T H E S I S

on

Tests made on Direct Current Side of a Double Current Generator.

Submitted to the Faculty

of the

<u>O R E G O N   A G R I C U L T U R A L   C O L L E G E</u>

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In long distance transmission where it is impossible to transmit a direct current for electric rail roading and for many other applications on a very low voltage, per cent line loss, it is essential to transmit the power by means of an alternating current at high pressure and then reduce its voltage by means of transformers then convert the alternating to a direct current by means of a machine called the rotary or synchronous Converter.

The Synchronous Converter is used mostly in street car service but takes an important part in charging storage batteries and in electrolytic work. It is often called the connecting link between alternating and direct current.

These machines are often used in lighting and heating plants or in substations in connection with secondary batteries where the excess of power generated while the line load is light is stored up and reconverted. And when the line load is heavy, it is given up, thus greatly assisting the prime movers.

The Synchronous Converter is frequently called the Rotary Converter and differs from the Motor Generator in that its windings are connected to slip rings on the opposite end of the armature from commutator at a proper phase difference, while the latter is simply a motor directly connected to the shaft of a generator.

The Rotary Converter when used to change simssoidal to unidirectional current has a better efficiency than a motor generator set. The efficiency of a fairly large size converter is 95%. The efficiency of the same size alternating current motor varies from 91 to 95 % with an average of 93% and that of a direct current generator varies from 90 to 94% with an average of 92% so that the efficiency of a motor generqtor set is about 85.6%. Hence the converter is in average cases 9 or 10 % more effieient than the motor generator set.

The machine is also called the Inverted Rotary Converter when taking in direct and supplying alternating current. The output in such cases is about 75 % of the intake, that is, the efficiency does not increase above 75 %. The reason for this is that the alternating currents flowing in the conductors of the armature demagnetize the field and thus decreases the excitation and the machinetends to run at a higher speed than synchronous speed and thus the efficiency is decreased.

When used as a double current generator and driven mechanically by belting or otherwise, it has greater efficiency than either that of a direct or alternating current generator, due to the fact that alternateing currents are opposite in phase to the direct currents, and thus armature currents remaining are equal to the difference between the alternating and the direct currents.

hence the I^2R losses are greatly reduced.

It may be in some cases necessary to change the phase of an alternating current generator, this may be easily and quickly accomplished by merely changing the connections of the windings at the slip rings. The alternating current side is provided with six xlip rings so that the machine can be used as a single phase, two phase, three phase, or six phase. In order to have single phase, the leads are taken from slip rings number 1 and 4 or 2 and 6 ; to have two phase the leads are taken from rings 1, 4 and 2 and 6. For three phase, the leads are taken from rings 1, 3, and 5 or 2, 4, and 6. Thus one machine can be used for different kinds of circuits at different times.

Since the machine is wound similar to a shunt dynamo with the additional six slip rings connected at a proper phase difference, it is evident that there must be some relation between alternating and direct current voltages. This depends only upon the wave shape of the induced alternating electromotive force. In a true sinusoidal curved wave machine the relation between alternating and direct current voltages are as

1 :.707 in two phase,
1 : .602 " three " "
1 : .5 " four " "
1 : .354 " six " "

and in ths same way there is a fixed relation between direct and alternating currents.

The machine we took for testing is a

DOUBLE CURRENT GENERATOR

Type A. C. S. Class 4--10--1800

Form P. Speed 1800.

CONTINUOUS CURRENT

Amperes 91 Volts 110.

ALTERNATING CURRENT.

Cycles 60. Volts________

GENERAL ELECTRIC COMPANY.

The object of the thesis is to test the machine for different services on the direct current side and plot curves showing the variation of voltages, efficiency, etc., at different loads. The machine does not give a true sinusoidal wave bu5 is very nearly so. The ratio between direct and alternating current E. M. F. is:

110 : 80 or 1 : .727 on two phase circuit.
110 : 70 or 1 : .636 on three phase circuit.

The no-load characteristic of the machine is taken in order to determine the relation between the field current and the terminal voltage. The machine was belt driven and an ammeter was inserted in the field in series with the field rheostat, and the readings were taken ranging from the highest possible value of field current to lowest, and the curves were plotted with fiel amperes as abscissae and volts as ordinates.

