T H E S I S

A COMPARISON OF THE PERFORMANCE OF A DIRECT CURRENT GENERATOR WITH THAT CALCULATED FROM ITS DIMENSIONS

For the Degree of

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Under

Dr. C. A. Perkins.

By

Frank Hacker Robinson.

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A COMPARISON OF THE PERFORMANCE OF A DIRECT CURRENT GENERATOR WITH THAT CALCULATED FROM ITS DIMENSIONS

The design of electrical machinery when undertaken as a thesis is usually done in the same order as in commercial work. The desired performance is specified. The electrical and mechanical dimensions are then calculated with the view of producing this performance. This method for a thesis is defective where the machinery, as is usually the case, cannot be built, because there is no way of judging the merits of the design.

For these reasons in the present case the order of proceedure is reversed. The electrical and mechanical dimensions are taken from a completed machine of the following rating:-

Crocker Wheeler Co.,
Type C. M. Size 10 D.
Output 13 H. P.
1175 R. P. M.
Volts 500
Amperes 22

The process of design was then gone through in the reversed order, the performance of the machine being predicted in detail from its dimensions. When this was done and curves plotted the machine was tested and the actual curves plotted on the same sheet for the purpose of comparison.

THE CALCULATIONS.

In the matter that follows formulae used are in a number of cases not explained, but references are made to the standard works and page numbers from which they are obtained.

G E N E R A T O R .

T A B L E   O F   D I M E N S I O N S .

Armature.

Dia. at face. (Dia.of core plate)	11.0 inches
Length between core heads	5.0 "
Number of core sheets to the inch	41.0
Number of vent ducts, radial	None
Net effective length of core	4.5 inches
Radial depth of core body	5.5 "
Internal Dia. of core	6-11/32 "
Number of slots	87
Depth of slots	0.5 "
Width of slots	0.25 "
Average width of tooth	0.1408 "
Number of circuits in parallel between brushes	2.0
Style of winding	Wave
Number of conductors in series between ends of a coil	12
Size and section of conductors (bare)	No.12, 0.082 in.
Size and section of conductors (insulated)	" 12, D. C. C. 0.094 in.
Mean length of a conductor per turn	$\frac{162.25}{6}$ inches
Pitch of winding and number of teeth	21
Arrangement of conductors in slots	6 in series
Length of magnetic circuit in armature core body	5.28 inches
Length of one great coil(see next to the last paragraph on page 4)	42.25 inches
Length of each minor coil(see as above)	34 "

G E N E R A T O R .

T A B L E O F D I M E N S I O N S .

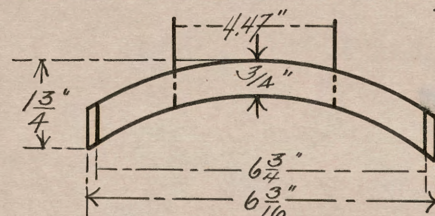
(Continued)

Commutator.

Diameter	7-13/64 inches
Length of segment over all	3-7/32 "
Active length of segment	3-7/32 "
Number of segments	87
Width of segments	15/64 inches
Useful depth of segments	1/4 "
Number of sets of brushes	4
Number in one set	2
Length side by side	2 x 1.11
Peripheral width of brush in inches	0.4815 inches
Total area of contact for one polarity	1.072 sq. in.
Length of brush	1-39-64 inches

Air Gap, and Pole Piece.

Length at center from iron to iron	0.12 inches
Pole piece (Shoe) For dimensions see sketch below.	
Actual average width in direction of revolution	5 inches



Field Magnet Core.

Length radially	5 inches
Length parallel to the shaft (round)	
Width or diameter	4.476 "

Bobbin.

Depth of winding (estimated)	1.293 Inches
Thickness of insulation on flanges (estimated)	5/16 in. lower 1/4 " upper
Thickness of insulation on core body(estimated)	7/64 inches
Length of shunt winding space, exclusive of insulation	3.5 "
Size of shunt wire (bare)	No.23,0.022 "
Size of shunt wire (insulated)	No.23,0.027 "
Estimated mean length per turn	19.4 "
Number of turns per bobbin (estimated)	6196
Number of conductors per inch	38
Diameter of wound space (estimated)	7-9/32 inches

G E N E R A T O R .

T A B L E O F D I M E N S I O N S .

(continued)

Yoke.

Outside diameter	25-5/8 inches
Thickness	2.25 "
Length parallel to shaft	9-13/16"
Area of yoke cross-section(carefully measured at parting of yoke)	21.9 sq. in.

The dimensions of the machine are given in the accompanying tabulation. The normal voltage and current were taken the same as rated but the normal speed was taken as 1200 R. P. M.

Preliminary to this test a brake test was made on the driving motor to determine its efficiency, the conditions of its operation being carefully observed. This test is not gone into in detail, the curve covering its performance being simply included with these papers. (See curve sheet No. 6.)

Tabulated results of each test with connection diagrams follow each sheet showing the curvesdeveloped from such tests.

FIELD MAGNET CALCULATION.

Let us suppose that the radius of the core is increased 7/64 inches by insulation.

Number 23 wire B. & S. has a diameter of 0.002257 In. with S. C. C. insulation 0.027.

This will be 35.72 insulated conductors to the inch according to table(see Foster's Electrical Engineers' Handbook, page 122.)

According to the micrometer measurement of the actual wire (see table of dimensions immediately preceding this page) there will be 37.05 conductors per inch. The number actually counted on the bobbin was 38.

Let us use 37 in the subsequent calculations.

Assuming no bedding there will be as indicated in the table of dimensions

$$(37 \times 3.5) \times \left(\frac{7.21 - 4.476 - .2187}{2}\right) 37 = 6196$$

turns per bobbin.

The mean length per turn will be:-

$$(4.4764 + 0.2187 + 1.293)\pi = 19.40 \text{ inches.}$$

Total length of wire per coil $= \frac{6196 \times 19.4}{12} = 10020$ ft.

The resistance of No. 23 at different temperaturesis as follows:- (see page 49 Standard Handbook)

Degrees (F	68	122	176
Degrees (C	20	50	80
Ohms.	0.02032	0.02271	0.02516

Among the curves included are two showing the variation of field and armature resistance with temperature. (See curve sheet No.5)

Then:-

Resistances of 1 bobbin at the above temperatures will be respectively

203.6 227.5 252.1 Ohms

Entire Field.

814 910 1008

At 500 volts pressure the field will have at these temperatures 0.614 Amps. 0.5496 Amps. 0.4956 Amps.

To Construct Saturation Curves for the Magnetic Circuit.

Mean length of one complete magnetic circuit in the yoke (from the dimensions in the table) = $\frac{(25.62-2.25)\pi}{4} + 2.25$ = 6.94 inches.

Mean length of two air gaps = 2 x 0.12 = 0.24 inches.

Length of magnetic circuit in the teeth is 2 x 0.5 = 1.00 in.

Diameter of field magnet core = 4.47 inches.

Area of field magnet core = 15.75 Sq.in.

Gross length of armature core = 5 Inches

Estimated net length of armature core = 5 x 0.9 = 4.5 in. allowing for paint on iron.

6-5/8" = Span of one pole shoe.

Then $\frac{6.525}{11\pi} \times 87 = 16.42$ number of slots or teeth under a pole shoe.

$\frac{87}{4} - 16.42 = 5.33$ number of slots or teeth between two pole shoes.

Area of the magnetic path in the teeth under one pole = 16.42 x 0.1408 x 4.5 = 10.41 Sq.in.

0.1475 in. width of top of tooth }
0.1342 in. " " base " " } 0.1408 Average width of a tooth.

