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Test of a Single Phase Commutator Motor

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE

By
Laurance
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Candidate for the Degree of

Bachelor of Science

June 1916

THESIS

PREFACE

The purpose in running a test on the 1 H.P. Alternating Current Commutator Motor as a thesis was, primarily, to get all of the data possible pertaining to this machine and, secondarily, to become entirely familiar with this type of electrical apparatus. A study has been made of its action under various loads, data taken and curves plotted from the calculated results, thereby giving a clear and complete record of the work taken up.

At first the question arose as to the best method to be used in making a test of this nature. The writer finally decided to use the prony brake throughout. The brake is capable of very fine adjustment which was the main reason for selecting this method.

Diagrammatic sketches have also been made of the motor and control box thereby illustrating the construction and operation of each.

L. F. C.

The first thing necessary, before the writer was able to start the testing, was to construct a prony brake. The construction of this brake is shown clearly by the accompanying drawing. The motor itself consists of a main field winding and a compensating winding on two of the poles. It is operated entirely in connection with the controller as shown in the sketch. A pulley, 6" X 4", was already fitted on the shaft. A voltage regulator was placed directly in the line. This regulator was necessary as the motor was rated to run on a 110 or 220 volt, 60 cycle circuit and the impressed voltage varied considerably from this. The source of E.M.F. was a rotary convertor. This rotary fluctuated in speed because of the fluctuation of the voltage on the D.C. side, this in turn caused the voltage to fluctuate on the A.C. side. To remedy this difficulty was beyond the control of the operator.

In spite of the fine adjustment obtainable by the voltage regulator the impressed voltage varied a slight amount. This in turn varied the speed of the motor so that it was necessary^{for} everything to be stable when the readings were taken. With the bringing out of a motor of this nature a wonderful work was accomplished. It is true of this machine, as with many other inventions, that when it first came out it was rather a crude piece of apparatus but by encountering difficulties one after another and overcoming these by various devices, it has grown today to be a wonderfully useful machine.

Improvements have by no means stopped as remarkable steps are being taken at the present time. It is remarkable because of the fact that the same machine can be made to act either as a series or a shunt motor with but very slight alterations. The fact of its great flexibility makes this type of A.C. motor exceptionally valuable. The developement of this line of apparatus has been slow but at the same time steady. It has been changed from the shunt variable speed motor to the constant speed motor which is desireable in many cases. It was later superceded by a brush shifting motor of double yoke construction which did not prove very satisfactory, but found a good market. A little later this type gave way to the single yoke construction and the sliding contacts were eliminated. Following this were other minor internal changes which tend toward improving the power-factor, torque etc.

LIST OF APPARATUS USED

MOTOR:

G. E. Single Phase Commutator Motor.
type RI, form A, amps 10.4 / 5.2
hp. 1, speed 1710, cycles 60, volts 110 / 220.

CONTROLLER:

Rheostat, Fort Wayne Electric Works.
CR. 172, cat. 114729, type RI,
hp. 1, cycles 60, volts 110 / 220.

WATTMETER:

Weston Portable Wattmeter.
max capacity 25 amps.
high range in volts 300, low 150.
" " " watts 6000, " 3000.
model 16, number 4995.

CURRENT TRANSFORMER:

Weston Switchboard Current Transformer.
model 236, type 1, No. 330, amps 25 to 5,
line voltage 2200, frequency 25 - 125,
watts 5.

AMMETER:

Weston Electrical Instrument Co.
model 155, range 5 amps. No. 8889.

VOLTMETER:

Weston Electrical Instrument Co.
model 156, range 250 - 500, No. 6822.

VOLTAGE REGULATOR:- Constructed at M.A.C. for thesis.

PRONY BRAKE:- As shown in this thesis.

SCALES:- Platform scales, range 5# on arm.

TACHOMETER:- Liquid type, range 2000 R.P.M. No. 489.

SYMBOLS USED

I	-----	current.
E	-----	volts.
#	-----	pounds weight.
T	-----	torque.
H.P.	-----	horse power.
hp.	-----	horse power.
Inst.	-----	instrument.
No.	-----	number.
Const.	-----	constant.
%	-----	percent.
Rdg.	-----	reading.
P.F.	-----	power factor.
Eff.	-----	efficiency.
R.P.M.	-----	rev. per. min.
W.	-----	watt.
W.M.	-----	wattmeter.
C.T.	-----	current transformer.
V.M.	-----	volt meter.
A.M.	-----	ammeter.
R.	-----	resistance.
Deg.	-----	degree.
C.	-----	centigrade.

BIBLIOGRAPHY

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Sheldon and Mason ----- Page 262.
Essentials of Elect. Eng. ----- John Fay Wilson.
Hawkins Electrical Guide ----- Hawkins.
Alternating Currents ----- Jackson. page 874.
A. C. Motors ----- McAllister.
Electrical Machine Design ----- Gray.
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" " " " ----- May, 1915.
Theory of S. P. C. M. ----- F. Creedy.
The Electric Journal ----- March, 1916.

Cold Resistance Measurements

The fall of potential method was used throughout in measuring the resistance of the different circuits. Readings of the voltage across the winding and the amperes input were taken as shown in the following tables.