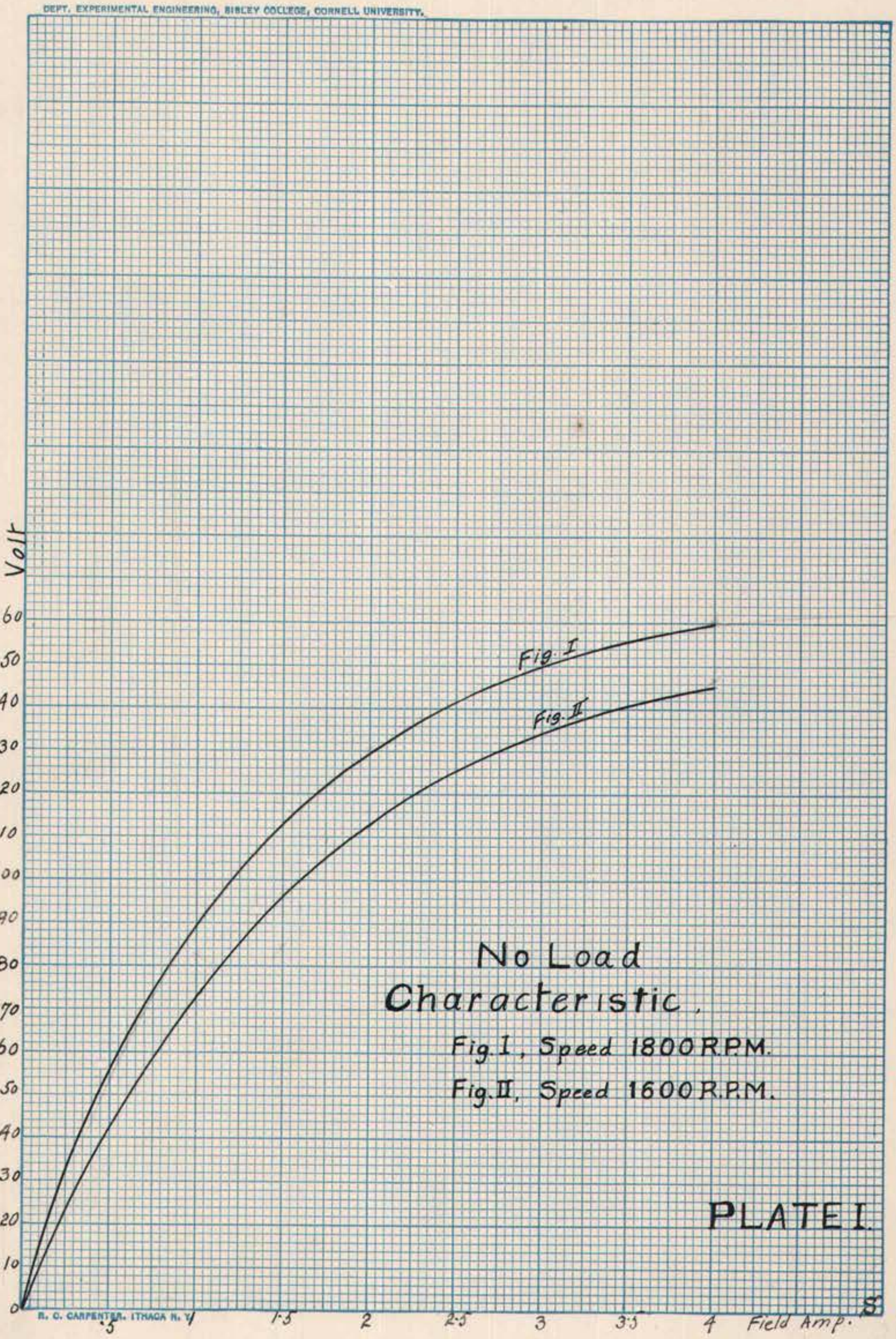
The following are the readings taken and the characteristic curve is plotted in Plate I.

Field Amps.	Terminal Volts
5.0	180
4.0	161
3.0	151
2.0	131
1.8	123
1.6	113
1.4	104
1.2	94.
1.0	82.
.8	67.2
.6	55
.4	34
.2	13.5

Speed for the above is 1800.

