THESIS

on

DESIGN OF A STANDARD SPEED, REVOLVING FIELD TYPE, THREE-PHASE ALTERNATOR.

Submitted to the Faculty

of the

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

for the degree of

Bachelor of Science

in

Electrical Engineering

by

Redacted for privacy

and

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Approved: Redacted for privacy

Department of Electrical Engineering

Approved: Redacted for privacy

Dean School Engineering.

INTRODUCTION.

The designing of electrical machinery is fully as essential to the thorough understanding of power equipment and apparatus, as is the taking of a laboratory testing course. One learns the relationship of the different parts, the methods of computing their dimensions, and the predetermination of outputs, efficiencies etc. and thus is enabled to better judge the favorable and unfavorable qualities--- the good and bad points of generators, motors and other appliances used in the great field of electrical engineering. The realization of the training value of such work especially in alternating current design led the writers of this thesis to select the subject chosen.

F. J. W.

R. E. R.

June 2, 1910.

Design of a standard Speed, Revolving Field Type, Three-Phase Alternator.

General Specifications

Revolving field--three phase--60 cycles--514 R.P.M.-400 K.W. output--no load voltage 2200, full load voltage 2300--power factor 85%. Net head 47 feet. Driven by 2--22" turbines mounted on a horizontal shaft.

Number of Poles.

$$\text{R.P.S. equals } \frac{2 \times \text{cycles}}{N_p} \text{ equals } \frac{514}{60}$$

$$\frac{514}{60} \text{ equals } \frac{2 \times 60}{N_p}$$

$$N_p \text{ equals } \frac{2 \times 60 \times 60}{514} \text{ equals 14 poles where}$$

2 equals constant, 60 equals number of seconds in a minute, 60 equals number of cycles, and 514 equals revolutions per minute.

Current.

$$\text{Current per winding I equals } \frac{W}{\frac{E.}{\sqrt{3}} \times 3 \times P.F.}$$

$$\text{equals } \frac{400000 \times 1.73}{2300 \times 3 \times 85}.$$ Where 400,000 equals watts output, 1.73 equals $\sqrt{3}$, 2300 equals terminal voltage, and 85% equals power factor.

FLUX.

$$\frac{K.V.A.}{R.P.M.} \text{ equals } \frac{471}{514} \text{ equals .91 K.V.A. per}$$

R.P.M., where 471 equals kilovolt amperes, and 514 equals revolutions per minute. From a curve taken from a design book it is found that the flux equals

57×10^6 lines.

Conductors per Phase.

$$\frac{K.V.A.}{N} \text{ equals } M \times Z \times C \times \phi \times \frac{\text{form factor}}{120 \times 10''}$$

$$.91 \text{ equals } (3Z \times 118) \times 57 \times 10^6 \times \frac{2.26}{120 \times 10''}$$

Z equals 240 conductors.

.91 equals Kilovolt amperes per revolution per minute, M equals 3 equals number of phases, Z equals conductors per phase, C equals current per phase, ϕ equals 57×10^6 equals flux, 2.26 form factor, and 120 x 10" equals constant.

3 x 3 x 14 equals 126 slots, where 3 slots are used per phase per pole and 14 equals poles; 126 equals total number of slots.

126 $\div$ 3 equals 42 slots per phase, where 126 equals total number of slots and 3 equals number of phases.

Since the number of conductors must be devisible by 42, 210 were used.

Total number of conductors for the three phases equals 210 x 3 equals 630.

DIAMETER OF REVOLVING FIELD.

$$(zc) \text{ equals } M \times Z \times \frac{C}{D \times 3.14} \text{ equals } 480 \text{ equals}$$

ampere conductors. 480 equals $\frac{3 \times 210 \times 118}{D \times 3.14}$

D equals 49.9 use 50" as the diameter of the revolving field. In this case XC equals ampere conductors, M equals number of phases, Z equals conductors per phase and 3.14 equals π.

PERIPHERAL VELOCITY.

V equals D x 3.14, x $\frac{N}{12}$, where V equals peripheral velocity.

D equals diameter of revolving field, 3.14 equals π, N equals revolutions per minute, and 12 equals conversion factor.

V equals 50 x 3.14 x $\frac{514}{12}$ eqùals 6725 peripheral velocity.

SIZE OF CONDUCTORS .

$\frac{\text{Current per phase}}{\text{Current density per sq. in.}}$ equals $\frac{118}{1800}$ equals .0605 sq. in.

Circular mils equals $\frac{.0656 \times 10^6}{.7854}$ equals 83500, where .7854 equals $\frac{1}{4}$ of π.