Cold resistance of the Stator winding at 22.2 deg. C.

	E	I	R
Inst. No.	6792	2193	
Const.	1	1	
	.80	.60	1.330
	1.55	1.17	1.325
	2.25	1.70	1.324
	2.70	2.07	1.303
	3.35	2.50	1.340

Ave.= 1.324

Cold resistance of the Commutating winding at 22.2 deg. C.

	E	I	R
Inst. No.	6792	2193	
Const.	1	1	
	.55	1.20	.458
	.80	1.75	.457
	.95	2.10	.453
	1.20	2.70	.438
	1.40	3.20	.434

Ave.= .448

Cold resistance of Rotor winding at 22.2 deg. C.
Segments 1 - 52

	E	I	corrected E	computed R
Inst. No.	3668	2193		
Const.	.02	1		
	2.50	1.20	.050	.0416
	4.00	1.80	.080	.0444
	4.50	2.13	.090	.0422
	6.00	2.75	.120	.0436
	7.25	3.30	.145	.0439
			Ave.*	.0431

Segments 1-53

	E	I	corrected E	computed R
	.50	.60	.010	.01668
	1.00	1.23	.020	.01628
	1.50	1.80	.030	.01660
	2.00	2.35	.040	.01700
	2.20	2.77	.044	.01592
			Ave.=	.01650

BRAKE TEST

A brake test on any motor is the operation necessary to find principally the H.P. output of the machine. In connection with this it is desirable to know the H.P. input, torque, % slip, % power-factor and the % efficiency. To obtain these quantities it is necessary to place suitable instruments in the line, the readings of which will, either directly or indirectly, give the results wished. In this test a voltmeter, ammeter and wattmeter were placed in the circuit, connecting all in the usual way. For the purpose of getting as accurate readings as possible a, 5 to 1, transformer was put in the line. Because of this much closer readings of the instrument were possible than before, as this meter read only five amps for full scale deflection. The voltage and frequency were kept constant at all time. From the instruments the operator read the volts, amperes input and watts.

On one end of the brake arm was constructed a knife edge exactly 1.5 feet from the center of the motor shaft and supported on a platform scale. The point of support was in the same horizontal plane as the center of the motor shaft. This scale was accurately balanced with the motor at rest. After the motor was running the weight was advanced on the scale arm by increments of $1/4$ pound each. At each new position the scale was balanced by means of tightening up on the brake band. Five tests were run in all,

one on each of the following points;- R-1, R-3, R-6, R-9, R-11.
 All readings were taken at each change of load and the following results were computed from, the curves were plotted as shown in the succeeding pages.

Formulae:

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

$$\text{Torque} = \text{weight on brake arm} \times \text{length of arm in feet} = \text{ft. lbs.}$$

$$\text{H.P.Output} = \frac{2\pi wln}{33000}$$

Where w = # wt. on arm.
 " l = length of arm in ft.
 " n = R.P.M. of motor

$$\% \text{ Slip} = \frac{1800 - \text{R.P.M.}}{1800} \times 100$$

$$\% \text{ P.F.} = \cos \phi = \frac{\text{watts input}}{\text{E} \times \text{I.}} \times 100$$

$$\% \text{ Eff.} = \frac{\text{H.P.Output}}{\text{H.P.Input}} \times 100$$

Brake test with regulator arm on contact point R-1.

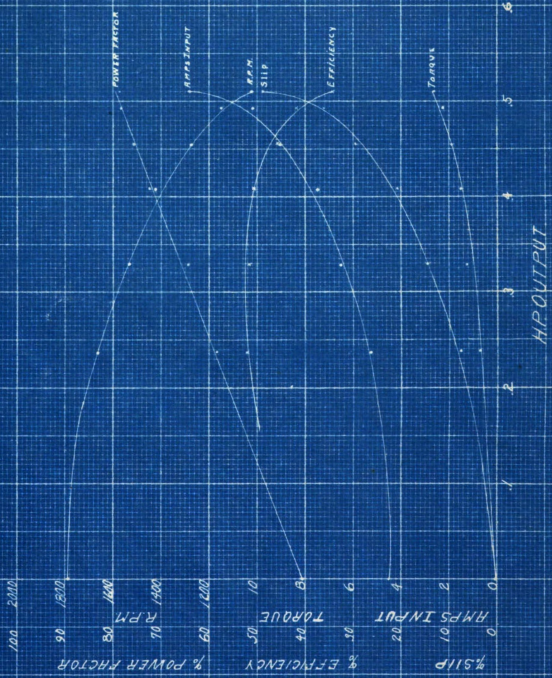
Test Data

Meter # Const.	Rdg.No.	Wt.#	Volts 6822 1	Amps 8892 5	Kilo- Watts 4995 1	R.P.M.
	1	0.00	110	.90	.20	1790
	2	0.50	110	1.06	.34	1660
	3	0.75	110	1.30	.46	1535
	4	1.00	110	1.51	.60	1425
	5	1.25	110	1.80	.75	1270
	6	1.50	110	2.04	.88	1150
	7	1.75	110	2.57	1.11	920
		2.00	Motor stopped			