5.0	156.5
4.0	114
3.0	116
2.0	109
1.8	102
1.4	93.25
1.2	85
1.0	72.5
.8	59.5
.6	46
.4	30.5
.2	15.2

The speed in this case was 1600 R. P. M.


DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
Volt
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
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·5
1
1·5
2
2·5
3
3·5
4
Field Amp.
Fig. I
Fig. II
No Load
Characteristic.
Fig. I, Speed 1800 R.P.M.
Fig. II, Speed 1600 R.P.M.
PLATE I.
S

The most important use of the rotary as a shunt dynamo is to supply currents for light and power and therefore it is necessary that the terminal voltage must be kept constant, which is impossible to be accomplished by a shunt dynamo, because as the load increases the voltage decreases which is evident from Plate 2. Thus it is seen that at 46 amperes or one half the capacity of the machine the voltage has dropped from 110 to 96.5. The per cent drop at that load is (110 - 96.5)÷ 96.5 X 100 equals 14% which is very poor for li ht circuit. Such a low voltage reduces the candle power of the light considerably and in order to kee the pressure constant the switch board attendant must regulate the voltage by means of a rheostat connected in series with the fiel coils and thus the resistance drop is compensated by increasing the field flux.

It is seen from Plate 2 that in order to get 110 volts at 46 amperes the field currents are increased from 1.12 to 1.25 amperes, i. e. it is 13 amperes or 11.6% more than the no load excitation of the machine.

Voltage Characteristic.

Field Amp.	Load Amp.	Volts	Speed
1.24	0	110	1800
1.23	10	108	"
1.19	20	106	"
1.16	30	102.5	"
1.10	40	96.5	"
1.01	50	89	"
.89	60	78	"
.74	70	64	"
.49	74.5	42	"
.48	70	40	

Table for Excitation Characteristic.

1.12	0	110	1800
1.15	10	"	"
1.12	20	"	"
1.22	30	"	"
1.24	40	"	"
1.26	50	"	"
1.35	60	"	"

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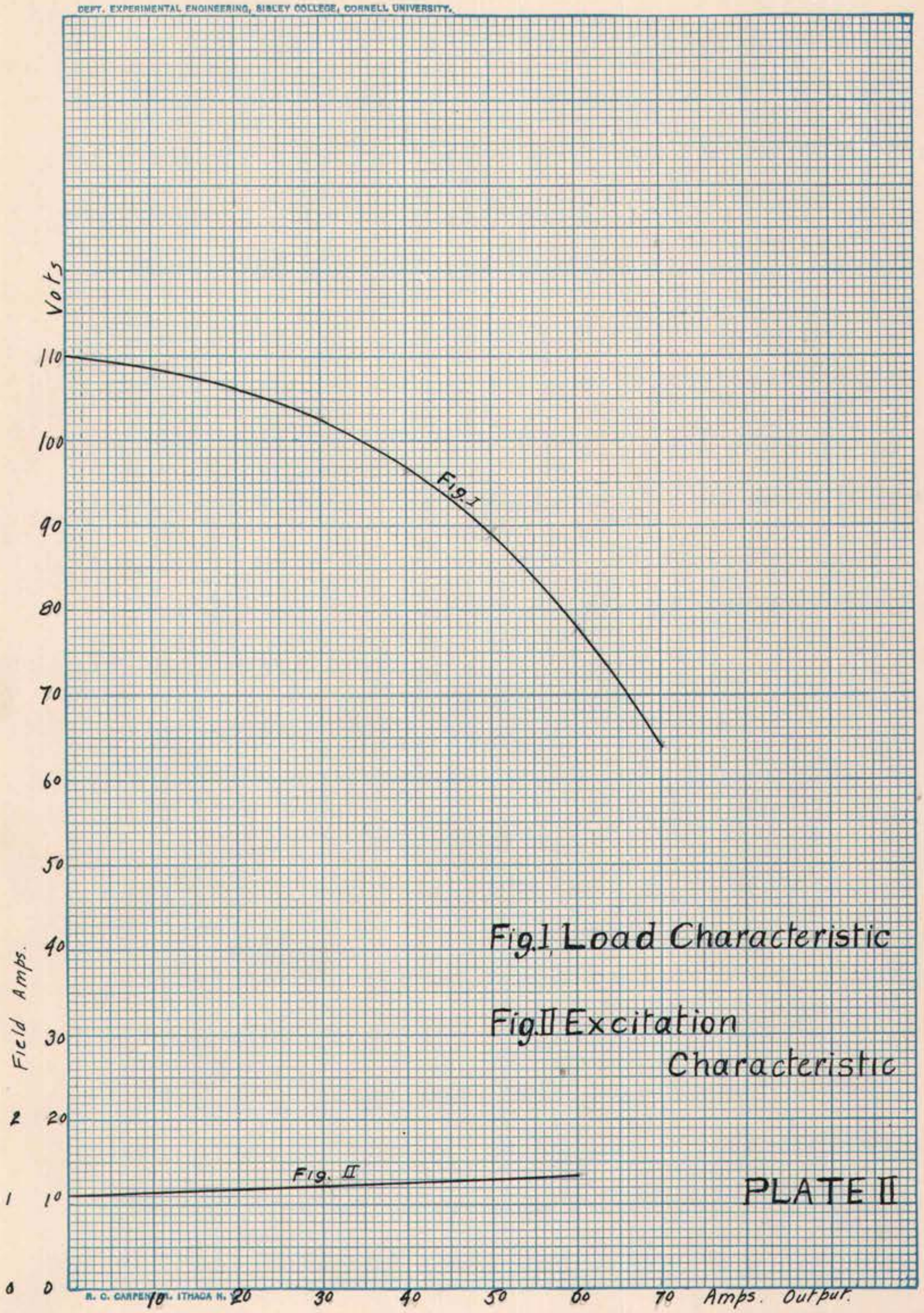