83500 corresponds to 2 No. 4 B & S wires.

2 No. 4 B & S wires were used in parallel per conductor. Total diameter of No. 4 wire equals 2.16".

SLOT AND TOOTH DIMENSIONS.

Thickness of insulator equals .05". Thickness of wooden wedge equals .2". Distance of wedge from end of tooth equals .04". Since there are five conductors per slot (2 wires equals 1 conductor), the slot must be two wires wide and five deep.

(2 x .05)+(2 x .216) equals .532" width of slot.

(2 x .05)+(5 x .216) .04 .2 equals 1.42" depth of slot.

Tooth pitch equals $\frac{\text{internal bore x } \pi}{\text{number of teeth}}$ equals

$\frac{50.6 \times \pi}{126}$ equals 1.26".

Tooth pitch — slot width equals 1.26 — .532 equals .728" width of top of tooth.

$\frac{(\text{Root pitch — slot width}) \times \pi}{\text{number of teeth}}$ — equals width of slot equals $\frac{(50.6 + 2.82)\ \pi}{126}$ — .532 equals .798" width of root of tooth. Mean thickness of tooth equals $\frac{.728\ \ .798}{2}$ equals .763 equals R where .728 = width of top of tooth, and .798 equals width of root of tooth.

LENGTH OF POLE ARC.

Ratio of pole arc to pole pitch was taken as .65 from a table. .65 equals $\frac{L}{\text{pole pitch}}$ equals $\frac{L}{11.25}$.

Then L equals 7.3" equals length of pole arc.

POLE PITCH .

Pole pitch equals $\frac{\text{diameter of revolving field x } \pi}{\text{number of poles}}$ equals $\frac{50 \times 3.14}{14}$ equals 11.25".

AIR GAP CALCULATIONS.

Calculation of Armature Ampere Turns.

T equals 210 ÷ 105 turns per phase, where 210 equals conductors per phase. AT_b equals 2.12 x c x T equals 2.12 x 118 x 105 equals 26260 armature back ampere turns, where 2.12 equals constant, 118 equals amperes per phase, and 105 equals turns of wire per phase. 26260 x 2.75 equals 72200 total number of ampere turns in the field, where 275 represents the times that the field ampere turns are larger than the armature ampere turns.

$\frac{\text{Total number of ampere turns in field}}{\text{number of poles}}$ equals 5150 Ampere turns per pole.

5150 x 70% equals 3610 Ampere turns lost in air gap where 5150 equals ampere turns per pole, and 70% are lost in air gap.

Ampere turns lost equals $\frac{\delta \times \text{constant}}{\text{pole pitch} \times \text{length of pole}}$ x flux.

$3610 \text{ equals } \frac{\delta \times 0.313}{7.3 \times 15.2} \times 4.07 \times 10^6.$

$\delta \text{ equals } \frac{3610 \times 7.3 \times 15.2}{4.07 \times 10^6 \times .313}$ equals .314 Length of air gap. Length of air gap was taken as .3

LENGTH OF ARMATURE.

$\frac{\text{Flux per pole}}{\text{density per sq. in. im teeth}}$ equals area of teeth under pole.

$\frac{4.07 \times 10^6}{70000}$ equals area of teeth under a pole equals qt.

$\frac{a}{O} \times r \times l$ equals qt.

a equals 7.3" pole arc.

O equals Tooth pitch equals 1.26"

r equals .763" mean thickness of tooth.

l " $\frac{58 \times 1.26}{7.3 \times .763}$ equals 15.5 Approximately length of armature. use 2 — ½" ventilating ducts.

$\frac{13.1}{.85} + 1$ equals 16.5" Length of armature, where .85 equals factor used to corect for laminations.

ARMATURE CORE.

Crossectionequals $\frac{\text{pole flux}}{2}$ ÷ core density.

$\frac{4.07 \times 10^6}{2 \times 35000 \times .85}$ equals 68.2 sq. in. in cross section.

35000 lines were taken as the density of the armature.

Depth of core equals $\frac{\text{core cross section}}{\text{core length}}$

$\frac{68.2}{15.5}$ equals 4.4" depth of arc.

4.4 + 50.6 + (1.42 x 2) equals 62.24" outside diameter of armature where 50.6 equals inside diameter of armature, and 142 equals depth of slot.

POLE CALCULATIONS.

$\frac{\text{Leakage factor x flux per pole}}{\text{Density per sq. in.}}$ equals sq. in. crossection of pole.

$\frac{1.3 \times 4.07 \times 10^6}{102000}$ equals 50.4 sq. in. cross section of pole.

15.2 was taken as the length of a pole.

