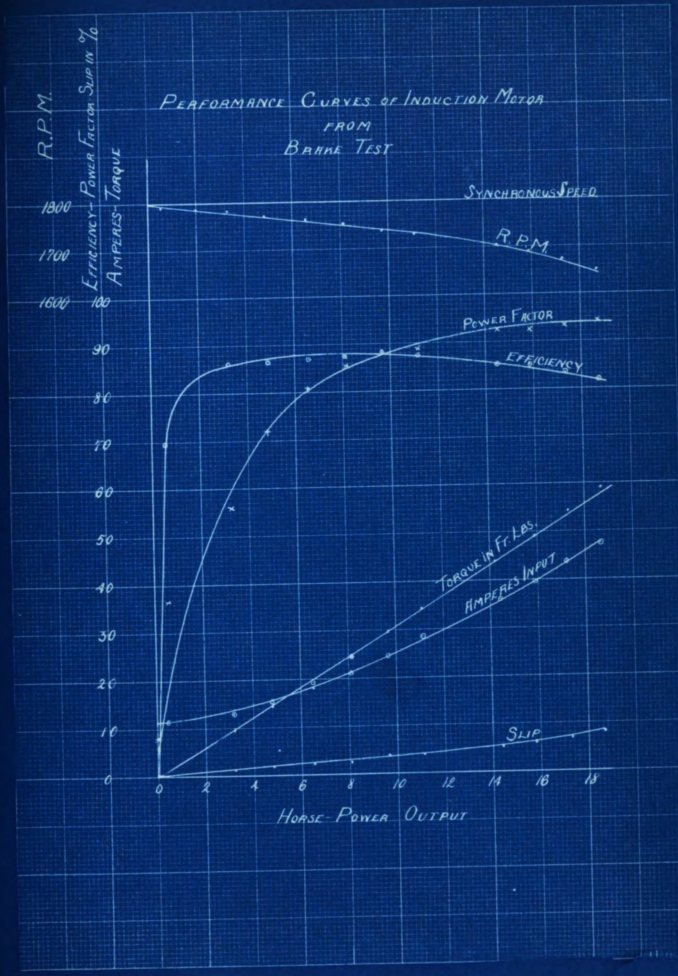
	PHASE A		PHASE C				
	KW.	I	KW	I	E	Load lbs.	R.PM.
Inst. No.	30	110	31	111	120		140
Constant	5	10	5	10	1		1
	-.18	1.6	.28	1.7	220	0	1798
	-.06	1.13	.38	1.16	"	4	1789
	.05	1.28	.5	1.3	"	6	1783
	.19	1.53	.648	1.52	"	8	1768
	.33	1.83	.79	1.83	"	10	1760
	.44	2.13	.945	2.13	"	12	1749
	.56	2.43	1.08	2.4	"	14	1734
	.7	2.85	1.23	2.8	"	16	1730
Constant	10		10				
	.47	3.6	.79	3.56	220	20	1705
	.53	4.0	.86	3.92	"	22	1690
	.58	4.4	.97	4.3	"	24	1675
	.64	4.8	1.06	4.7	"	26	1650

(Corrected Data).

PHASE A		PHASE C					
KW	I	KW	I	E	Total KW	Av. I	
-.9	16.2	1.4	17.0	219	.5	16.6	(1)
-.3	11.3	1.9	11.6	"	1.6	11.45	(2)
.25	12.9	2.5	13.0	"	2.75	12.95	(3)
.95	15.5	3.24	15.2	"	4.19	15.35	(4)
1.65	18.3	3.95	18.3	"	5.6	18.3	(5)
2.2	21.3	4.73	21.3	"	6.93	21.3	(6)
2.8	24.7	5.4	24.1	"	8.2	24.4	(7)
3.6	28.8	6.15	28.4	"	9.65	28.6	(8)
4.6	36.1	7.9	35.7	"	12.6	35.9	(9)
5.3	40.0	8.6	39.3	"	13.9	39.65	(10)
5.8	44.1	9.7	43.2	"	15.5	43.65	(11)
6.4	48.0	10.6	47.2	"	17.0	47.6	(12)

Calculated Data

Load	H.P. input	H.P. output	% Eff.	% Slip	% P.F.	R.P.M.	
0	.67	0	0	.11	7.94	1798	(1)
1.75	2.145	1.49	69.5	.61	36.8	1789	(2)
3.75	3.685	3.175	86.15	1.11	56	1780	(3)
5.75	5.62	4.845	86.3	1.67	72	1770	(4)
7.75	7.5	6.51	86.8	2.06	80.6	1763	(5)
9.75	9.23	8.1	87.4	2.83	85.8	1749	(6)
11.75	11.0	9.75	88.1	3.56	88.5	1734	(7)
13.75	12.94	11.31	87.5	3.87	88.9	1730	(8)
17.75	16.9	14.45	85.4	5.28	92.6	1705	(9)
19.75	18.6	15.85	85.2	6.11	92.5	1690	(10)
21.75	20.8	17.83	83.4	6.95	93.5	1675	(11)
23.75	22.8	18.7	82	8.34	94.2	1650	(12)


PERFORMANCE CURVES OF INDUCTION MOTOR
FROM
BRAKE TEST
R.P.M.
EFFICIENCY - POWER FACTOR SLIP IN %
AMPERES - TORQUE
1800
1700
1600
100
90
80
70
60
50
40
30
20
10
0
SYNCHRONOUS SPEED
R.P.M.
POWER FACTOR
EFFICIENCY
TORQUE IN FT. LBS.
AMPERES INPUT
SLIP
0
2
4
6
8
10
12
14
16
18
HORSE-POWER OUTPUT

INDUCTION MOTOR REGULATION.

From data obtained from the brake test we figured the speed regulation of the induction motor by means of the following formula:

$$\text{Speed regulation} = \frac{\text{no load speed} - \text{full load speed}}{\text{full load speed}}$$

Data

$$\frac{1798 - 1733}{1733} = \frac{65}{1733} = 3.7\%$$

GENERAL CONCLUSIONS DRAWN FROM TESTS ON INDUCTION MOTOR.

The results of thest tests show that the efficiency of the motor is very high at all loads, specially does it hold up well under heavy overload. It has a strong starting torque and its power factor is very good under full load. Also, the regulation of the machine as determined from the brake test is very good.

We believe that the results of these tests were altogether satisfactory as shown by the fact that the results of the circle diagram and brake test check very closely.

SECTION THREE

ALTERNATING CURRENT GENERATOR EXPERIMENTS AND RESULTS.