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COMMERCIAL TESTS

To find the efficiency and separate the losses.

As the user of electrical machinery demands highly efficient machines, it is the purpose of the designer to minimize all the losses and thus to increase its efficiency.

The total loss of the machine at normal speed is found by running the machine as motor and find the power taken in at no load. In this case the power taken in was 1240 watts and subtracting the I^2R loss which is equal to 190 watts at normal speed, leaves 1050 watts as a constant loss of the machine.

The losses in the machine may be divided into separate component losses, as follows;-

(1) Copper loss: in armature; in field

(2) Core loss: Hysteresis; Eddy current

(3) Mechanical losses: Bearing friction; Brush friction; Windage

Knowledge of the separate losses is of importance for the following reasons:

(a) The losses and their dependency on the load, speed, etc., determine the rating of the machine for different classes of service (intermittent load, variable load, constant load, etc.,)

(b) The magnitude of the separate losses is a check on the quality of materials, workmanship and design.

(c) Knowing the values of the principal losses the designer is enabled to vary the dimensions still keeping the efficiency as high as possible.

Copper loss is found by finding the resistance of the aramature by the potential drop method which is equal to .05 ohms for this particular machine and multiplying by the square of the current in the armature. This I^2R loss goes in heating the winding of the machine.

The total loss minus the copper loss equals the core loss plus the mechanical losses.

Mechanical losses depend only on the speed of the machine and is constant under all loads for the same speed. In order to separate these losses the machine is driven by a motor and the power consumed is found. Then the auxiliary machine is run light and its power consumed is found. Then the difference between these is the power used up in driving the generator.

Thus when driven by a motor the energy consumed by the motor was foune to be 772 watts. Substracting 2% for the belt friction 757 and when the motor was run light the loss in the motor was found to be 202 watts. This leaves the mechanical loss equal to 555 watts. In the same way the mechanical loss in the machine without the brushes was found to be equal to (604 -202) or 402 watts. Thus leaving 555 - 402 or 153 watts loss in the brush friction.

The rest of the loss goes in core loss which in this case equals 1050 -555 equals 495 watts.

The efficiency of anymachine may be found by dividing output by input. It is difficult to measure the output of the machine directly. The only possible way would be to apply the Prony brake on the pulley of the machine. But it is not easily operated, neither is it accurate in results even in small machines and hardly applicable for large machines. Moreover the waste of power is objectionable.

Therefore the indirect method i.e. (Input- losses) (equals Output) divided by the Input, is usually employed and gives very satisfactory results.