Next let the air gap area be calculated by use of the Carter Coefficient (See P. 43 A. Gray's Electrical Machine Design.)

$$\frac{S}{\delta} = \frac{0.25}{0.24} = 1.041 \qquad f = 0.8$$

$$x = 0.1408 + 0.80 \times 0.025 = 0.3408$$

$$C. = \frac{\lambda}{x} = \frac{0.3975}{0.3408} = 1.167$$

33.14 sq.in. = Area of a pole shoe

$\frac{6\text{-}5/8 \times 5}{1.167} = 28.42$ sq. in. effective area of the air gap.

Let us proceed directly to calculate the no load saturation curve.

Let the leakage factor be taken as 1.32. This is an average value for machines of this size according to S. P. Thompson, Dynamo Electric Machinery Vol. I.

First find the flux to produce 500 Volts terminal voltage at 1200 R. P. M. and no load.

N=lines of flux. n=rev. per min. c=paths in armature. E=electromotive force. Z=conductors (from table of dimensions preceding page 2.) p= number of poles.

$$N = \frac{Ec \times 10^8}{nZp} = \frac{500 \times 2 \times 10^8}{\frac{1200}{60} \times 1044 \times 4} = 1198000 \text{ Lines in the Air Gap}$$

Multiplying by the leakage Coefficient.

1.32 x 1198000 = 1581000 lines in the field core and yoke.

Density (yoke) $= \frac{1581000}{21.92 \times 2} = 36100$ lines.
per sq.in.

Armature Body Density $= \frac{1198000}{8.225 \times 2} = 72850$ lines.
per sq.in.

Tooth Density $= \frac{1198000}{10.41} = 115000$ lines
per sq.in.

Gap Density $= \frac{1198000}{28.42} = 42175$ lines
per sq.in.

Pole Core Density $= \frac{1581000}{15.74} = 100450$ lines
per sq. in.

Pole Shoe Density $= \frac{1198000}{33.14} = 36155$ lines
per sq. in.

The accompanying tabulation gives the flux densities in each part of the magnetic circuit on the above basis from 0 to 575 volts calculated in the same manner for each voltage, also the ampere turns written in parentheses required to produce them respectively. Three distinct columns give respectively the total ampere turns per pole required, the amperes in the field circuit, and the field amperes needed to produce the flux in tooth and gaps only. (The curves for cast steel and sheet steel on P.366 of Foster's Electrical Engineers' Handbook have been used.) (The tabulation appears on the following page number 4a.)

From the above mentioned data the Curve No.1 entitled No Load Saturation has been calculated. The title of the curves in this thesis if succeeded by a 'c' in parentheses, thus (c), mean that same were calculated and not found by experiment. An (e) in parentheses means 'found by experiment.'

The Next Problem is to Construct a Full Load Saturation Curve.

The drops in voltage with armature current flowing are three:-

The R. I. loss in armature.
That due to armature demagnetization.
That due to armature distortion.

Let the resistance between brush studs be estimated. The coil between commutator bars is composed of the equivalent of 6 coils in series, viz. 5 coils found to be 34 in. in length, and the one by means of which connection is made to the commutator 42.5 in. in length.(The winding is a two circuit wave) . There are 87 such compound coils. The total length of armature wire is therefore 1847 inches. By micrometer measurement it is found to be No. 12. Resistance of the armature winding $= \frac{\text{Length of coil in inches} \times \text{Resistance per ft.}}{12 \times 4}$

$= 0.666.$ Ohms.

The armature is considered to have an average temperature of 110°F. during the taking of resistance, etc.

TABLE OF FLUX DENSITIES.

(For discussion of this table see page 4, of this thesis. See page 366, of Foster's Electrical Engineers' Handbook for curves on cast and sheet steel.)

Note:- The figures in parentheses are Amp. turns per pole.

Terminal Volts	Arm. Body	Teeth	Air Gap	Pole Core	Yoke	Pole Shoe	Total Amp. Turns per pole	F'l'd Amps. for Gaps & Teeth Only	F'l'd Amps.
575	83750 (126.8)	132200 (860)	48500 (3720)	115500 (2360)	41500 (55.6)	41600 (18.5)	3570	0.3705	0.5765
525	76500 (87.2)	120700 (360)	44250 (3360)	105350 (1410)	37885 (52.2)	37950 (16.2)	2643	0.3003	0.4265
500	72850 (68.7)	115000 (230)	42175 (3230)	100450 (970)	36100 (47.3)	36150 (15.7)	2281		0.3685
450	65600 (47.5)	103750 (65)	37920 (2928)	90400 (498)	32500 (45.2)	32520 (13.9)	1799	0.2418	0.2900
400	58350 (34.3)	92000 (37,5)	33750 (2594)	80400 (276.4)	28880 (41.7)	28920 (12.7)	1498		0.2418
350	51000 (26.4)	80500 (20.0)	29500 (2272)	70350 (167.7)	25275 (27.8)	25320 (10.4)	1262	0.1849	0.2035
300	43720 (21.1)	69000 (11.5)	25300 (1956)	60350 (47.8)	21650 (26.1)	21690 (9.3)	1071		0.1728
250	36420 (15.8)	57600 (6.5)	21100 (1632)	50250 (95.2)	18050 (22.6)	18100 (8.1)	890	0.1323	0.1437
200	29175 (10.6)	46000 (4.0)	16875 (1297)	40200 (72.5)	14440 (17.4)	14460 (6.9)	704		0.1137
150	21862 (7.9)	34500 (3.0)	12650 (960)	30175 (54.3)	10825 (13.9)	10845 (4.6)	522	0.0777	0.0843
100	14580 (5.3)	23000 (2.0)	8437 (647)	20100 (31.7)	7220 (10.4)	7230 (3.5)	334		0.0539

Area of brushes = 1.072 sq. in.
(one stud)

Full load current including field I is 22.50 Amps.

$\frac{11.25}{1.072}$ = 1050 Amp. per square in. current density of the collection.

(From the method of A. Gray's Electrical Machine Design P. 77.)

The contact resistance = 4(0.06 x 1.072) = 0.2573 Ohms

R. I. drop of contact = 22.5 x 0.2573 = 5.785 Volts

R. I. Armature drop = 0.666 x 22.5 = 14.97 Volts

Total pressure drop = 20;75 Volts.

The between brush resistance = .9225 Ohms

Now consider the demagnetization at full load with the brushes shifted forward to the edge of pole shoe. There are 5.33 slots between the pole tips. There are12 conductors per slot hence:-

12 x 5.33 x 11.25 = 720 demagnetizing ampere turns per pair of poles.

A full current of 0.0766 amperes will produce this magnetization.

Let the cross magnetizing amperes under the poles be considered.

Then:-

$\frac{16.42 \times 12 \times 11.75}{6196 \times 2}$ = .1790 Amperes needed in field circuit to counteract the cross magnetization.

Now use the method fully explained in A. Gray's Electrical Machine Design (Art. 51, P. 59). In this connection see the sheet entitled Saturation Curve number 1.

The field amperes for a terminal voltage of 500 is : 3.685 of which 2.2800 aré required for the gap and teeth. At full load the ampere turns at one pole tip are :- 0.28 + .1790 = 0.459 and the other pole tip = 0.28 - 0.1790 = 0.1010 ampere turns.

The flux crossing the gap is reduced in the ratio (see curve sheet No.1).

$\frac{(\text{Area aefd})}{(\text{Area abcd})} = \frac{16.07}{17.50} = 0.9195$

The voltage generated is reduced to 459.6.

To maintain the desired voltage 0.3685 + 0.0765 = 0.445 amperes are required.

The construction is then made (as per A. Gray's Electrical Machine Design.) and the Full Load Saturation curve drawn through g parallel to the no load saturation curve.