Calculated Results

Rdg. No.	Hp. Input	Torque	Hp. Output	% Slip	% P.F.	% Eff.
1	.268	0.000	.000	0.01	40.4	0.00
2	.455	0.750	.237	7.78	58.3	58.10
3	.615	1.125	.328	14.70	64.2	51.70
4	.805	1.500	.407	20.80	72.4	50.60
5	1.003	1.875	.453	29.40	75.7	45.20
6	1.180	2.250	.493	36.10	78.4	41.80
7	1.490	2.625	.510	48.90	78.7	34.20

CHARACTERISTIC CURVES OF MOTOR
WITH ARM ON POINT "1"



Brake test with regulator arm on contact point R-3

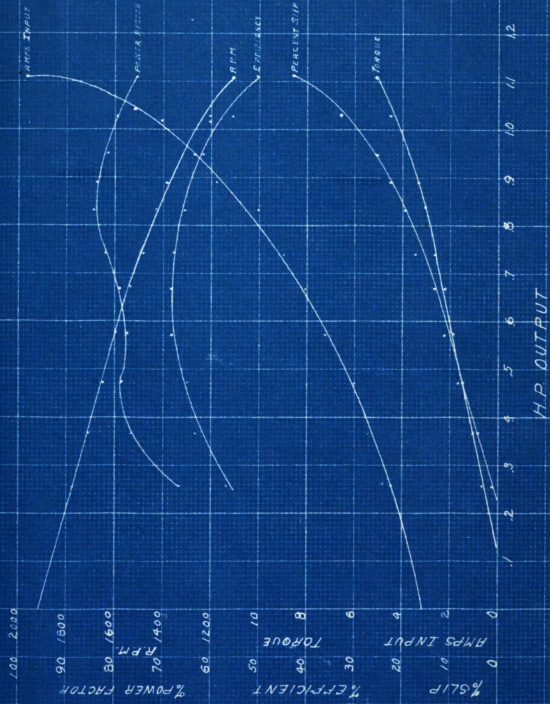
Test Data

Meter # Const.	Rdg.No.	Wt.#	Volts	Amps	Kilo- Watts	R.P.M.
			6822 1	8892 5	4995 1	
	1	0.00	110	.80	.20	1815
	2	0.50	110	1.00	.32	1705
	3	0.75	110	1.22	.46	1610
	4	1.00	110	1.45	.57	1520
	5	1.25	110	1.60	.68	1440
	6	1.50	110	1.85	.80	1360
	7	1.75	110	2.15	.93	1230
	8	2.00	110	2.48	1.08	1120
	9	2.25	110	2.82	1.26	980
	10	2.50	110	3.63	1.54	670
		2.75	Motor stopped			

Calculated Results

Rdg. No.	Hp. Input	Torque	Hp. Output	% Slip	% P.F.	% Eff.
1	.268	0.000	.000	0.84	45.5	0.00
2	.430	0.750	.244	5.50	58.1	56.70
3	.617	1.125	.344	10.60	69.6	61.00
4	.713	1.500	.435	15.50	71.5	56.40
5	.912	1.875	.514	20.00	77.0	54.40
6	1.070	2.250	.582	24.40	78.8	56.00
7	1.245	2.625	.615	31.70	78.8	49.40
8	1.450	3.000	.640	37.80	80.3	44.00
9	1.690	3.375	.629	45.60	81.2	37.10
10	2.060	3.750	.478	62.80	77.2	23.20

CHARACTERISTIC CURVES OF MOTOR WITH ARM ON POINT R_2



Brake test with regulator arm on contact point R-6.

Test Data

Meter # Const.	Rdg.No.	Wt.#	Volts	Amps	Kilo- Watts	R.P.M.
			6822 1	8892 5	4995 1	
	1	0.00	110	0.80	.20	1840
	2	0.50	110	1.03	.36	1730
	3	0.75	110	1.20	.46	1670
	4	1.00	110	1.39	.56	1590
	5	1.25	110	1.54	.65	1510
	6	1.50	110	1.70	.74	1450
	7	1.75	110	1.94	.86	1390
	8	2.00	110	2.22	.96	1310
	9	2.25	110	2.55	1.12	1225
	10	2.50	110	2.90	1.28	1130
	11	2.75	110	3.32	1.40	980
		3.00	Motor stopped			

Calculated Results

Rdg. No.	Hp. Input	Torque	Hp. Output	% Slip	% P.F.	% Eff.
1	.268	0.000	.000	-2.22	45.5	0.00
2	.482	0.750	.246	3.89	63.6	51.20
3	.617	1.125	.357	7.23	69.6	57.80
4	.750	1.500	.454	11.66	73.3	60.50
5	.872	1.875	.565	16.10	76.7	65.00
6	.993	2.250	.621	19.44	79.2	62.50
7	1.150	2.625	.645	22.80	80.6	60.40
8	1.286	3.000	.717	27.20	77.8	58.20
9	1.500	3.375	.786	31.95	80.7	51.50
10	1.715	3.750	.806	37.20	80.3	47.10
11	1.878	4.125	.847	45.50	84.0	45.20