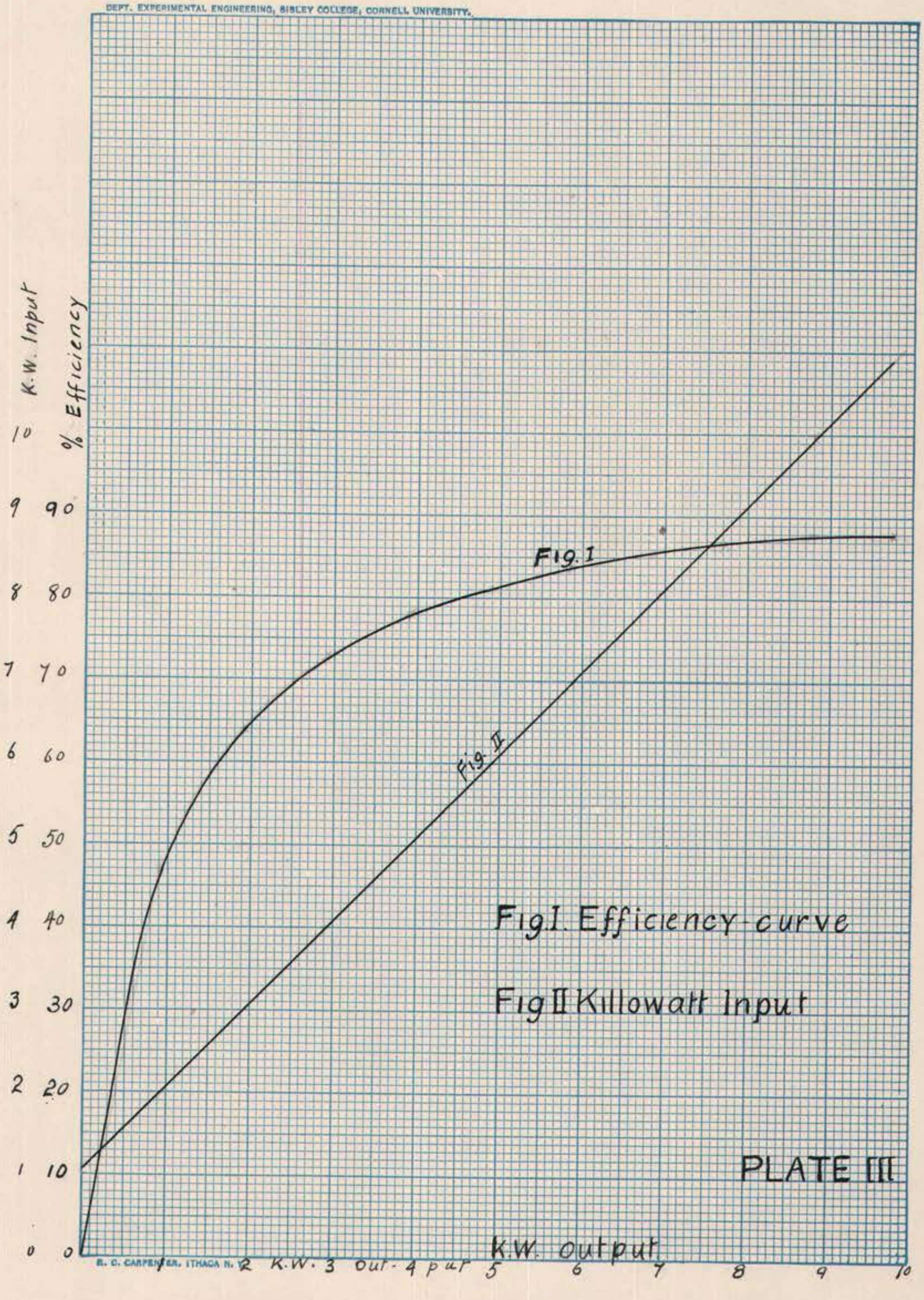
The efficiency curve in plate 5 is figured the same way.

Losses And Efficiency Curves
Readings and Computations.

Field Amp.	Armature A.	Volts	Speed	Losses
1.6	5.9	164	1800	978
"	5.8	"	1700	952
"	5.7	"	1600	935
"	5.6	"	1500	919
"	5.45	"	1400	895
"	5.3	"	1300	870
"	5.2	"	1200	854
"	5.15	"	1100	845

Computation of Losses at Normal Speed.