Let the same calculations be made for ¾ load as a means of verification. The result is shown on the curve sheet. Let the brushes be considered as shifted ¾ of the distance for which they are considered as shifted for full load.

$\frac{8.44}{1.07}$ = 7.89 amperes per sq. in of contact surface.

4(.07 x 1.072) = 0.30 ohms. contact resistance.

R. I. drop = 16.88 x .3 = 5.064 Volts of contact.

Ar.R. I. Drop = 0.666 x 1688 = 11.26 volts.

m Total pressure drop due to resistance = 16.32 volts

There are 9.43 demagnetizing slots.

$\frac{12 \times 9.43 \times 8.44 \times 1.32}{6196 \times 2}$ = 0.1017 Amperes of demagnetisization per pole.

At ¾ load the demagnetizing ampere turns at one pole tip are = 0.28 + 0.1007 = 0.3807

At ¾ load at the other pole tip are = 0.28 - 0.1007 = 0.1793.

The flux crossing the air gap is reduced in the ratio

$$\frac{a'' e'' f'' d''}{a'' b'' c'' d''} = \frac{9.6}{10} = 0.96$$

The voltage is reduced to 480.

The full load saturation curve is drawn not because it is to be verified by experiment (for it is not a curve taken in commercial work) but because it is of assistance in drawing the Regulation Curve which will next be proceeded with.

First the matter of regulation is considered in terms of the Series Field winding that would have to be supplied to perfect it. (curve #3)

From the Excitation Load Curve/(constructed from the no load saturation and full load saturation) it is seen that at full load 0.6325 Shunt field amperes are required.

For no load (from the NoLoad Saturation Curve) 0.3685 Shunt Field amperes are required. Hence:-

0.6325 - 0.3685 = 0.2640 Shunt Field amperes are required to sustain the voltage. This corresponds to 6196 x 0.2640 = 1636 ampere turns per pole. With 22 amperes line current this would mean (arranged short shunt)

$\frac{1636}{22}$ = 74.3 turns of wire per pole.

The greatest current density in the Shunt Field winding that is apt to occur is $\frac{625}{0.37}$ = 1689 circular mills per ampere.

Increasing this by 20% because the field winding is nearer the surface and cooler we find a wire having a section of 4455 circular mills is suitable and No. 16 will serve the purpose.

This would mean four layers on each field coil with a total length of 634.5 ft. or 2.81 lbs.

In the case of this 500 volt machine the winding was not put on because of the high voltage small current and large number ofturns needed .

See the Regulation Curve (curve #2)

Let the curve showing the relation between load and terminal volts with the field kept constant and excited sufficiently to give 500 volts on full load be drawn. On the Excitation Load Curve (curve No. 3) see that 500 volts on full load requires 0.6325 amperes of shunt field current.

The volts given by the same turns at no load are 580 (see No. Load Saturation (c))

Then plot the load lines between the full load and no load saturation and where these strike the excitation line read the voltages.

Excitation 0.6325 Amperes

Load, %	0	25	50	75	100
Volts	580	562	542	515	500

The curve is plotted and titled. The regulation taken from it is

$$\frac{580 - 500}{500} = \frac{80}{500} = 16\%$$

CALCULATIONS OF LOSSES AND HEATING.

To calculate the watts loss in armature copper and iron. (see A. Gray's Electrical Machine Design P. 102.)

The weights of the armature core and teeth are estimated at 58.85 and 7.67 lbs respectively

B teeth = 132200 B body = 83750

$$\text{Frequency} = \frac{1200 \times 2}{6} = 400$$

Watts loss per lb. body = 5.5

Watts loss per lb. teeth = 14.30

Total core loss = 58.85 x 5.5 + 7.67 x 14.30 = 434 Watts iron on full load.

Next calculate the armature copper loss (See A. Gray's Electrical Machine Design P. 102)

Consider the resistance under operating conditions.

Resistance = 1 ohm per circular mill per inch length.

The armature wire is composed of 18470 in. of No. 12.

No. 12 = 6530 circular mills.

$$\frac{18470}{6530} \times 11.25 = 358 \text{ Watts.}$$

Total armature loss at Full load = 782 Watts.

Next calculate the heating of the armature.

Temperature Centegrade = $T = \frac{a}{1+b} \times \frac{p}{a}$ (See W. Cramps Continuous Current Machine Design Pp 80 & 81)

$$P = 782$$

$$A = (11 \times 5 + 10 \times 2 + 9.5 \times 1.5 + 9.75 \times 4\text{-}7/8)\pi = 429.6$$

$b = 0.0005$ $a = 90$

$$v = \frac{11 \times 1200\pi}{12} = 3460 \text{ ft. per minute}$$

per speed

$$T = \frac{90}{1 + 0.0005 \times 3460} \times \frac{782}{429.6} = 60 \text{ degrees C.}$$

The commutator contact resistance drop = 5.78 Volts.

5.785 x 22.5 = 130.0 Watts loss.

With $1\frac{1}{2}$ lbs. per sq. in. brush pressure. (See Thompson's Dynamo Electric Machinery Vol. I P. 519)

Brush Friction loss = $1\frac{1}{2}$ x area x ft. per min x 0.3

$$\times \frac{746}{33000} = \frac{1.5 \times 2.14 \times 3460 \times 0.3 \times 746}{33000} = 75.5 \text{ Watts}$$

Temperature rise for commutator = θ = Cent. degrees.
(See Thompson's Dynamo Electric Machinery VolI P.520)

v = per. speed in ft. per minute
S_3= radiating surface sq. in.
W_b= total loss

$$\theta = \frac{46.5 \times 205.5}{(3.2186 \times 7.203)(1 + 0.0005 \times 346)\pi}$$

θ = 50.40° C.

Now consider the heating of the field coil:
At the excitation to give 500 volts on full load

$$\theta_m = \frac{h \times Wm}{A}$$

h= 60

A_m = (7.281 x 3.5)π= 80

R. per foot at at 154° F. (considering the room 18 and rise 50 at full load.) = 0.02425

R of one coil =

10020 x 0.02425 = 243.3 Ohms.

RI^2 = 243.3 x 0.6325^2 = 97.28 or 98 Watts

Total field loss = 392 Watts.

Then $T_0C = \frac{60 \times 98}{80}$ = 73.5° C.

Estimate the friction loss exclusive of brush friction.(See A. Gray's Electrical Machine Design P. 97)

$$\text{Loss } W = 0.81 d_b b_b \left(\frac{V_b}{100}\right)^{3/2}$$

$$W = 0.81 \times 1.75 \times 4 \left(\frac{0.75\pi \times 1200}{12 \times 100}\right)^{3/2}$$

W = 74.4

Calculation of Efficiency--Full Load.

Assume 500 terminal volts at full load. Neglect windage. (See A. Gray's Electrical Machine Design. p. 99.)

$$\text{Eff.} = \frac{\text{Output}}{(\text{Output} + \text{Bearing Friction} + \text{Brush Friction} + \text{Contact loss} + \text{Armature iron loss} + \text{Ar. Copper loss} + \text{Field Loss})}$$

$$\text{Eff.} = \frac{22 \times 500}{(22 \times 500 + 75 + 205.5 + 434 + 358 + 392)} = 80.35\%$$

Half Load.

The following are constant, bearing friction and brush friction.

The Armature Copper Loss $= \frac{358}{4} = 89.5$ Watts

Contact Resistance loss the drop being the same = 65 Watts.

Field Loss. (See Amperes excitation for this load.)
= 238.5 Watts

Armature Iron Loss. body

B. Teeth = 12620 B/= 80000

58.85 x 5 + 7.67 x 12.0 = 386 Watts iron loss.