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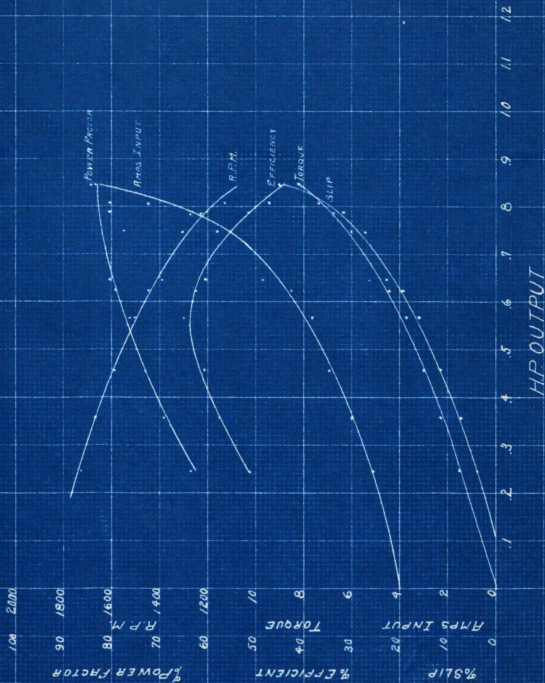
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CHARACTERISTIC CURVES OF MOTOR
WITH ARM ON POINT "A"



Brake test with regulator arm on contact R.9.

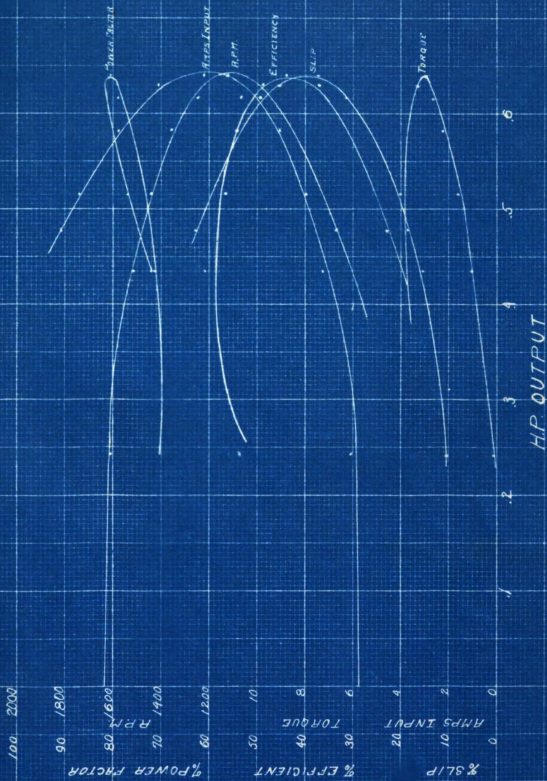
Test Data

Meter #	Rdg.No.	Wt.#	Volts	Amps	Kilo-Watts	R.P.M.
Const.			6822	8892	4995	
			1	5	1	
	1	0.00	110	.80	.20	1865
	2	0.50	110	.90	.33	1775
	3	0.75	110	1.10	.43	1715
	4	1.00	110	1.30	.54	1645
	5	1.25	110	1.45	.62	1600
	6	1.50	110	1.61	.70	1550
	7	1.75	110	1.81	.81	1480
	8	2.00	110	2.03	.94	1450
	9	2.25	110	2.24	1.03	1390
	10	2.50	110	2.54	1.14	1325
	11	2.75	110	2.81	1.27	1300
	12	3.00	110	3.18	1.38	1200
	13	3.25	110	3.58	1.50	1120
	14	3.50	110	3.94	1.64	1110
		3.75	Motor stopped			

Calculated Results.

Rdg. No.	Hp. Input	Torque	Hp. Output	% Slip	% P.F.	% Eff.
1	.268	1.125	.000	-3.61	45.5	0.00
2	.443	.750	.254	1.39	66.6	57.1
3	.576	1.125	.367	4.72	77.5	63.7
4	.724	1.500	.470	8.62	78.8	65.0
5	.830	1.875	.570	11.10	77.6	68.6
6	.937	2.250	.664	13.90	79.1	68.3
7	1.085	2.625	.740	17.77	81.6	68.2
8	1.260	3.000	.830	19.45	84.3	65.8
9	1.380	3.375	.892	22.80	83.8	64.6
10	1.530	3.750	.945	25.40	81.8	61.8
11	1.700	4.125	1.020	27.80	80.8	60.0
12	1.850	4.500	1.028	33.30	78.0	55.5
13	2.010	4.875	1.038	37.80	76.2	51.7
14	2.200	5.250	1.110	43.80	75.8	50.5