TESTS ON ALTERNATING CURRENT GENERATOR.

This machine has six slip rings with connections to the winding which allows the machine to be used as either a single phase two-phase or three- phase generator.

Since three-phase systems are most common in alternating current pradtice of the present day, due to economy of line construction and various other reasons, we decided to confine our tests on this machine to the three-phase connection.

Cold Resistance of Alternator.

Taken at 24.7° C.

Drop of Potential Method.

Field Resistance.

	E	E (corr)	I	I (corr)	R
Inst. No.	21		10		
Constant	1		.01		
	48	47.9	99	.97	49.4
	65.2	64.2	13	1.3	49.4
	78.5	77	17.5	1.75	49.4
	101	99	20	2.0	49.5
	121	118.8	24	2.4	49.1
	130.7	128.4	26	2.6	49.8
	140	137.8	28	2.8	49.1
	147	144.5	29.6	2.97	48.7
				Average	49.2

Armature Resistance.

Phase A - B

	E	E (corr)	I	I (corr)	R
Inst. No.	21		10		
Constant	.1		1		
	27.5	2.71	7.5	7.65	.354
	53	5.2	14.55	14.65	.355
	85	8.33	23.3	23.45	.355
	91	8.92	25	25.1	.3555
	96	9.42	26.4	26.45	.3555
	102	10	28	28.05	.356
	108	10.6	29.6	29.6	.358
	113	11.1	31	31	.358
				Average	.356

Phase A - C

31.3	3.08	8.5	8.6	.358
46.1	4.51	12.6	12.7	.355
54	5.3	14.75	14.85	.357
61	6.0	16.7	16.85	.356
71	6.98	19.45	19.65	.356
82	8.04	22.5	22.65	.355
88	8.62	24.2	24.35	.354
93	9.12	25.5	25.6	.356
			Average	.356

Phase B - C

28	2.76	7.6	7.75	.356
34	3.33	9.3	9.4	.3545
47	4.6	12.8	12.9	.357
72	7.08	19.7	19.9	.356
76	7.46	20.75	20.95	.356
80	7.85	21.8	21.95	.357
90	8.82	24.6	24.7	.357
			Average	.3562

REGULATION.

THREE PHASE REGULATION BY E.M.F. AND M.M.F. METHODS.

The object of this test is to determine the decrease in voltage between phases from no load to full load and express it in terms of per cent of the full load voltage.

$$\text{Regulation} = \frac{\text{Volts at no load} - \text{Volts at full load}}{\text{Volts at full load}}$$

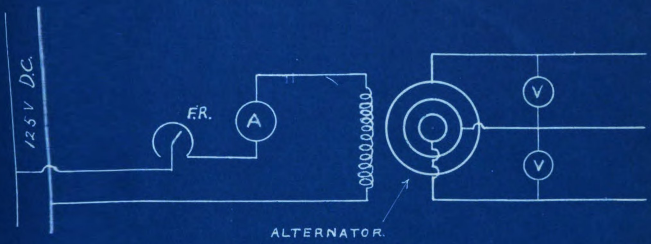
When it is impossible to obtain regulation by direct loading of the machine one of the above methods is generally used. By these methods the only data necessary is a no load saturation test and a short circuit or impedance test. Very little power compared to that required for full load is required for these tests, i. e. for the saturation test only the power necessary to drive the machine at no load with full field excitation, and for the short circuit test it is only that required to send 125% rated current ~~to~~ thru the windings on short circuit.

The connections for the saturation test are shown in figure one on the preceeding blue print. Figure two gives the connections for the short circuit test.

The machine was driven at rated speed by the D.C. motor and readings taken of field I and armature E up to about 100 per cent above rating. The curve obtained was practically a straight line up to a little above rated voltage (220), showing that the iron does not become saturated when working under normal conditions.

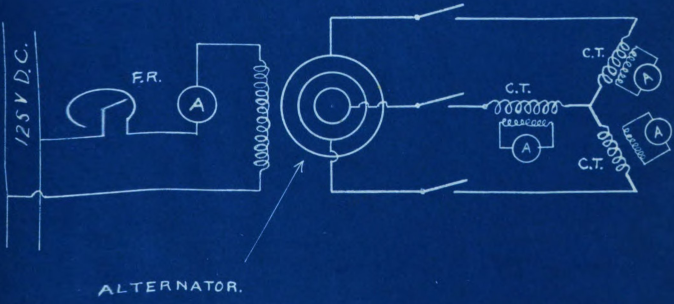
SATURATION TEST A.C. GEN.

CONNECTION DIAGRAM



SHORT CIRCUIT TEST.

CONNECTION DIAGRAM



THESIS - H. H. and B.
1915.

In the short circuit test readings are taken of field I and armature I up to about 125 per cent rated current.