Eff. at $\frac{1}{2}$ load =

$$= \frac{500 \times 11}{(5500 + 75 + 75.5 + 65 + 386 + 89.5 + 223.3 + 238.5)} = 85.5\%$$

The Eff. for $\frac{3}{4}$ load is calculated in the same manner and found to be 87.63%.

From the above data the curve is plotted.

COMPARISON OF CALCULATED WITH EXPERIMENTAL DATA.

The No Load Saturation Curve.

The direction of this curve shows that an iron of too high permeability was presupposed. It was impossible, as was hoped, to obtain a saturation curve from the manufacturer and a standard iron was selected from the handbook. The curves for cast steel and sheet steel on p.366 of Foster's Electrical Engineer's Pocket-Book were used.

The full load saturation was plotted merely to assist in obtaining other curves and was not verified by experiment.

The field resistance was calculated as varying from 814 to 910 ohms between 68 and 122°F. See the resistances on Test Sheet No. 2 entitled " Test to obtain regulation." This shows and average R. of 0.864 Ohms. In view of the fact that the space taken up by insulation on the core had to be estimated this calculation is good.

The Armature resistance between pairs of studs was calculated as .922 Ohms. The standing resistance was found to average 0.74 ohms. and one turning resistance 1.00. (See data sheet "No load saturation, #3) In view of the fact that no data on the armature winding could be obtained from manufacturer and it was difficult to measure without dessembling, this calculation of the resistance is fairly satisfactory.

The Excitation Load Curve (See Curve #4) calculated does not check very well with the one found by experiment. The failure of the points on the latter to line up is probably partially due to the difficulty of one man reading so many instruments.

It was impossible to maintain the terminal volts on full load at 500. Hence 478 volts, the voltage obtainable with all field resistance out on full load had to be taken as the full load voltage. The calculated regulation was 16% (See Curve #2) The experimental regulation was found to be 14.5%. The calculation is fairly satisfactory in this case.

The results of the calculations for temperature rise are seen to be far off. The formula for these was applied after much study of the conditions. There is great difference in the formulae of different authors. The writer is led to believe that this feature of design is very hard to reduce to formulae and predictions regarding temperature rise must be based on data obtained from tests of a large number of machines of similar design.

The Calculated Efficiency Curve (See Curve #2) is too high. This would indicate that a consideration of the temperature rises is a vital part of the calculation of efficiency.

C O N C L U S I O N .

The writer believes much better work could have been done had the asked for data been obtainable from the manufacturer. He is impressed with the extent to which design must be based on previous experimentally obtained data and the great variety of methods by which different authors approach the same thing. He is also impressed withthe lack of definite information in texts, etc., along the lines of this thesis. For instance the method of procedure in constructing the Excitation Load Curve (See Curve #4), Regulation Curve (See Curve #2) was not described in the works used.

TEST SHEET NO. 1.

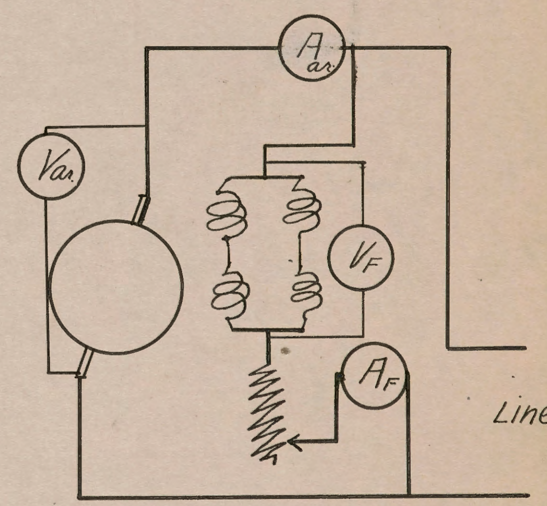
NO LOAD SATURATION.

Motor.

Ob.	Volts F'l'd Read (814)	Volts F'l'd Cor.	Amp. F'l'd Read (3962)	Amp. F'l'd Cor.	Volts Arm. Read (823)	Volts Arm. Cor	Amps Arm. Read (2909)	Amps Arm. Cor	R. P. M.
1	100.0	97.6	12.2	12.0	103	102.25	21.27	21.27	1201
2	97.2	95.0	12.0	12.0	103	102.25	22.6	22.6	1200
3	97.0	94.8	12.0	12.0	103	102.25	23.2	23.2	1201
4	76.4	73.7	11.2	11.6	99.4	99.0	24.5	24.5	1195
5	80.7	78.1	11.5	11.7	101.0	100.5	26.0	26.0	1194
6	80.5	78.0	11.3	11.7	100.8	100.3	27.35	27.35	1196
7	81.4	78.0	11.3	11.7	101.0	100.5	28.75	28.75	1206
8	81.5	79.0	11.15	11.5	101.0	100.5	29.75	29.75	1204
9	82.0	79.5	10.95	11.55	101.0	100.5	29.85	29.85	1202

Generator.

Ob.	R.P.M.	Amp. F'l'd. Read (11509 Sp.C)	Amp. F'l'd. Cor.	Volts Ter. Read (1813)	Volts Ter. Cor. times 5
1	1201	.085	.0625	31.3	153.0
2	1200	.175	.1445	55.0	265.0
3	1201	.216	.1810	62.5	300.0
4	1195	.343	.2880	80.8	392.5
5	1194	.413	.3485	89.5	432.5
6	1196	.520	.4360	98.4	474.0
7	1206	.613	.5150	104.7	505.0
8	1204	.692	.5500	108.6	523.0
9	1202	.730	.6125	112.0	540.0