Input	Amps.	I^2R	Total Loss	Output	% Eff.
11,000	67	224	1274	9726	88.4
10000	60.4	180	1227	8773	87.73
9000	53.2	141	1191	7809	86.77
8000	47.1	111	1161	6839	85.5
7000	41	84	1134	5866	83.8
6000	35	61	1111	4889	81.49
5000	29	44	1094	3906	78.12
4000	22.8	26	1076	2924	73.1
3000	17	15	1065	1935	64.5
2000	13	8.5	1058	942	47.1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K.W. Input
% Efficiency
10
9 90
8 80
7 70
6 60
5 50
4 40
3 30
2 20
1 10
0 0
Fig. I
Fig. II
FigI. Efficiency-curve
FigII Killowatt Input
K.W. output
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1 2 K.W. 3 Out- 4 put 5 6 7 8 9 10

PLATE III

Inverted Rotary Tests.

The machine is wired up from the direct current side as a shunt motor and the load is put on the single phase of the alternating current. Two tests were run as an inverted rotary. In the first test the power factor used was equal to 100%. In the second test an inductive load was put on the alternating current side thus making the power factor 49.2%.

The efficiency was found by dividing the alternating current out put by the direct current input. The alternating current output was read on the wattmeter and the direct current input was computed by multiplying the aramature plus field amperes by direct current voltage.

It is seen from these tests that the efficiency of the inverted rotary is about 75% at 1005 power factor and 37% at 49.2% power factor. Thus it is seen that a Double Current generator is not a very satisfactory machine when used as an inverted rotaru. The machine under test has an efficiency about 88% at full as a direct current machine, while a larger machine has an efficiency of about 93%. Hence a Double Current Generator gives a better efficiency used as a rotary converter, direct current or alternating current generator than an Inverted Rotary Converter.

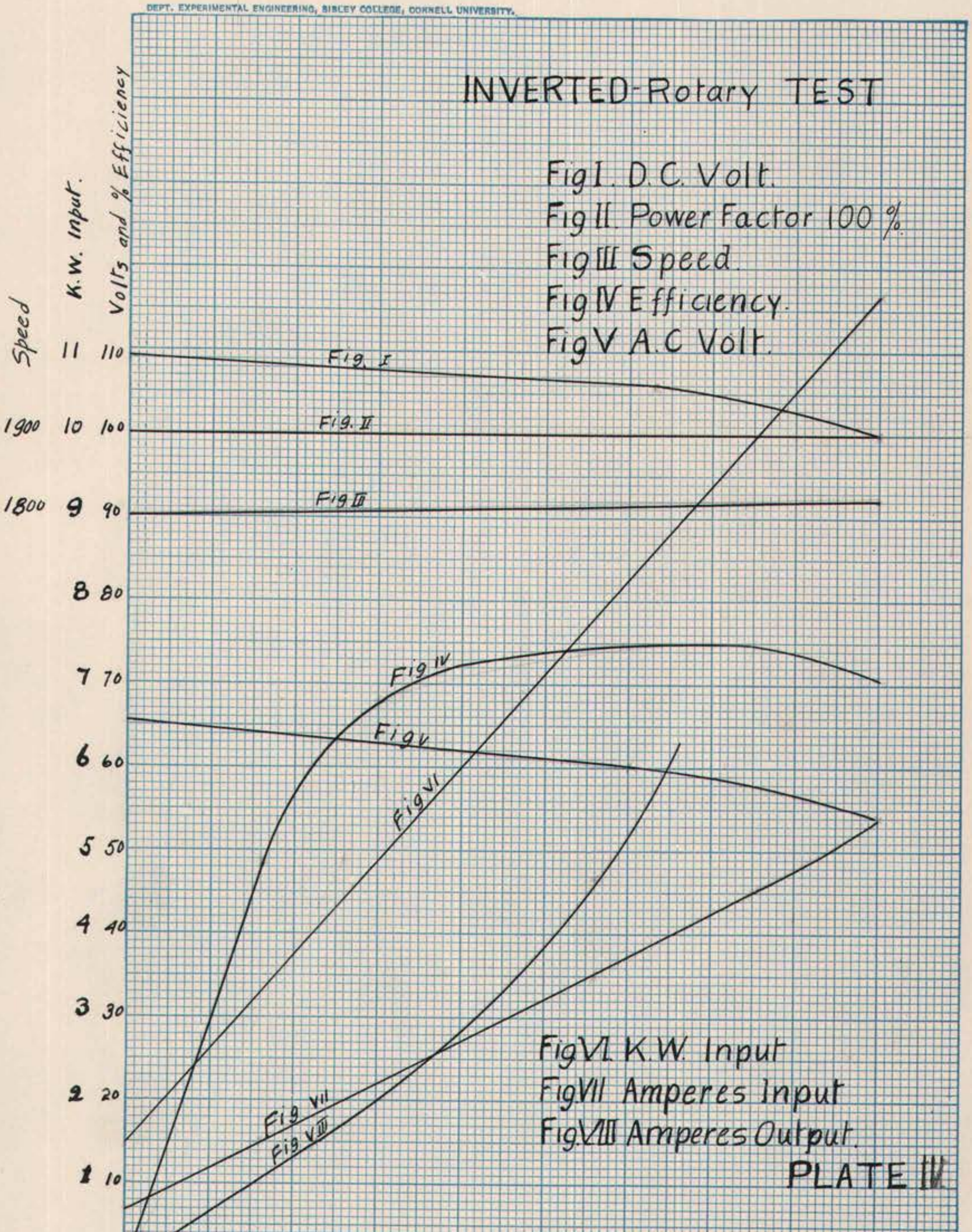
Non-Inductive Load.