SATURATION TEST DATA. A.C. GENERATOR

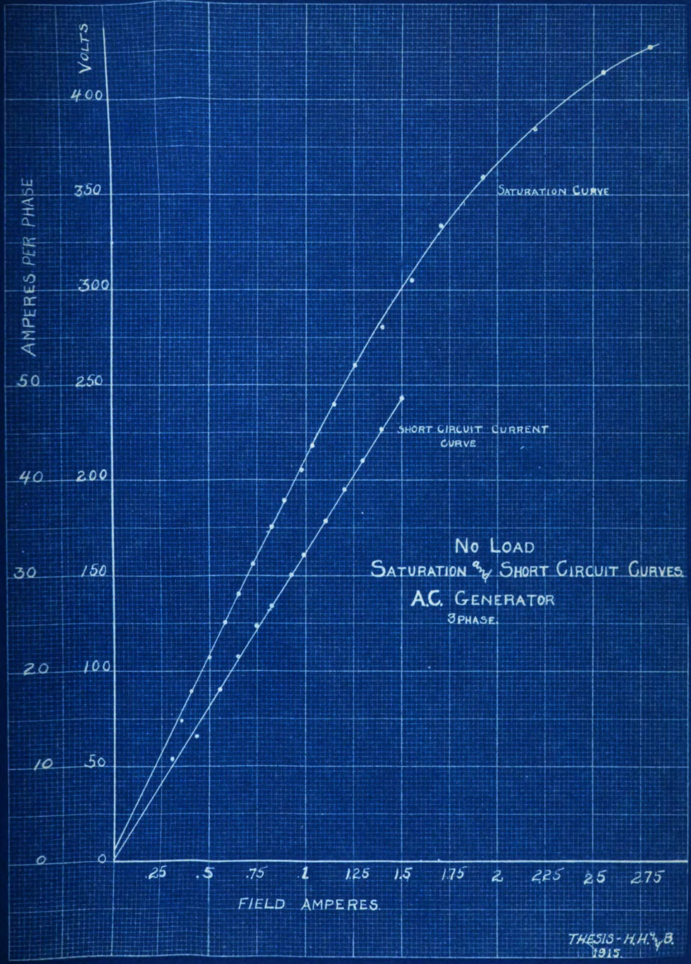
R.P.M. 1800

	Phase B - C E	Phase B - C E (corr)	Phase A - C E	Phase A - C E (corr)	Aver. E	Field I	Field I (corr)
Inst. No.	121		123			11	
Constant	1		1			.01	
	71	74	72	75	74.5	36	.34
	87	89	89	91	90	42.5	.405
	107	107	108	108	107.5	52	.50
	124	126	125	125.5	125.7	60	.58
	139	139	140	141	140	67.5	.655
	155	155	156	157	156	75	.73
	175	175	176	177	176	84.52	.825
	189	188.5	190	190	189.2	90.5	.885
	205	204	206	206	205	99	.982
Constant						.1	
	218	217	218	219	218	10.2	1.02
	240	239	240	241	240	11.5	1.15
	260	260	261	261	260.5	12.5	1.25
	280	280	281	281	280.5	14	1.4
	306	306	307	307	306.5	15.5	1.55
	335	335	335	335	335	17.1	1.71
	360	360	360	360	360	22	2.2
	415	415	415	415	415	25.6	2.56
	428	428	428	428	428	28	2.81
	430	430	430	430	430	28	2.81
			Decreasing field				
	309	309	309	309	309	15	1.5
	190	190	192	192	191	8.5	.85
Constant						.01	
	125	125	130	130	127.5	60	.58
	65	65	60	70	67.5	37.6	.356

SHORT CIRCUIT TEST DATA. A.C. GENERATOR.

R.P.M. 1800.

	Phase A I	Phase A I (corr)	Phase B I	Phase B I (corr)	Phase C I	Phase C I (corr)	Aver. I	Field. I	Field. I (corr
Inst.No.	110		114		113			11	
Constant	10		20		10			.01	
	1.12	11.2	.525	10.1	1.08	10.8	10.7	33	.315
	1.5	15.2	.5	9.6	1.47	14.9	13.2	46	.44
	1.9	19	.9	17.8	1.87	18.8	18.5	58	.56
	2.21	22.3	1.06	21.04	2.17	21.7	21.68	68	.66
	2.51	25.6	1.19	23.6	2.45	24.8	24.66	77	.75
	2.74	27.8	1.31	26	2.68	27	26.9	84	.82
	3.1	31.2	1.47	29.2	3.03	30.3	30.2	94	.923
	3.31	33.25	1.57	31.4	3.24	32.4	32.35	100	.995
Constant								.1	
	3.66	36.7	1.74	34.8	3.58	35.8	35.76	11	1.1
	4.02	40.2	1.92	38.4	3.93	39.1	39.2	12	1.2
Inst. No.			111						
Constant			20						
	4.3	43.1	2.05	41	4.22	42	42	13	1.3
	4.65	46.7	2.22	44.4	4.56	45.7	45.6	14	1.4
	5	50	2.39	47.8	4.91	49	48.9	15	1.5


VOLTS
AMPERES PER PHASE
400
350
300
50 250
40 200
30 150
20 100
10 50
0 0
.25 .5 .75 1 1.25 1.5 1.75 2 2.25 2.5 2.75
FIELD AMPERES
SATURATION CURVE
SHORT CIRCUIT CURRENT CURVE
NO LOAD
SATURATION and SHORT CIRCUIT CURVES
A.C. GENERATOR
3 PHASE
THESIS - H.H. & B.
1915

REGULATION BY THE E.M.F. METHOD

100% P.F.

Rated current per terminal $= \frac{P}{\sqrt{3}\,E} = \frac{10,000}{\sqrt{3} \times 220} = 26.25$

Average armature resistance between terminals measured at 24.7° C. = .356 Ohms.

The temperature limit to which the windings will rise is taken as 65° C.

Res. at 65° C. = $.356 + .004 \times .356\ (65 - 24.7) = .411$ ohms.

Armature IR drop $= \frac{\sqrt{3}\,IR}{2} = \frac{\sqrt{3} \times 26.25 \times .411}{2} = 9.34$ volts. and is in phase with the terminal voltage since 100% P.F. is assumed.

The armature resistance drop plus rated voltage is

$$220 + 9.34 = 229.34 \text{ volts.}$$

The field excitation necessary to produce rated current on short circuit from the short circuit curve is .81 Amp. The no load voltage corresponding to this excitation from the no load saturation curve is 173 volts. Adding this at right angles to the 229.34 volts we have

$$\sqrt{(229.34)^2 + (173)^2} = 287 \text{ volts}$$

$$\text{Regulation} = \frac{287 - 220}{220} = 30.4\%$$

M.M.F. METHOD.

100% P.F.

The field current corresponding to 229.34 volts on the saturation curve is $I_1 = 1.08$. The field current corresponding to 26.25 amps. on the short circuit curve is $I_2 = .81$ amp. Adding these two values at right angles we have

$$I_3 = \sqrt{(1.08)^2 + (.81)^2} = 1.35 \text{ amps.}$$

The voltage corresponding to this field current on the no-load saturation curve is 277 volts

$$\text{Regulation} = \frac{277 - 220}{220} = 25.9\%$$

REGULATION BY E.M.F. METHOD

80% P.F.

Rated current same as above = 26.25 amps.

Resistance, as before, = .411 ohms.

Armature IR drop = 9.34 volts.

The terminal voltage may be considered as consisting of two components, one in phase with the current and the other at right angles to it. The E.M.F. in phase with the current is $E_1 = E \times .8 = 220 \times .8 = 176$ volts.

The E.M.F. at right angles to the current is

$$E_2 = E \times \sin \cos^{-1} .8 = 220 \times .6 = 132 \text{ volts}$$

Adding, - $176 + 9.34 = 185.34$ volts.

The impedence voltage as obtained from saturation and short circuit curves as before is 173 volts.

Adding,- $173 + 132 = 305$ volts. Total E.M.F. at right angles to the current.