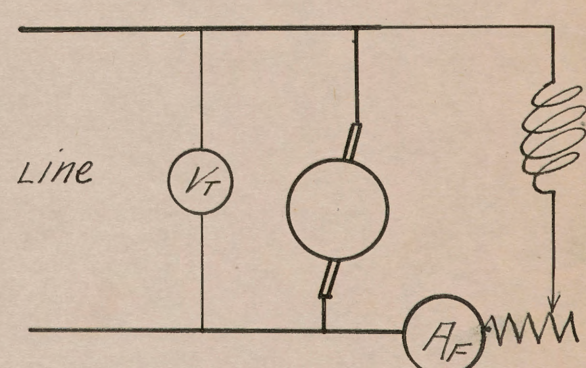


Motor

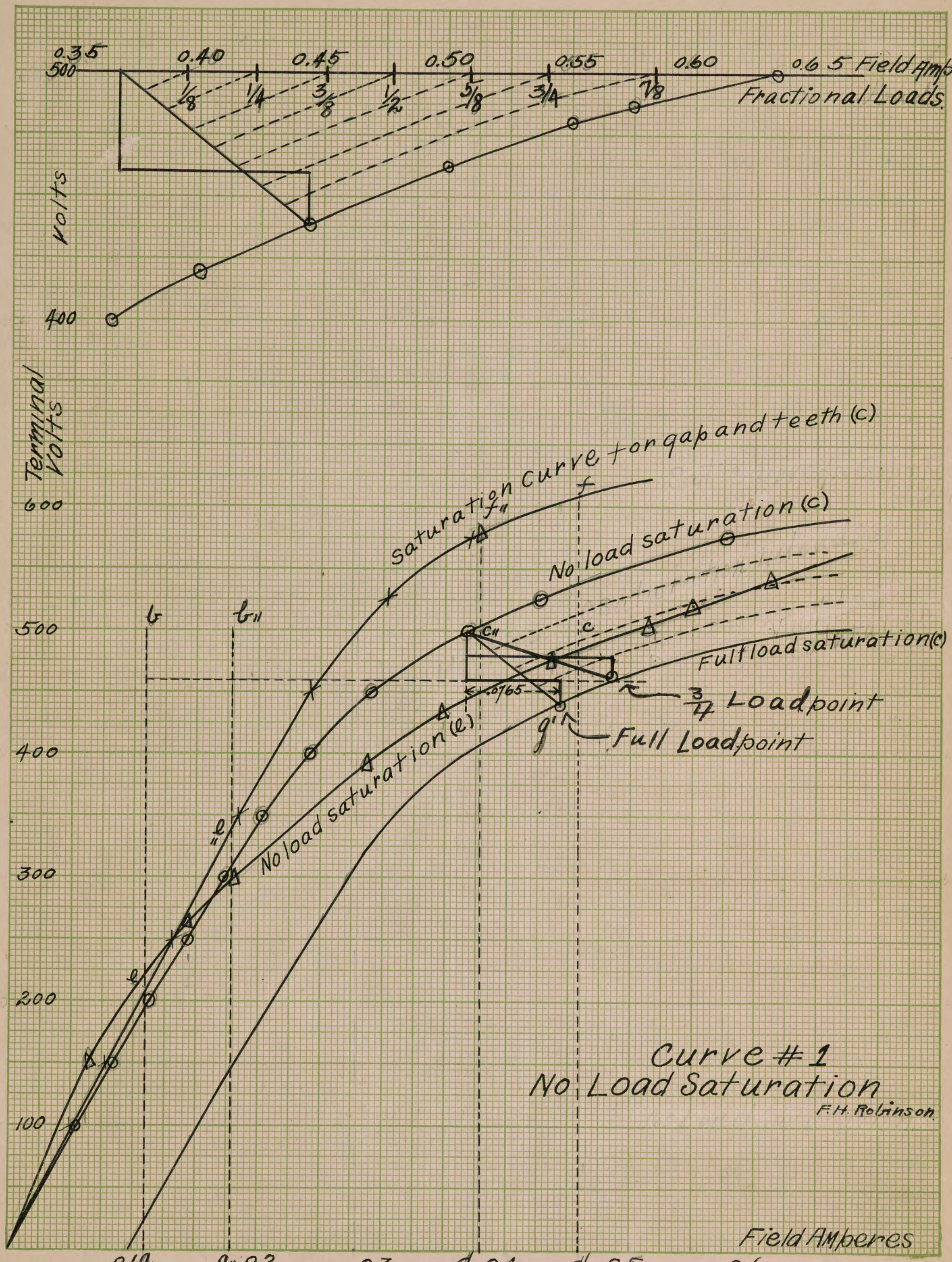
Armature Resistance.

Volts Read (16901)	Volts Cor.	Amperes Read (11508)	Amperes Cor.	Res.
T U R N I N G				
28.35	27.0	27.2	26.8	1.008
S T A N D I N G				
4.737	4.483	6.50	6.32	0.71
3.583	3.404	4.75	4.6	0.739
3.715	2.591	3.40	3.31	0.780

Average standing Resistance 0.743.



Generator



Curve #1
No Load Saturation

F. H. Robinson

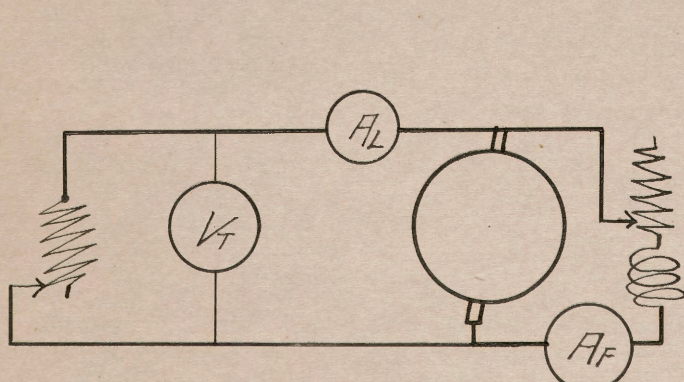
T E S T S H E E T N O. 2.

REGULATION.

Generator.

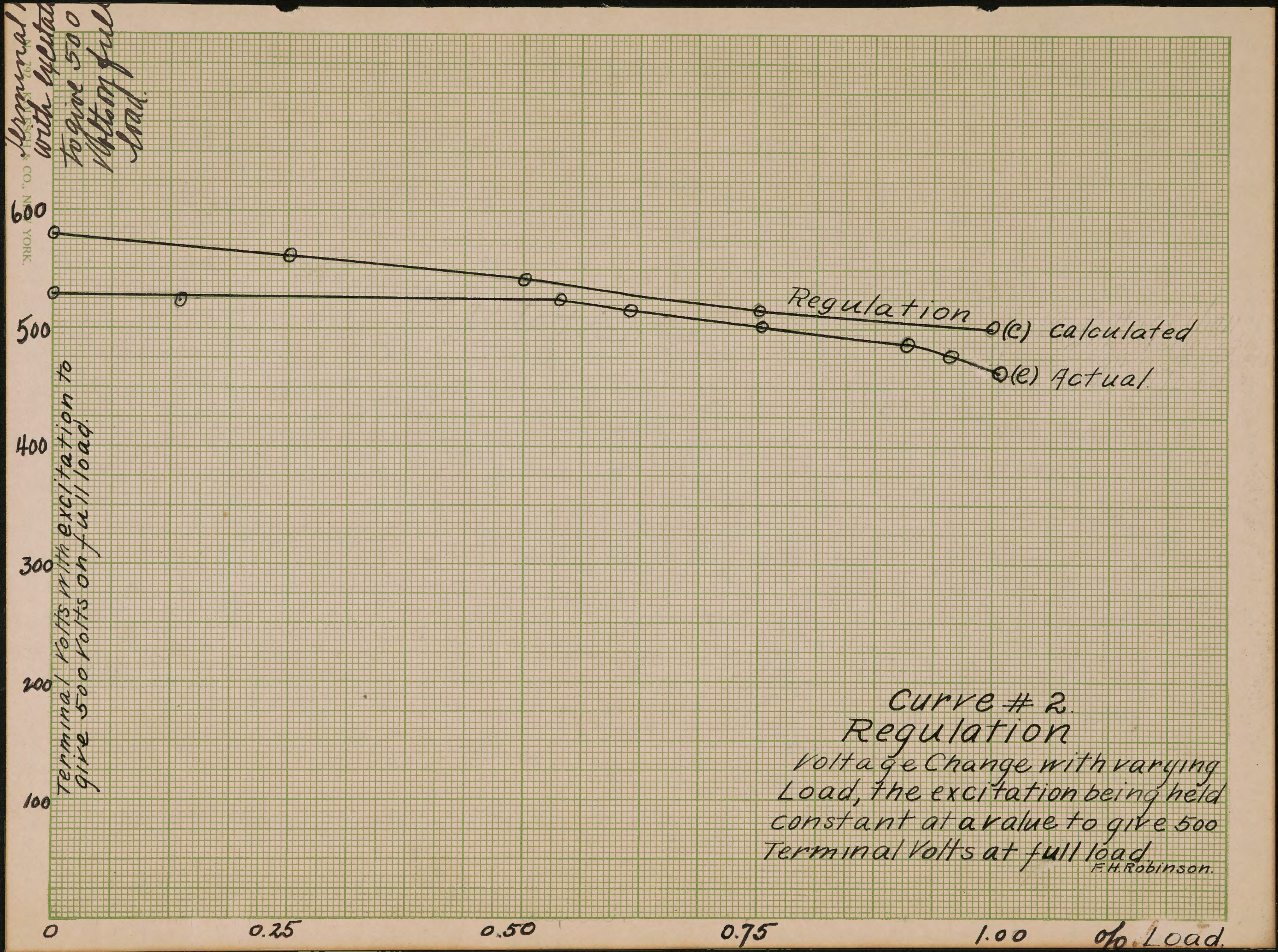
Ob	R.P.M	Volts Ter. Read '1813)	Cor	Amps. Line Read (7864)	Cor	Amps. F'l'd Read (11509)	Cor.	Vlts Rise.	% Load	F'l'd Resis. Ohms.
1	1200	99.0	478	22.0	22.0	.6600	.5525	15	100.0	873
2	1204	101.0	487	20.5	20.5	.6640	.5570	24	91.0	865
3	1199	101.5	490	17.1	17.1	.6700	.5620	27	76.2	855
4	1194	104.0	502	15.0	15.0	.6600	.5525	39	75.4	
5	1207	106.0	510	12.0	12.0	.6700	.5620	47	61.35	
6	1202	108.8	525	10.25	10.25	.7008	.5940	62	53.85	
7	1194	108.8	525	7.00	7.0	.6890	.5790	62	36.75	
8	1202	108.5	525	(11508) 3.40	2.6	.6750	.5650	62	13.63	
9	1195	110.6	530	0.00	0.0	.6905	.5800	67	0.0	