CHARACTERISTIC CURVES OF MOTOR WITH ARM ON POINT R_2



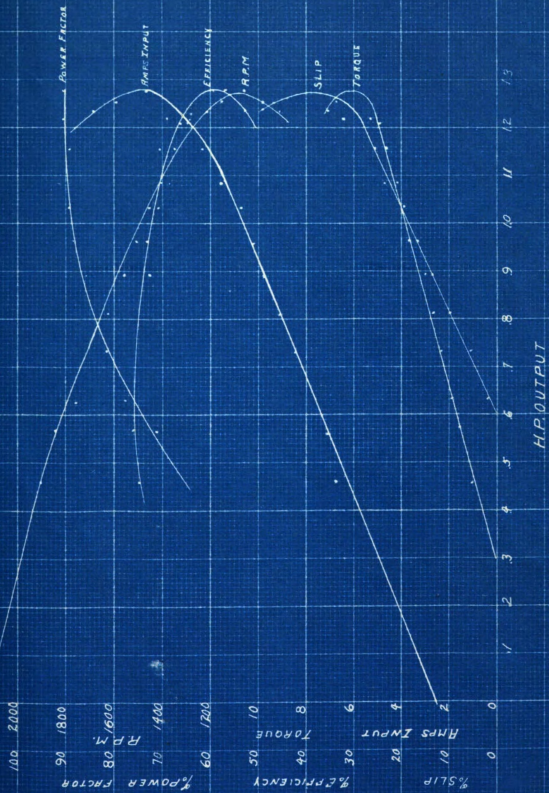
Brake test with regulator arm on last contact point.

Meter # Const.	Rdg.No.	Test Data			Kilo- Watts 4995	R.P.M.
		Wt.#	Volts	Amps		
			6822	8892		
			1	5	1	
	1	0.00	110	1.35	.30	2130
	2	1.00	110	1.43	.56	1965
	3	1.25	110	1.55	.66	1760
	4	1.50	110	1.68	.73	1705
	5	1.75	110	1.80	.80	1620
	6	2.00	110	1.91	.90	1560
	7	2.25	110	2.04	.99	1500
	8	2.50	110	2.14	1.05	1450
	9	2.75	110	2.32	1.14	1375
	10	3.00	110	2.46	1.23	1350
	11	3.25	110	2.56	1.27	1300
	12	3.50	110	2.76	1.37	1215
	13	3.75	110	2.89	1.42	1130
	14	4.00	110	3.07	1.53	1120
	15	4.25	110	3.18	1.58	1050
	16	4.50	110	3.37	1.62	970
	17	4.75	110	3.60	1.74	900
	18	5.00	110	3.77	1.82	880
	19	5.25	110	3.91	1.85	800

Calculated Results

Rdg. No.	Hp. Input	Torque	Hp. Output	% Slip	% P.F.	% Eff.
1	.537	1.125	.432	-18.32	40.500	80.0
2	.750	1.500	.563	-9.16	72.100	75.0
3	.885	1.875	.628	2.22	77.400	70.9
4	.978	2.250	.730	5.28	81.800	74.7
5	1.070	2.625	.810	10.00	80.700	75.7
6	1.206	3.000	.892	13.32	85.500	74.0
7	1.327	3.375	.963	16.68	88.200	72.6
8	1.408	3.750	1.035	19.44	89.000	73.7
9	1.527	4.125	1.080	23.60	89.100	70.8
10	1.650	4.500	1.157	25.00	89.200	70.1
11	1.700	4.875	1.205	27.80	90.800	70.8
12	1.835	5.250	1.215	32.50	90.200	66.3
13	1.900	5.625	1.210	37.25	89.500	63.7
14	2.050	6.000	1.280	37.70	90.800	63.7
15	2.120	6.375	1.271	41.60	90.400	60.2
16	2.175	6.750	1.250	46.20	87.600	57.5
17	2.335	7.125	1.220	50.00	88.000	52.3
18	2.440	7.500	1.258	51.00	87.600	51.5
19	2.480	7.875	1.200	55.60	87.600	48.5

CHARACTERISTIC CURVES OF MOTOR ON POINT "A"



Constant Torque Test

A constant torque test is made for the purpose of showing how the other quantities vary, while the torque is held constant. Two tests were made one with 1 # weight and one with 1.75 # on the scale arm. The method employed for making this test was as follows:

As in the brake test, the voltage and frequency were kept constant. When the regulating arm was put on the first point, R-1, the motor started and the scale arm was balanced by adjusting the brake on the pulley. When the conditions became stable a reading was taken of the speed, volts, amperes input and watts. The regulator arm was then advanced to the second point, R-2, the scale was again balanced, and when running conditions became stable all readings were again taken. This method was continued for the entire number of contact points. Calculated results and corresponding curves are shown on the succeeding pages. The formulae used are shown on the following page.

Constant Torque Test

Formulae:

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

Torque in ft. lbs. = weight on brake arm x length
of arm in feet.

$$\text{H.P.Output} = \frac{2\pi wln}{33000}$$

Where w = # wt. on arm.
" l = length of arm in ft.
" n = R.P.M. of motor.

$$\% \text{ Slip} = \frac{1800 - \text{R.P.M.}}{1800} \times 100$$

$$\% \text{ P.F.} = \cos \phi = \frac{\text{watts input}}{E \times I} \times 100$$

$$\% \text{ Eff.} = \frac{\text{H.P.Output}}{\text{H.P.Input}} \times 100$$

Constant Torque test with 1 # on scale arm.