Adding vectorially as before we have,

$$\sqrt{(305)^2 + (185.34)^2} = 357 \text{ volts}$$

$$\text{Regulation} = \frac{357 - 220}{220} = 62.3\%$$

REGULATION BY THE M.M.F. METHOD

80% P.F.

$$I = \frac{26.25}{\%P.F.} = \frac{26.25}{.8} = 32.8$$

In this case $I_3 = \sqrt{I_1^2 + I_2^2 + 2I_1I_2 \sin \cos^{-1}.8}$

$$I_3 = \sqrt{(1.08)^2 + (.81)^2 + 2 \times 1.08 \times .81 \times .6}$$

$$= \sqrt{2.876} = 1.695$$

The voltage corresponding to this field current from the no load saturation curve is 330 volts

$$\text{Regulation} = \frac{330 - 220}{220} = 50\%$$

REGULATION BY ACTUAL LOADING.

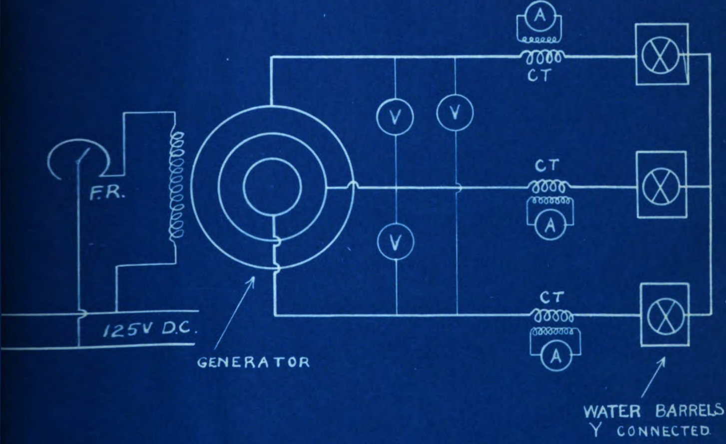
The connections for this test are shown on the blue print.

Machine was run by the induction motor and the D.C. motor working together. The reason for this was that neither machine, working alone was able to maintain the rated speed when the alternator was carrying full load.

The alternator was loaded to its rated current capacity and the voltage adjusted to 220. Then the load was thrown off and holding the same speed, open circuit voltage was read. This test was repeated several times and the regulation is obtained directly from the voltage readings. Following are the results obtained by this method:

REGULATION BY ACTUAL LOADING.
A.C. GENERATOR.

CONNECTION DIAGRAM.



APPARATUS USED

NO	KIND	RANGE.
3	WESTON A.C. AMMETERS	0 - 5 AMPS
3	" " VOLTMETERS	0 - 500 V.
3	" CURRENT TRANSFORMERS	50-5 100-5
3	WATER BARRELS.	

THESIS H.H.&B
1915.

TEST DATA. REGULATION BY ACTUAL LOADING.
(Original)

	Phase B.	Phase C.	Phase A.	Phase B - C	Phase A - B	Phase A - C	RPM.
	I	I	I	E	E	E	
Inst.No.	113	114	110	122	121	123	140
Constant	10	20	10	1	1	1	1
	2.65	1.25	2.6	219	219	220	1815
	0	0	0	270	270	270	1815
	2.58	1.07	2.67	219	217	223	1815
	0	0	0	269	268	269	1815
	2.63	1.31	2.5	219	220	220	1812
	0	0	0	268	268	269	1812
	2.62	1.29	2.65	222	221	220	1808
	0	0	0	278	278	278	1808
	2.61	1.31	2.61	220	218	218	1800
	0	0	0	271	271	272	1800

Corrected data.

						% Reg.
26.8	24.8	26.4	219	219	220	18.88
0	0	0	270	270	270	
26.1	21.2	27	219	217	223	18.38
0	0	0	269	268	269	
26.6	26	25.5	219	220	220	18.15
0	0	0	268	268	269	
26.5	25.8	26.9	222	221	220	20.5
0	0	0	278	278	278	
26.4	26	26.5	220	218	218	19.4
0	0	0	271	271	272	
					Average	19.06

COMPARISON OF THE REGULATION AS DETERMINED

BY DIFFERENT METHODS.

E.M.F. Method 100% P.F. - - - - - - - - - - - - - - 30.4%

M.M.F. Method 100% P.F. - - - - - - - - - - - - - - 25.9%

Actual Loading - - - - - - - - - - - - - - - - - - 19.06%

BRAKE TEST ON A.C. GENERATOR
running as
A SYNCHRONOUS MOTOR.

The purpose of this test was to determine the performance of the A.C. generator while running as a synchronous motor.

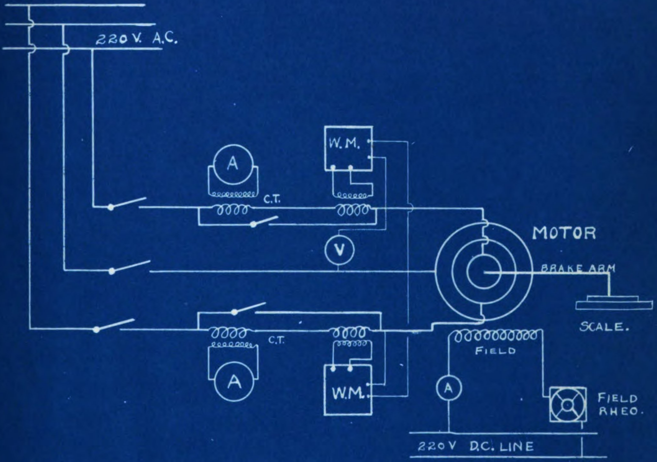
The motor was started by throwing a low voltage on to the machine without any field excitation, thus starting it as an induction motor. When its speed had nearly reached synchronism the voltage of the line was raised to normal and the field switch closed. When we did this the motor came quietly into step and ran synchronously with the large alternator. The field rheostat was adjusted to give unity power factor or until the line ammeter readings were the lowest at a given load. The load was applied by means of the pony brake, starting at 0 and increasing by 2# increments until the motor went out of synchronism and stopped.

At each load readings were taken of watts input, amps. input, volts, R.P.M., and load. The two watt meter method of three phase power measurement was used.

From the data obtained curves were plotted with horse power output as abscissae and amps. input, per cent efficieny, per cent power factor, and torque as ordinates.