% Reg. from 0 to full load calculated is 16.0
% " " " " " " actual " 14.46
Average resistance of field is 864 Ohms



Motor connected as in Test 1. (No Measurements)

Generator



Terminal Volts with excitation to give 500 Volts on full load.
600
500
400
300
200
100
0
0.25
0.50
0.75
1.00
% Load.
Regulation
(c) calculated
(e) Actual.
Curve # 2.
Regulation
Voltage Change with varying Load, the excitation being held constant at a value to give 500 Terminal Volts at full load.
F.H.Robinson.

T E S T S H E E T N O . 3

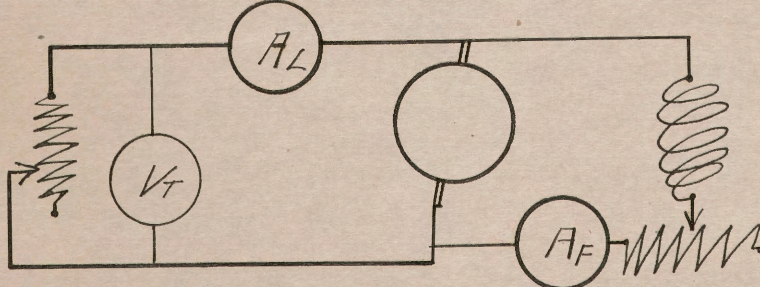
Efficiency and Excitation Load.

Motor.

Ob.	R.P.M.	Volts F'l'd. Read (1814)	Volts F'l'd. Cor	Amps. F'l'd. Read (13962)	Amps. F'l'd. Cor.	Volts Armature Read (823)	Volts Armature Cor.
1	1202	106.5	103.5	13.4	12.60	106.0	105.2
2	1200	103.0	100.5	13.1	12.45	105.0	104.2
3	1205	96.0	94.0	12.6	12.20	104.7	104.0
4	1207	108.0	105.0	12.9	12.35	107.0	106.2
5	1199	104.0	101.3	12.6	12.20	106.0	105.2
6	1206	107;5	104.5	13.2	12.50	107.0	106.2
7	1197	104.0	101.3	12.4	12.60	104.0	103.3
8	1205	104.0	101.3	12.3	12.10	104.0	103.3
9	1209	108.0	105.0	12.4	12.60	106.0	105.3
10	1208	107.0	104.0	12.4	12.60	105.5	104.7
11	1205	112.0	109.0	16.6	16.20	117.5	115.5
12	1204	116.0	103.0	16.0	14.60	117.0	115.5

Motor (Continued)

Ob.	R.P.M.	Amps. Armature Read (7864)	Amps. Armature Cor.	Power Supplied in Watts	Power Delivered in Watts
1	1202	43.5	42.5	5825	3000
2	1200	54.0	54.0	6882	3920
3	1205	62.0	62.0	7597	4635
4	1207	71.5	71.5	8955	6138
5	1199	84.5	84.5	10132	7580
6	1206	93.0	93.0	11197	8900
7	1197	102.0	102.0	11778	9575
8	1205	113.0	113.0	12908	10700
9	1209	126.0	126.0	14593	12180
10	1208	134.0	134.0	15350	12810
11	1205	140.0	140.0	18117	15640
12	1204	154.0	154.0	19304	16525



Motor connected as in Test #1 (all Measurements taken)

Generator.

T E S T S H E E T N O . 3 (Cont'd.)

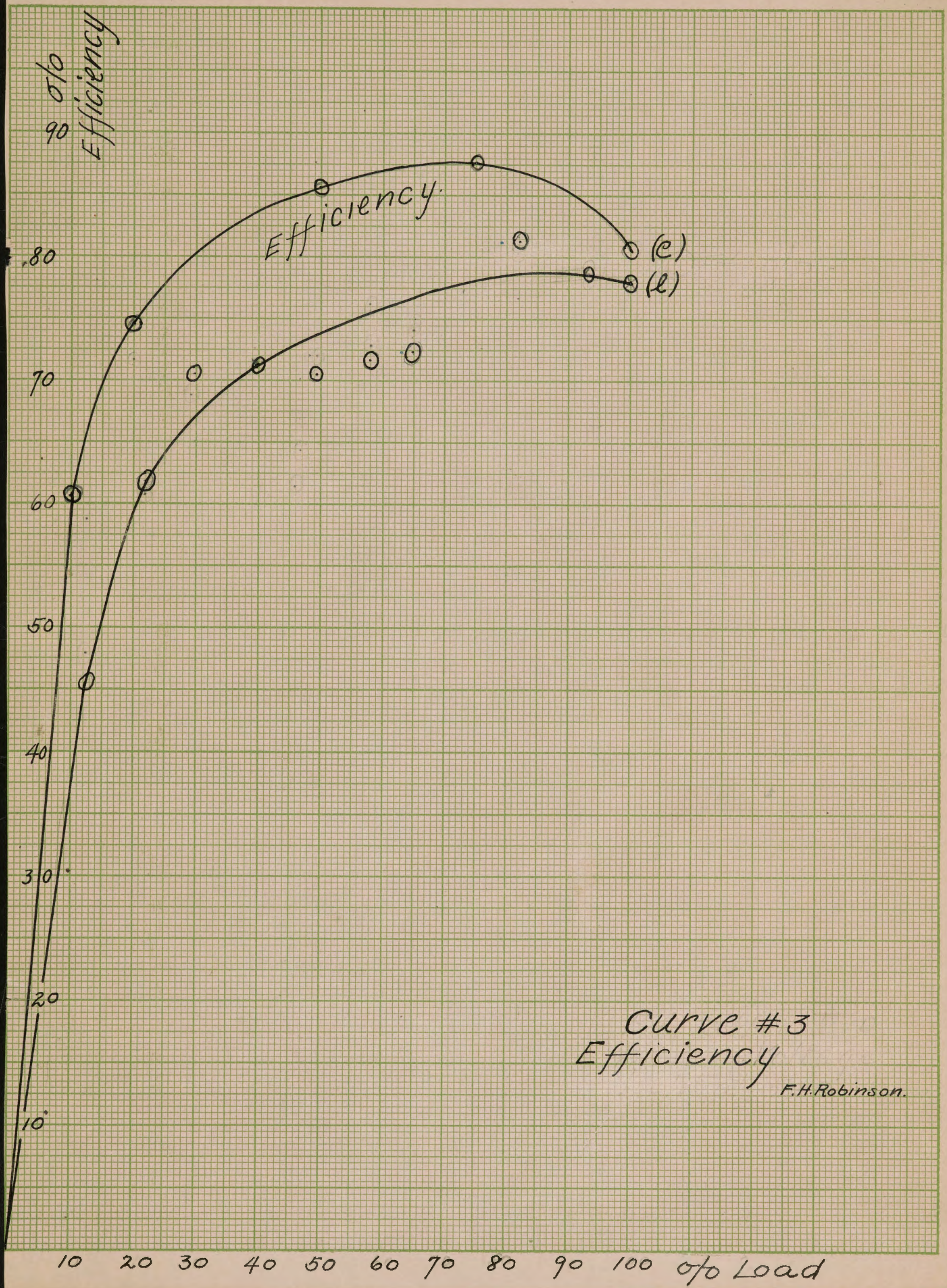
Efficiency and Excitation Load (Cont'd.)