Test Data						
Meter #	Rdg.No.	Cont.No.	Volts	Amps	Kilo Watts	R.P.M.
Const.			6822 1	8892 5	4995 1	
	1	1	110	1.45	.58	1440
	2	R-1	110	1.45	.58	1445
	3	R-2	110	1.42	.56	1490
	4	R-3	110	1.40	.54	1555
	5	R-4	110	1.38	.54	1570
	6	R-5	110	1.36	.53	1600
	7	R-6	110	1.29	.50	1640
	8	R-7	110	1.30	.54	1655
	9	R-8	110	1.35	.56	1675
	10	R-9	110	1.32	.55	1650
	11	R-10	110	1.30	.54	1675
	12	R-11	110	1.20	.52	1700
	13	R-12	110	1.20	.52	1700
	13	R-13	110	1.36	.54	1740
	14	L.P.	110	1.41	.55	1790

Calculated Results

Rdg. No.	Hp. Input	Torque	Hp. Output	% Slip	% P.F.	% Eff.
1	.777	1.5	.411	20.00	72.8	51.6
2	.777	"	.415	19.15	72.8	51.7
3	.750	"	.425	17.20	71.7	56.6
4	.737	"	.443	13.60	71.5	60.2
5	.723	"	.448	12.78	71.3	62.0
6	.723	"	.456	11.10	72.3	63.1
7	.670	"	.468	8.90	70.5	69.8
8	.723	"	.472	8.06	75.6	65.4
9	.750	"	.480	7.95	75.5	64.0
10	.730	"	.471	8.33	75.8	64.6
11	.720	"	.480	7.95	75.6	66.7
12	.696	"	.485	5.55	78.8	69.4
13	.724	"	.496	3.43	75.6	68.6
14	.730	"	.511	0.55	71.5	70.2

CHARACTERISTIC CURVES OF MOTOR
CONSTANT TORQUE
WEIGHT 1"

Constant Torque test with 1 3/4 # on scale arm.

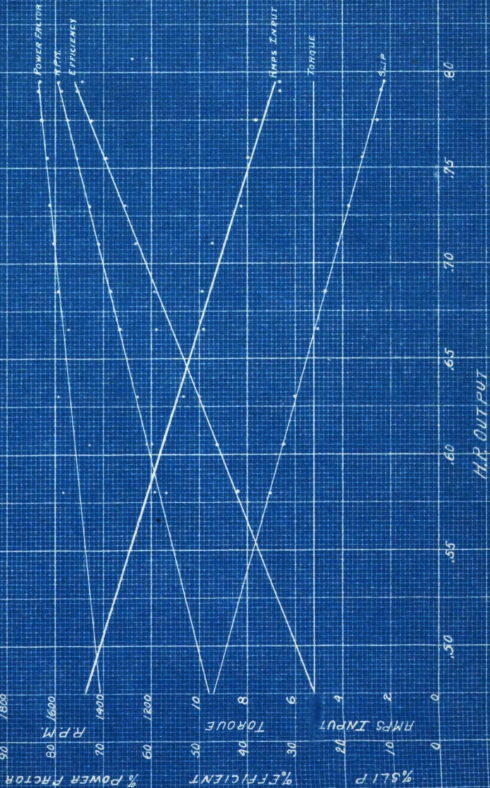
Meter # Const.	Rdg.No.	Cont.No.	Test Data			R.P.M.
			Volts 6822	Amps 8892	Kilo- Watts 4995	
			1	5	1	
	1	1	110	2.50	1.08	910
	2	R-1	110	2.51	1.08	900
	3	R-2	110	2.38	1.03	1160
	4	R-3	110	2.20	.97	1210
	5	R-4	110	2.15	.94	1260
	6	R-5	110	1.97	.84	1330
	7	R-6	110	1.98	.86	1370
	8	R-7	110	1.90	.84	1420
	9	R-8	110	1.86	.83	1460
	10	R-9	110	1.80	.81	1510
	11	R-10	110	1.75	.80	1550
	12	R-11	110	1.75	.78	1580
	13	R-12	110	1.75	.81	1580
	14	R-13	110	1.75	.81	1585
	15	L.P.	110	1.75	.80	1590

Calculated Results

Rdg. No.	Hp. Input	Torque	Hp. Output	% Slip	% P.F.	% Eff.
1	1.448	2.625	.455	49.4	78.5	31.4
2	1.448	"	.450	50.0	78.5	31.4
3	1.380	"	.580	35.5	78.6	42.0
4	1.300	"	.605	32.8	73.5	46.5
5	1.260	"	.630	30.0	79.5	50.0
6	1.125	"	.665	25.5	77.5	59.0
7	1.150	"	.685	23.9	79.5	59.5
8	1.125	"	.710	21.1	80.5	63.1
9	1.110	"	.730	18.9	81.2	65.7
10	1.085	"	.755	16.1	81.8	69.6
11	1.070	"	.775	13.9	83.0	72.4
12	1.040	"	.790	12.2	83.5	75.8
13	1.040	"	.790	12.2	83.5	75.8
14	1.080	"	.790	12.2	84.0	73.8
15	1.070	"	.795	11.6	83.0	74.4

CHARACTERISTIC CURVES OF MOTOR

CONSTANT TORQUE

WEIGHT $1\frac{3}{4}$ 

STARTING TORQUE

In preparing to make a test of this nature it was necessary to provide a spring balance and support the brake arm on the knife edge in a manner which would allow free deflection of the balance. The brake band was clamped on to the pulley on the motor so that the armature or rotor could not turn. Now that everything was ready the brake arm was raised about two inches above the horizontal plane of the normal position by means of the spring balance on the knife edge. Then the brake arm was lowered until about two inches below the normal position, and readings were taken during both the up and down movement. From these readings it was possible to calculate the weight plus friction and the weight minus friction. For finding the torque the same method was used when the controller arm was over on the first contact point. Both scale readings were taken and also the volts, amps and watts input.