D. C. Volts	D. C. Field Amps.	D. C. Amps.	A. C. Volts	A. C. Amps.	Speed	Power	% Eff.
					1800	0	
109	1.11	7	65.5	0	1840	800	0
108.5	1.11	15	64.5	120	1840	1175	49.2
107.5	1.10	25	63	298	1840	2800	73
106.5	1.09	35	60	46.5	1840	3100	75
106.5	1.09	40	59.5	53	1840	3575	73.8
106	1.09	45	56	63	1840	3640	74.6
101	1.00	50	54.5	66.5	1840	3980	72.1
101	1.01	55	53	75.8	1840	4325	71.8
100	1.0	60	56	85	1840	4475	72
100	1.0	65	54	91	1840		69

Table

112	1.085	6	67	0	1800	493
111.5	2 " "	8.5	65	18.2	1780	474
110	1.07	15	65.5	15.16	1760	688
110	1.06	20	63	25.5	"	920
110	1.07	25	63	30.32	"	1000
110	1.07	30	62.5	37.90	"	1175
110	1.06	35	60	47.0	"	1385
109.5	1.06	40	58.5	55.4	1740	1591
109	1.05	45	57	62.9	1720	1820
108	1.05	50	55.5	72.0	1700	1970

The Power factor for this case is equal to 49.2%.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INVERTED-Rotary TEST
Fig I. D.C. Volt.
Fig II. Power Factor 100 %.
Fig III Speed.
Fig IV Efficiency.
Fig V A.C Volt.
Speed
K.W. Input.
Volts and % Efficiency
11 110
1900 10 100
1800 9 90
8 80
7 70
6 60
5 50
4 40
3 30
2 20
1 10
0 0
Fig. I
Fig. II
Fig III
Fig IV
Fig V
Fig VI
Fig VII
Fig VIII
Fig VI. K.W. Input
Fig VII Amperes Input
Fig VIII Amperes Output.
PLATE IV
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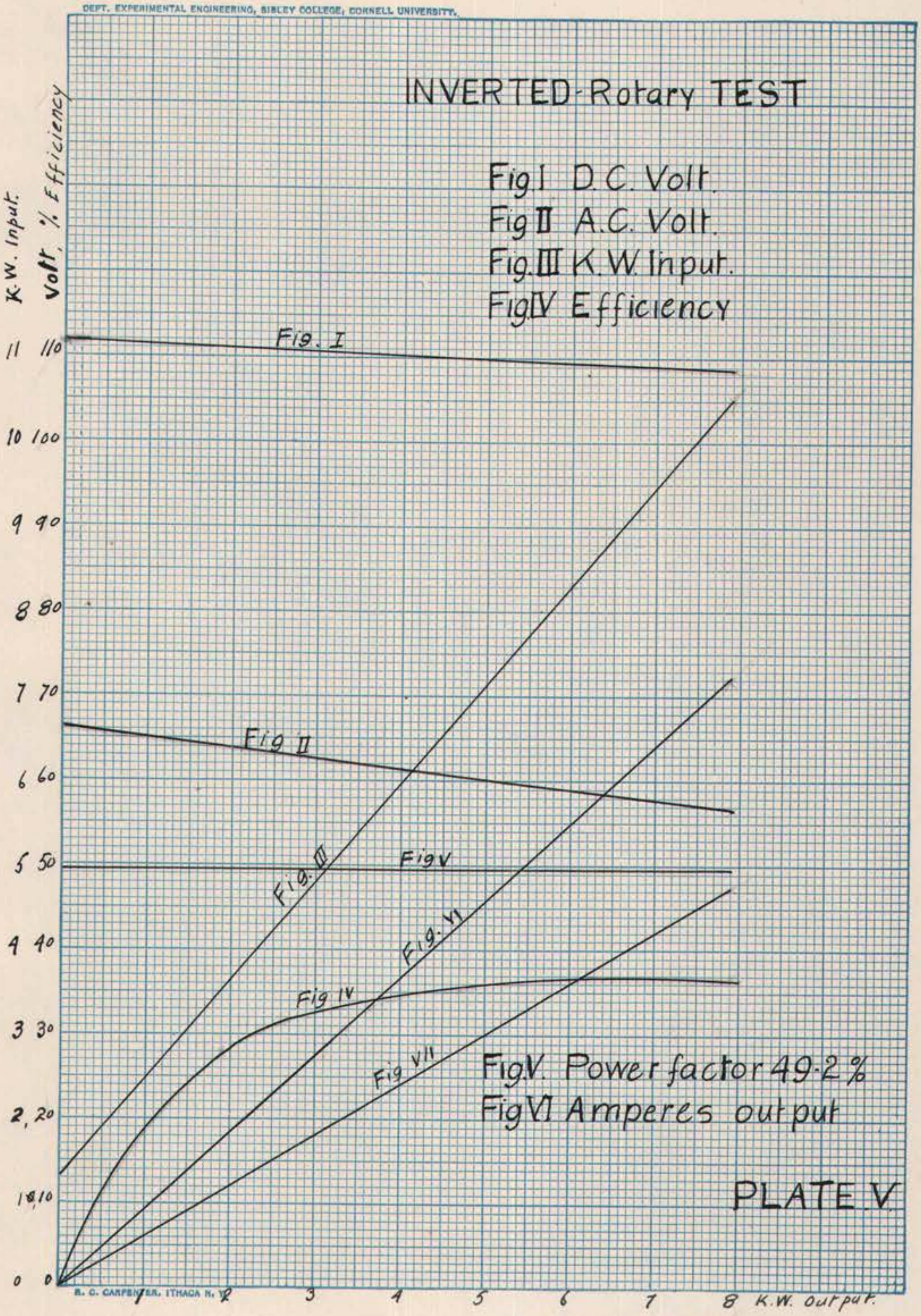
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INVERTED-Rotary TEST
Fig I D.C. Volt.
Fig II A.C. Volt.
Fig. III K.W. Input.
Fig IV Efficiency
K.W. Input.
Volt, % Efficiency
Fig. I
Fig II
Fig. III
Fig V
Fig. VI
Fig IV
Fig VII
Fig V. Power factor 49.2 %
Fig VI Amperes output
PLATE V.
11 110
10 100
9 90
8 80
7 70
6 60
5 50
4 40
3 30
2, 20
1, 10
0 0
1
2
3
4
5
6
7
8 K.W. output.
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In the tests just described it has been shown that the efficiency of a Rotary Converter when used as a direct current generator is satisfactory. When used as a shunt motor, the regulation is not quite constant, the speed falling off with the load. When used as a machine for converting the alternating currents into direct for the purpose of supplying electricity to incandescant lamps; the increase in voltage to compensate for the IR drop infeeders and mains must be accomplished, not by reducing the resistance in the shunt circuit; but by raising the pressure on the alternating side by means of regulating transformers.

Changing the excitation through its full range only varies the working voltage about 5%; it does however, change the power factor of the supplied cirrent greatly. At will, the operator can have a heavy lagging current with under-excitation, or a heavy leading one with an over-excited field.

The end.