Generator.

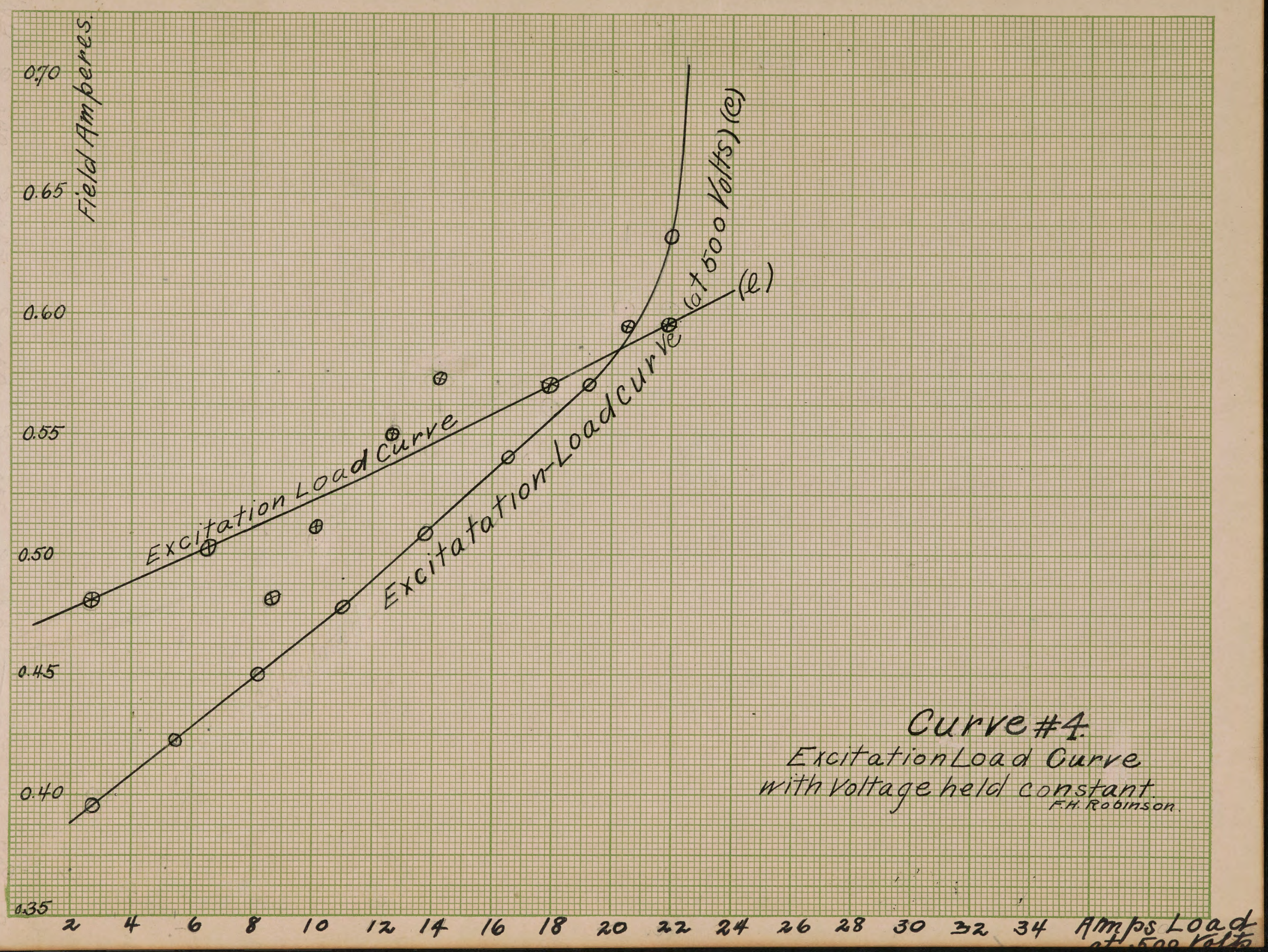
Ob.	R.P.M.	Amperes Lines Read (1812)	Amperes Lines Cor (11508)	Volts Ter. Read	Volts Ter. Cor (1813)	Amps. Field Read (11509)	Amps. Field Cor. and special shunt
1	1202	.77 1.85	2.73	518	500	.577	.4810
2	1200	1.50 3.40	4.82	518	500	.620	.5200
3	1205	2.05 4.65	6.53	518	500	.600	.5025
4	1207	2.73 6.10	8.65	518	500	.576	.4820
5	1199	3.50 7.76	10.81	518	500	.6100	.5120
6	1205	12.90	12.75	518	500	.655	.5500
7	1197	14.50	14.25	101	486	.637	.5350
8	1205	18.00	18.00	100	483	.625	.5250
9	1209	20.50	20.50	97	467	.6005	.5050
10	1208	22.00	22.00	97	467	.595	.5000
11	1205	25.00	25.00	96.5	465	.640	.5370
12	1204	28.00	28.00	95.5	460	.625	.5240

Generator (Cont'd)