Test;-

Let w = weight of brake arm.

" f = friction.

" W = watts input.

" I = current or amps input.

" E = volts.

" T = torque.

STARTING TORQUE

Mechanical readings.

$$w \text{ plus } F = .3$$

$$w \text{ minus } F = .0$$

$$w + F + T = 2.0$$

$$w - F + T = 1.6$$

$$T = w l$$

Electrical Readings

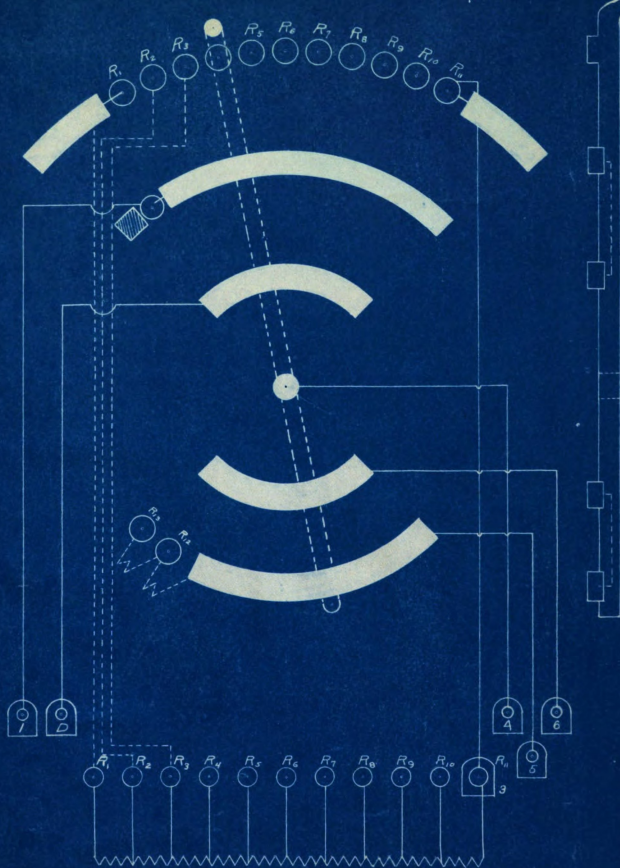
	Kilowatts.	I.	E.
Meter No.	4995	8892	6822
Const.	1	5	1
	1.825	4.25	112

$$\frac{2.0 + 1.6}{2} = 1.8$$

$$\frac{.3}{2} = .15$$

$$1.8 - .15 = 1.65\#$$

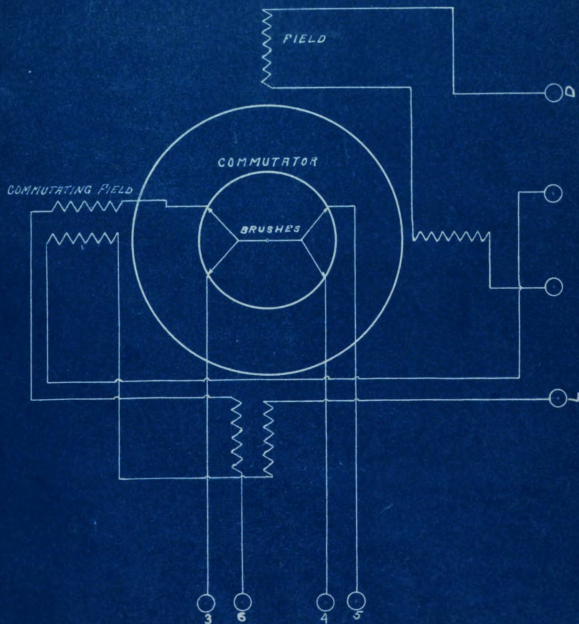
$$1.65 \times 1.5 = 2.475 \text{ ft. lbs. torque}$$