BRAKE TEST ON ALTERNATOR AS A SYNCHRONOUS MOTOR

CONNECTION DIAGRAM



APPARATUS USED

NO	KIND	RANGE
2	WESTON WATTMETERS	0-20 AMPS 0-300 VOLTS 0-3 KW
3	" AMMETERS A.C.	0-5 AMPS
2	CURRENT TRANSFORMERS	25-5 AMPS used with W.M.
2	" "	50-5 " " " AMMETERS.
1	WESTON VOLTMETER AC	0-500V
3	FIELD RHEOSTATS	
1	D.C. AMMETER	0-10 AMPS.

THESIS - H. H. & B.
1915.

Test data

BRAKE TEST ON SYNCHRONOUS MOTOR.
(Original data).

Length of brake arm = 30 in.

Weight of brake arm = 6.5 lbs.

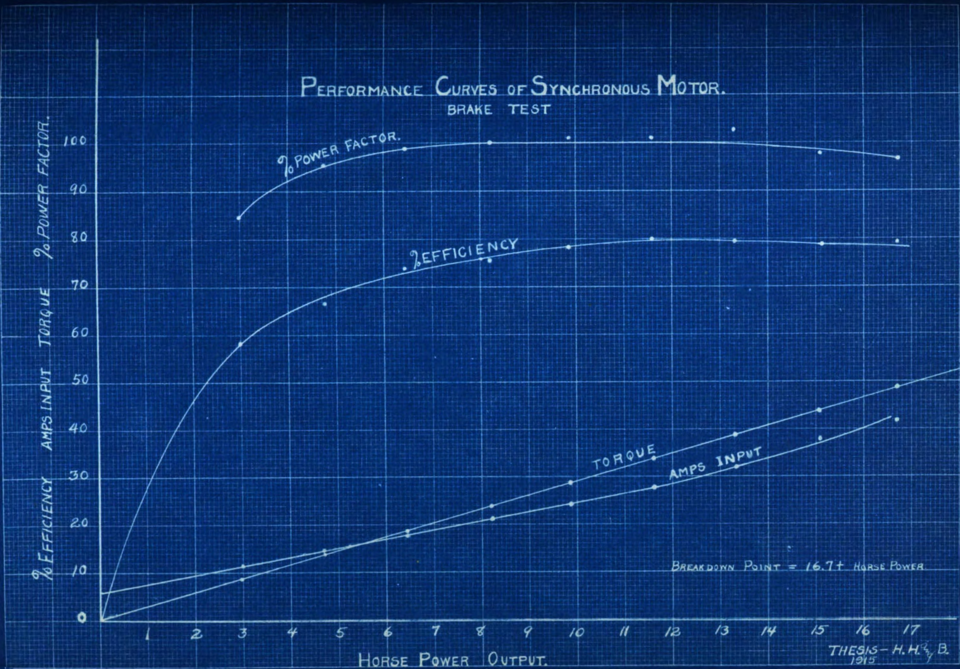
	PHASE A		PHASE C				
	KW	I	KW	I	E	R.P.M.	Load lbs.
Inst. No.	31	111	30	110	121	140	
Constant	10	10	10	10	1	1	
	.26	1.25	.12	1.08	223	1790	10 (1)
	.33	1.5	.2	1.37	223	1808	12 (2)
	.39	1.8	.26	1.7	219	1806	14 (3)
	.45	2.15	.36	2.05	220	1810	16 (4)
	.49	2.5	.45	2.4	218	1810	18 (5)
	.55	2.8	.53	2.75	222	1804	20 (6)
	.59	3.2	.665	3.15	221	1806	22 (7)
	.64	3.85	.78	3.8	220	1807	24 (8)
	.65	4.2	.91	4.15	223	1803	26 (9)

Motor broke down at this point at a little over fifty amperes.

Corrected data.

PHASE A		PHASE C				
KW.	I	KW.	I	E	R.P.M.	Load lbs.
2.6	12.5	1.2	10.8	222	1790	3.5 (1)
3.3	15	2	13.8	222	1808	5.5 (2)
3.9	17.9	2.6	17.1	218	1806	7.5 (3)
4.5	21.4	3.6	20.5	220	1810	9.5 (4)
4.9	25.25	4.5	24.2	217	1800	11.5 (5)
5.5	28.3	5.3	27.7	221	1804	13.5 (6)
5.9	32.3	6.65	31.7	220	1806	15.5 (7)
6.4	38.6	7.8	38.1	219	1807	17.5 (8)
6.5	42.1	9.1	41.5	222	1803	19.5 (9)

Total KW.	Av. I	H.P. Input	H.P. Output	% Eff.	% P.F.	Torque Ft.lbs.	
3.8	11.65	5.1	2.98	58.4	84.8	8.75	(1
5.3	14.4	7.1	4.73	66.6	95.9	13.75	(2
6.5	17.5	8.71	6.44	73.9	98.5	18.75	(3
8.1	21.05	10.86	8.2	75.5	100	23.75	(4
9.4	24.73	12.6	9.85	78.2	101	28.75	(5
10.8	28	14.48	11.6	80.2	101	33.75	(6
12.55	32	16.8	13.31	79.3	103	38.75	(7
14.2	38.35	19.02	15.08	79	97.6	43.75	(8
15.6	41.8	20.9	16.7	79.8	96.9	48.75	(9


PERFORMANCE CURVES OF SYNCHRONOUS MOTOR.
BRAKE TEST
% POWER FACTOR.
% EFFICIENCY
TORQUE
AMPS INPUT
% EFFICIENCY AMPS INPUT TORQUE % POWER FACTOR.
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
HORSE POWER OUTPUT.
BREAKDOWN POINT = 16.7+ HORSE POWER
THESIS - H.H. & B.
1915

SYNCHRONOUS MOTOR V. CURVES.

The object of this test is to show the relation of the armature current and power factor to the excitation of a Synchronous Motor.

The connections were made the same as shown on the Synchronous Motor brake test connection diagram, except that several rheostats and an ammeter were placed in the field circuit of the motor. The machine was started on low voltage as an Induction Motor and when nearly synchronous speed was reached the field switch was closed and the motor came into step. The motor will run synchronously regardless of the field current within certain limits. If the field current is weak the motor will draw a large lagging current, while if the field current is above normal it will draw a large leading current, there being one value of field current at which the line current and E. M.F. are in phase, or at which the power factor is unity.

In conducting this test the load was kept absolutely constant. The field current was reduced until the motor drew about rated current, then the field was increased by steps until the line current had reached a minimum and again increased to about the same value as at the start. The voltage and frequency were held constant at 220 volts and 60 cycles respectfully. Readings were taken of Amps. per phase, Watts input, Volts, R.P.M., and field Amps. for each value of the field current. The test was performed with the motor running free and repeated at approximately half load.