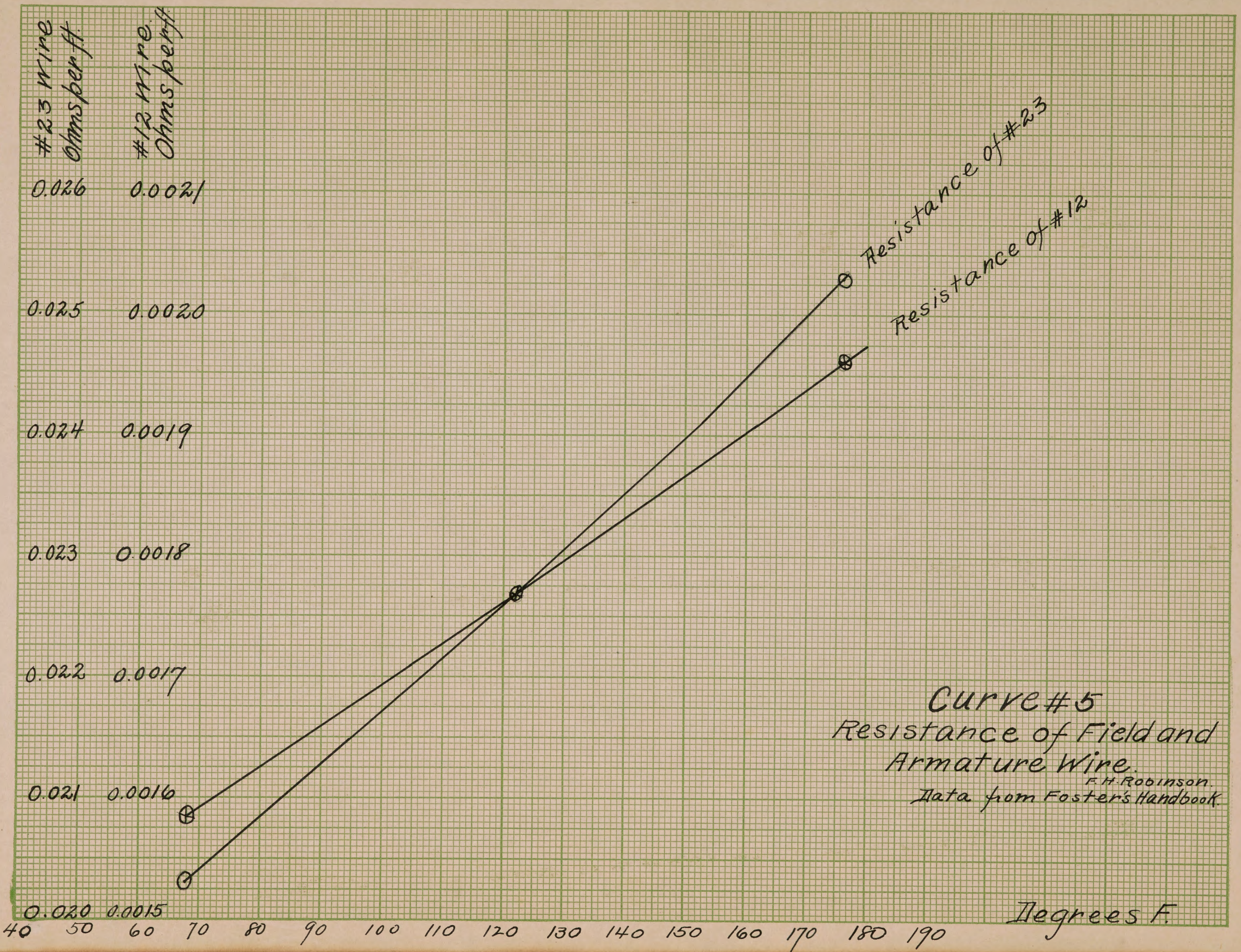
Ob.	R.P.M.	Power Del'v'd: Watts	% of full load	Eff. %
1	1202	1366	12.40	45.50
2	1200	2426	21.90	61.90
3	1205	3265	29.70	70.50
4	1207	4328	39.30	70.55
5	1199	5405	48.15	72.00
6	1205	6375	58.00	71.70
7	1197	6930	64.77	72.40
8	1205	8700	81.75	81.28
9	1209	9585	93.20	78.60
10	1208	10270	100.00	78.00
11	1205	11580	113.80	74.00
12	1204	12880	127.20	66.80



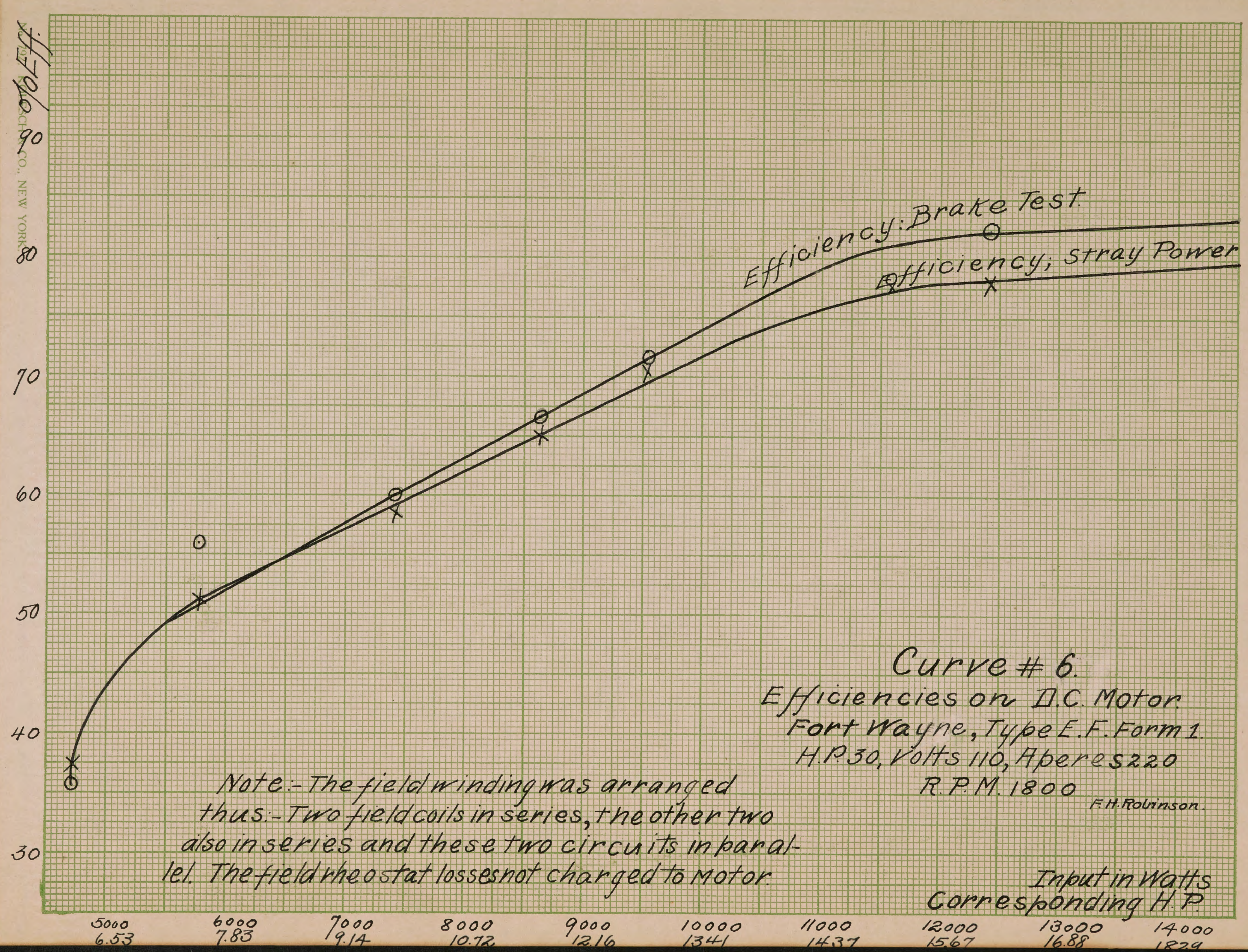
% Efficiency
90
.80
70
60
50
40
30
20
10
10 20 30 40 50 60 70 80 90 100 % Load
Efficiency
(e)
(l)
Curve #3
Efficiency
F.H.Robinson.



Curve #4.
Excitation Load Curve
with Voltage held constant.
F.H. Robinson.



#23 Wire Ohms per ft.
#12 Wire. Ohms per ft.
0.026
0.0021
0.025
0.0020
0.024
0.0019
0.023
0.0018
0.022
0.0017
0.021
0.0016
0.020
0.0015
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Degrees F.
Resistance of #23
Resistance of #12
Curve #5
Resistance of Field and Armature Wire.
F. H. Robinson.
Data from Foster's Handbook.



Eff %
90
80
70
60
50
40
30
Efficiency: Brake Test.
Efficiency; Stray Power
Curve # 6.
Efficiencies on D.C. Motor.
Fort Wayne, Type E.F. Form 1.
H.P. 30, Volts 110, Aperes 220
R.P.M. 1800
F.H. Robinson.
Note:- The field winding was arranged thus:- Two field coils in series, the other two also in series and these two circuits in parallel. The field rheostat losses not charged to Motor.
Input in Watts
Corresponding H.P.
5000
6.53
6000
7.83
7000
9.14
8000
10.72
9000
12.16
10000
13.41
11000
12000
15.67
13000
16.88
14000

T E S T S H E E T N O . 4.

Two hour heat run of generator at normal voltage, current, and speed.

Shut Down Temperatures .

Time	Armature	Commutator	Field Coil	
7-25				
9-25	56	49	50	C.

Rises.
(Room Temperature 25)

	31	24	25	C.

Calculated Temperature Rises.

	60	50	74	C.