CONTROLLING RHEOSTAT

STARTING BOX, COMMUTATOR MOTOR

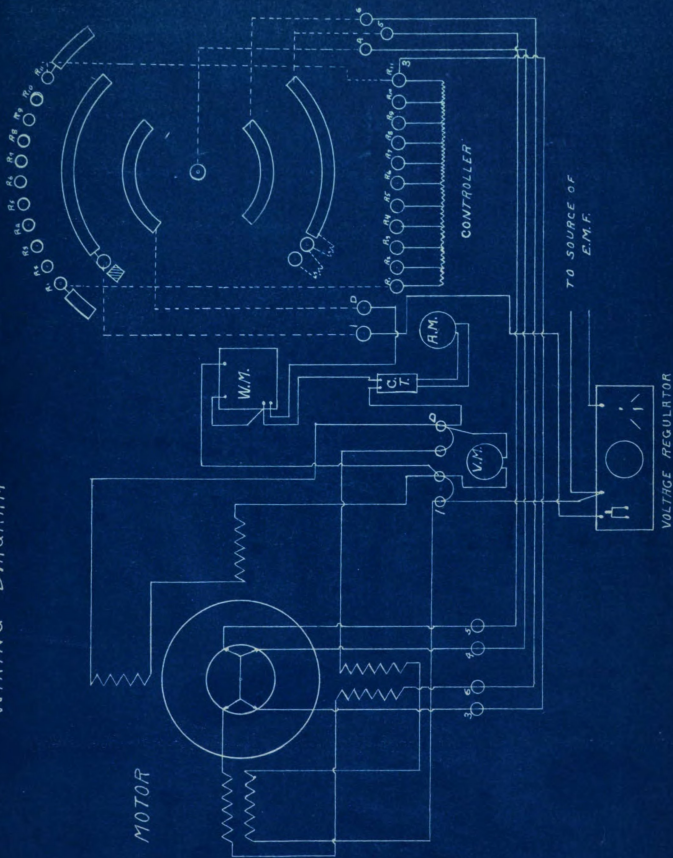
FIELD CONNECTIONS
OF MOTOR



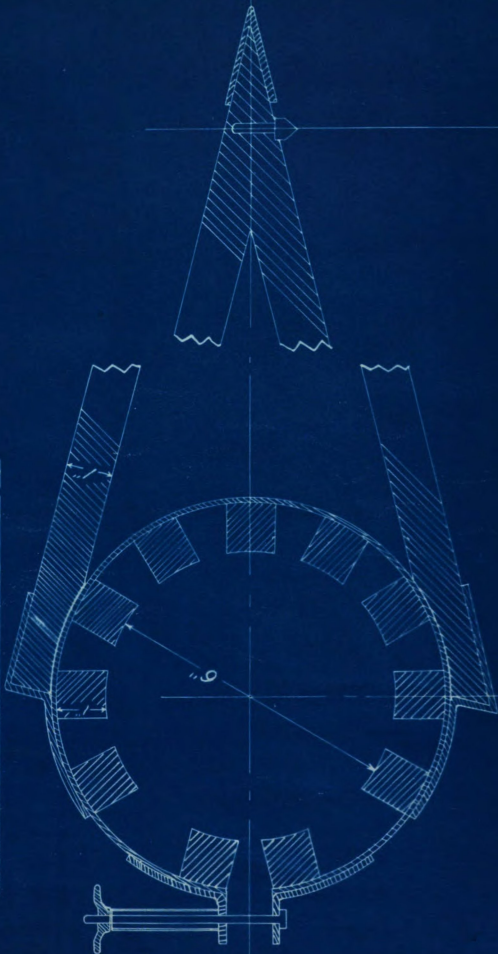
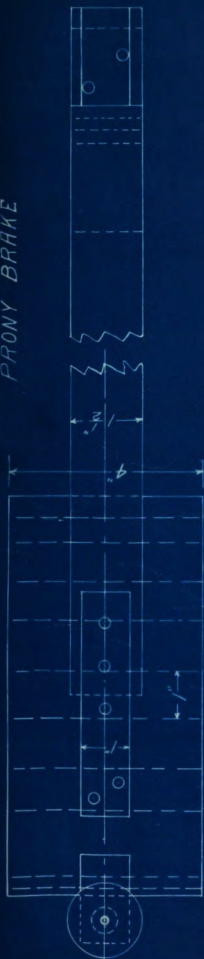


ARMATURE WINDING DIAGRAM

WIRING DIAGRAM



PRONY BRAKE

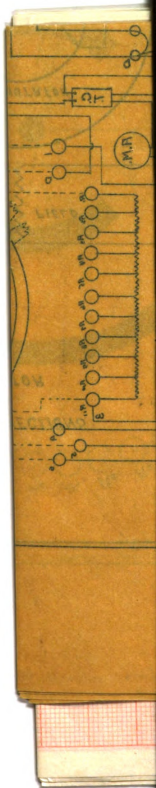


CONCLUSION

In summarizing this thesis the following features and characteristics are shown:

The shunt motor is valuable because of the different speeds available by making slight changes in the construction, likewise the torque can be controlled and varied to some extent. These features are also desirable in an alternating current motor. By comparing the curves of the test made on point R-11, with those of a typical shunt wound motor, it is found that they resemble each other in many respects. In both, the speed drops off gradually as the horse-power output increases. Likewise the efficiency curves are very similar. The torque curves are straight lines in both cases, and they increase at nearly the same rate. The starting torque of the single phase commutator motor is 2.475 ft. lbs. while full load torque is 3.8 ft. lbs. This shows that where a very heavy starting torque and a lighter running torque is necessary it would not answer the purpose, but the starting torque is just the same as the torque at 75% of full load so that it could be used where the total load is taken on after the motor is up to speed. With but slight changes these motors can be operated on either alternating or direct current.

So in closing it is hoped that this thesis will serve the purpose as outlined in the preface, to be of value to the electrical department, and serve to stimulate further work along this line at the M. A. C.



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