From this data curves were plotted with field Amps. as abscissae and line amps. as ordinates, also with field amps as abscissae and percentage power factor as ordinates.

SYNCHRONOUS MOTOR V-CURVES. (original).

Motor running free.

	PHASE A		PHASE C				Field	
	KW	I	KW.	I	E	R.P.M.	I	
Inst.No.	31	111	30	110	121	140	11	
Con stant	10	10	10	10	1	1	.1	
	-.18	2.33	.34	2.42	220	1795	3.5	(1)
	-.12	1.72	.24	1.8	220	1800	5.0	(2)
	-.09	1.45	.21	1.5	220	1800	6.0	(3)
	-.04	.8	.14	.9	220	1800	8.0	(4)
	.04	.3	.06	.2	220	1800	10.0	(5)
	.12	.7	-.03	.65	220	1800	12	(6)
	.19	1.8	-.08	1.65	220	1803	14	(7)
	.28	1.95	-.15	1.82	220	1800	16	(8)
	.36	2.65	-.21	2.55	220	1800	18	(9)
	.45	3.1	-.27	3	220	1805	20	(10)

Brake load 12 pounds (approx. 1/2 load).

-.01	2.95	.54	3.0	220	1800	3.0	(11)
.07	2.5	.49	2.6	220	1795	4.3	(12)
.08	2.25	.44	2.3	220	1800	5.5	(13)
.06	2.2	.45	2.25	220	1800	5.7	(14)
.13	1.8	.38	1.85	220	1800	7.0	(15)
.13	1.6	.35	1.6	220	1800	7.8	(16)
.23	1.3	.25	1.2	220	1800	10.0	(17)
.31	1.4	.19	1.3	220	1805	12	(18)
.39	1.8	.12	1.7	220	1800	14	(19)
.47	2.3	.05	2.2	220	1800	16	(20)
.56	2.85	0	2.75	220	1800	18	(21)
.65	3.55	-.06	3.45	220	1800	20	(22)

Corrected data.

Machine running free.

PHASE A		PHASE C			
KW.	I	KW.	I	E	
-1.8	23.5	3.4	24.5	219	(1)
-1.2	17.3	2.4	18	"	(2)
- .9	14.5	2.1	15.2	"	(3)
-.4	8	1.4	9	"	(4)
.4	3	.6	2	"	(5)
1.2	7	-.3	6.5	"	(6)
1.9	18.1	-.8	16.6	"	(7)
2.8	19.7	-1.5	18.2	"	(8)
3.6	26.8	-2.1	26	"	(9)
4.5	31.3	-2.7	30.2	"	(10)

Corrected data.

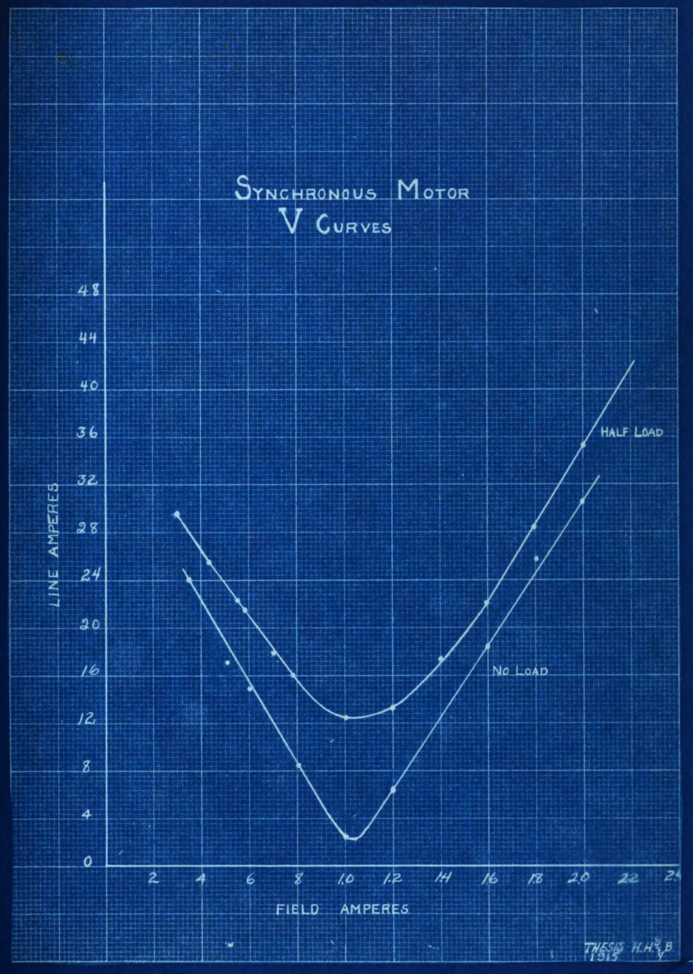
Machine running free. (Continued).

AV. I	Total KW.	R.P.M.	% P.F.		Field I	
24	1.6	1795	17.55	Lagging.	.35	(1)
17.65	1.2	1800	17.9	"	.5	(2)
14.85	1.2	1800	21.3	"	.6	(3)
8.5	1.0	1800	31	"	.8	(4)
2.5	1.0	1800	105		1.0	(5)
6.75	.9	1800	35.2	leading	1.2	(6)
17.35	1.1	1803	16.75	"	1.4	(7)
18.95	1.3	1800	18	"	1.6	(8)
26.4	1.5	1800	15	"	1.08	(9)
30.75	1.8	1805	15.4	"	2.0	(10)

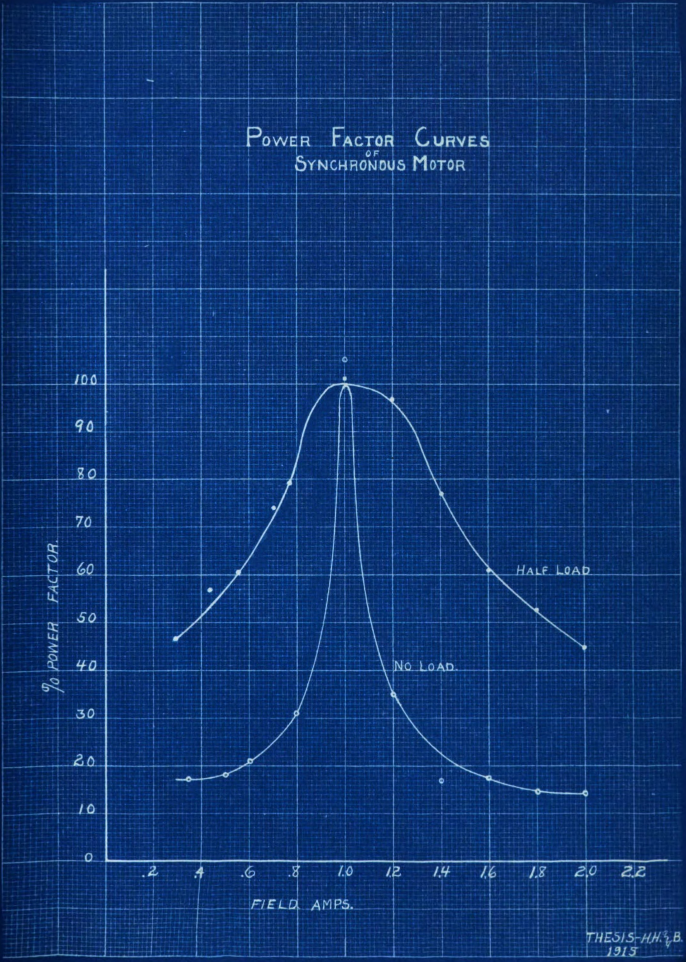
Brake load 12 pounds (approx. 1/2 load).

PHASE A		PHASE C			
KW	I	KW	I	E	
-.1	29.9	5.4	30.4	219	(11)
.7	25.3	4.9	26.3	"	(12)
.8	22.5	4.4	23.	"	(13)
.6	22	4.5	22.5	"	(14)
1.3	17.9	3.8	18.4	"	(15)
1.3	16	3.5	16	"	(16)
2.3	13	2.5	12	"	(17)
3.1	14	1.9	13	"	(18)
3.9	17.9	1.2	16.9	"	(19)
4.7	23	.5	22	"	(20)
5.6	28.7	0	27.8	"	(21)
6.5	35.6	-.6	34.6	"	(22)

Av. I	Total KW.	R.P.M.	% P.F.		Field I	
30.15	5.3	1800	46.4	lagging	.3	(11)
28.8	5.6	1795	57.2	"	.43	(12)
22.7	5.2	1800	60.4	"	.55	(13)
22.25	5.1	1800	60.5	"	.57	(14)
18.15	5.1	1800	74	"	.7	(15)
16.	4.8	1800	79	"	.78	(16)
12.5	4.8	1800	101		1.0	(17)
13.5	5.0	1805	97.5	leading	1.2	(18)
17.4	5.1	1800	77.2	"	1.4	(19)
22.5	5.2	1800	61	"	1.6	(20)
28.2	5.6	1800	52.4	"	1.8	(21)
35.1	5.9	1800	44.2	"	2	(22)



SYNCHRONOUS MOTOR
V CURVES
48
44
40
36
32
28
24
20
16
12
8
4
0
LINE AMPERES
2
4
6
8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
HALF LOAD
NO LOAD
FIELD AMPERES
THESIS H.H. & B.
1915



POWER FACTOR CURVES
OF
SYNCHRONOUS MOTOR
% POWER FACTOR.
100
90
80
70
60
50
40
30
20
10
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
FIELD AMPS.
HALF LOAD
NO LOAD.
THESIS-H.H.&B.
1915

CORE LOSS TEST ON ALTERNATING CURRENT GENERATOR.

This test was run with the same machine as a driving motor, and by the same method as was used in the core loss tests on the Direct Current Machine. The only difference between the two was the running of the former test at one speed, because of this machine being designed for 1800 R.P.M.

A curve was then plotted with field Amps. as abscissae and core loss as ordinates.

CORE LOSS TEST. (Original).

Brushes down, field excited, of A.C. generator.

Driving motor running against the brushes.

	Driving motor				A.C. generator			
	Arm. KW.	Arm. I	Arm E	Field E	Arm. E	Field E	Field I	RPM.
Inst. No.	30	10	20	23	121	22	11	140
Constant	1	1	1	1	1	1	0.1	
	1.015	11.8	88	45	0	0	0	1800
	1.03	12.0	88	"	40	12	2.7	"
	1.025	12.1	88	"	61	15	3.5	"
	1.0	11.75	86	"	75	17.5	4.0	"
	1.01	11.8	87	"	87	21	4.5	"
	1.038	12	87	"	100	23	5.0	"
	1.036	---	87	"	115	27.5	6.0	"
	1.05	12.25	88	"	132	31	7.0	"
	1.055	12.4	87	"	135	31	7.0	"
	1.1	12.7	89	"	154	36.5	8.0	"
	1.132	13.0	89	"	180	43	9.0	"
	1.19	13.6	88	"	203	49	10.1	"
	1.225	14.2	88	"	223	44	11	"
	1.289	14.65	88	"	247	60	12.3	"
	1.405	15.8	90	"	283	72	14.5	"
Constant	2							
	.759	17.15	90	45	305	78	16	1800
	.78	17.6	90	"	323	85	19	"
	.62	14.4	90	"	248	60	12	"
Constant	1							
	1.135	13.1	90	"	190	44	9	1800
	1.05	12.1	88	"	147	33.5	7	"
	.979	11.4	87	"	98	22	5	"
	.905	10.5	87	"	60	14	3	"
	.89	10.4	87	"	0	0	0	"

WINDAGE AND BEARING FRICTION.

Brushes raised, 0 field, of A.C. generator.

Driving motor running against the brushes.

	KW.	I	Field E	R.P.M.
Inst. No.	30	10	23	140
Constant	1	1	1	1
	.65	7.6	45	1800
	.635	7.5	"	"
	.64	7.5	"	"

CORE LOSS TEST. (Corrected data).

Brushes down, field excited, of A.C. Generator.

Driving motor running against the brushes.

Driving motor								
Field E	Arm. I	Arm. E	Watts	EI Input	Arm. Res.	I^2R loss	Watts - I^2R	
45	11.9	85.5	1015	1018	.395	56	959	(1)
"	12.1	85.5	1030	1035	.395	57.8	972	(2)
"	12.2	85.5	1035	1042	.395	58.8	976.2	(3)
"	11.85	85.5	1000	1015	.395	55.3	944.7	(4)
"	11.9	83.6	1010	1000	.395	56.0	954	(5)
"	12.1	84.5	1038	1022	.395	57.8	980.2	(6)
"	---	84.5	1036	-----	----	----	----	(7)
"	12.35	84.5	1050	1045	.39	59.3	990.7	(8)
"	12.5	85.5	1055	1068	.39	61.0	994.0	(9)
"	12.8	84.5	1100	1081	.39	63.8	1036.2	(10)
"	13.1	86.5	1132	1132	.39	67	1065	(11)
"	13.7	86.5	1190	1185	.39	73.2	116.8	(12)
"	14.3	85.5	1225	1223	.29	79.8	1145.2	(13)
"	14.75	85.5	1289	1262	.39	84.9	1204.1	(14)
"	15.95	87.4	1405	1496	.39	99.2	1305.8	(15)
"	17.3	87.4	1518	1512	.39	108.3	1409.7	(16)
"	17.75	87.4	1560	1553	.39	123	1437.0	(17)
"	14.5	87.4	1240	1268	.39	82	1158.0	(18)
"	13.2	87.4	1135	1153	.39	68	1067	(19)
"	12.2	85.5	1050	1043	.395	58.8	991.2	(20)
"	11.5	84.5	979	972	.397	52.4	926.6	(21)
"	10.6	84.5	905	896	.402	45.2	859.8	(22)
"	10.5	84.5	890	887	.402	44.3	845.7	(23)

A.C. Generator						
Total loss	Core loss	R.P.M.	Arm. E	Field E	Field I	
749	0	1800	0	0	0	(1)
762	71	"	40	12	.27	(2)
766.2	75	"	66	15	.35	(3)
734.7	43.7	"	78	17.5	.40	(4)
744.7	53.7	"	89	21	.45	(5)
770.2	78.5	"	100	23	.5	(6)
---	---	"	115	27.5	.6	(7)
780.7	89.7	"	133	31	.7	(8)
784.0	93	"	136	31	.7	(9)
826.2	135.2	"	155	36.4	.8	(10)
855.0	164	"	180	42.8	.9	(11)
906.8	215.8	"	203	48.6	1.01	(12)
935.2	244.2	"	224	43.7	1.1	(13)

CORE LOSS TEST. (Corrected data). Cont'd.

Total loss	Core loss	R.P.M.	Arm. E	Field E	Field I	
994.1	303.1	1800	248	59.5	1.23	(14)
1095.8	404.8	"	283	71.6	1.45	(15)
1199.7	508.7	"	305	77.4	1.6	(16)
1227.0	536	"	323	84.1	1.9	(17)
948	257	"	249	59.5	1.2	(18)
857	166	"	190	43.7	.9	(19)
781.2	90.2	"	148	33.5	.7	(20)
716.6	25.6	"	98	22	.5	(21)
649.8		"	64	14	.3	(22)
635.0		"	0	0	0	(23)

WINDAGE AND BEARING FRICTION. (Corrected data).

Brushes raised, 0 field, of A.C. generator.

Driving motor running against the brushes.

Field E	Arm. I	Watts	Arm. Res.	I^2R loss	Watts $- I^2R$
45	7.75	650	.44	26.4	623.6
"	7.65	635	.44	25.7	609.3
"	7.65	640	.44	25.7	614.3
				Average	615.7

BRUSH LOSS. (Calculated).

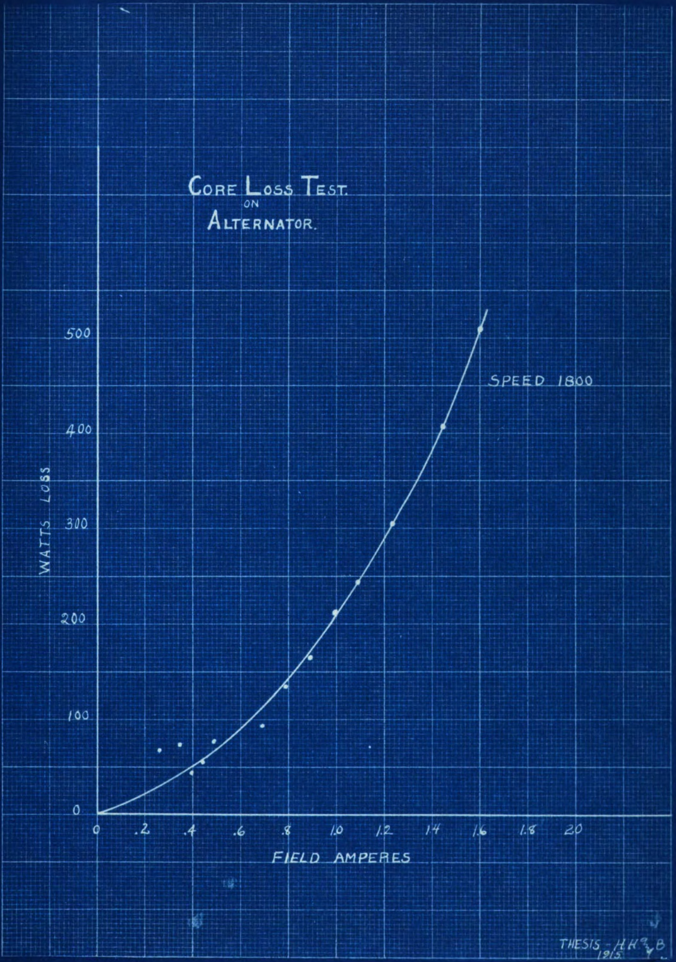
965 - (210 + 615.7) = 133.3 watts loss.

845.7 - (210 + 615.7) = 20 " "

Average 76.65 watts loss.

Note:

We contribute the comparatively poor results of of this test to the high speed of the machines varying the friction loss, of the coupling between the two machines.


CORE LOSS TEST
ON
ALTERNATOR.
SPEED 1800
WATTS LOSS
500
400
300
200
100
0
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
FIELD AMPERES
THESIS - H.H.&B.
1915.

GENERAL CONCLUSIONS DRAWN FROM TESTS ON ALTERNATING CURRENT GENERATOR.

The results of the test show that this machine performed very creditably, both as an alternating current three phase generator, and a synchronous motor.

The saturation curves show that the magnetic circuit is properly designed for 220 volts at a frequency of 60 cycles. The voltage regulation on actual load was found to be considerable better than as determined by either the E.M.F. or M.M.F. methods, and is as good as can be expected.

As a Synchronous Motor the machine ran very stable and was capable of carrying a fairly heavy overload. The efficiency as a motor is not as high as that of the Induction Motor. It is reasonably good, however, and holds up well to the break down point. The machine did not show signs of hunting at any time.