$\frac{50.4}{15.2 \times .95}$ equals 3.5" width of pole, where 50.4 equals cross section of pole, 15.2 equals length of pole, and .95 equals factor to correct for laminations.

$\frac{5160}{1300 \times .4}$ equals 9.9 sq. in. cross section of winding.

5160 equals ampere turns per pole, 1300 current density in amperes per sq. in., .4 space factor.

Limit of winding depth was taken as 1.8"

$\frac{9.9"}{1.8"}$ equals 5.5 Height of coil, where 9.9 equals cross section of winding, and 1.8" equals winding depth.

Allow 1" for depth of pole shoe.

5.5 +1 equals 6.5" Total depth of pole.

50—(6.5 x 2) equals 37" Diameter of revolving field at base of poles where 50= outside diameter of revolving field, and 6.5 x 2 equals total depth of two poles.

CALCULATIONS OF LEAGAKE FACTOR.

$$0 \text{ Equals } 1 + \frac{r_o}{r_1'} + \frac{r_2}{r_1'} + \frac{r_2}{r_2'}$$

$$r_o \text{ equals } \frac{.313}{\frac{a \times r \times l}{o \times \sigma} + \frac{a \times l \times (u + \frac{s}{2})}{0\,(u + \sigma)}} = \text{Reluctance of}$$

air gap system.

$$r_1' \text{ equals } \frac{.313}{\frac{4c \times f}{N} + \frac{4d \times f}{M} + \frac{4b \times d}{m + b}} = \text{Reluctance of field path.}$$

$$r_2 \text{ equals } \left(\frac{i \times 0}{a \times r \times l \times u_t \times j} + \frac{v}{2k \times l \times ua \times j}\right) \times$$

.313=Reluctance of armature system.

$$r_2' \text{ equals } \frac{.313}{\frac{4i \times l \times o}{3\,(n+a)} + \frac{4l \times r[(a+k)+Q]}{(a+n) \times 0} + (a+n) + 2l} =$$

Armature leakage path reluctance.

σ equals Length of air gap equals .3"

f " " of pole " 15.2"

c " Thickness of pole shoes equals 1".

d " Distance between pole shoe and wheel rim equals 5.5".

v equals $\frac{\text{flux path in armature}}{2}$ equals 6.86"

i " Depth of slot equals 1.42"

0 " Slot pitch " 1.26

a equals Pole pitch equals 7.3"

r " Mean thickness of tooth equals .763"

l " Length of armature equals 15.5

u_a " Permeability of armature equals 1950

j " Constant for lamination equals .85

s " Width of slot equals .532"

N " Mean distance between pole shoes equals 3.91"

M " " " " poles equals 6.05"

K " Depth of armature core equals 4.4"

b " Width of pole equals 3.5

u " Height of tooth above wires equals .24"

Substituting in the formulas we get:

r_0 equals .00102

r_1' " .004

r_2 " .000018

r_2' " .00745

$$\sigma \text{ equals } 1 + \frac{.00102}{.004} + \frac{.000018}{.004} + \frac{.000018}{.00745}$$

σ " 1 + .256 + .0045 + .00242 equals 1.263

Actual leakage factor.

CALCULATION OF ARMATURE RESISTANCE.

A chain winding was used. The lengths of the flat coils are 79.2", 72.6" and 67.2". The lengths of the bent coils are 83.14", 75.16", and 67.5". Mean length of a coil equals $\frac{(79.2 + 72.6 + 67.2 + 83.14 + 75.16 + 67.5)}{2}$ equals 74".

Since 210 conductors per phase there are 105 turns per phase.

Then the length of winding per phase equals 105 x 74 equals 7770" where 105 equals turns per phase, and 74 equals mean length of a turn.

Resistance equals $\dfrac{\text{length in inches} \times .8}{\text{cross section of con.} \times 10^6}$

equals .095 ohms per phase.

WHEEL RIM.

Assuming that the rim projects 1.9" on either side of the poles then 19" equals width of rim.

Thickness equals $\dfrac{\text{pole flux}}{2 \times 19 \times \text{rim density}}$.

$\dfrac{4.07 \times 10^6}{2 \times 19 \times 45000}$ equals 3" depth of wheel rim.

CALCULATION OF SHORT CIRCUIT CHARACTERISTIC.

K_s equals $1 + \dfrac{r_o}{r_2} + \dfrac{r_1}{r_2} + \dfrac{r_1}{r_1'}$

All of these reluctances were found except r_1.

r_1 equals $.313 \times \left(\dfrac{d}{b \times f \times u_p} + \dfrac{e}{2g \times h \times u_t} \right)$

equals magnetic reluctance of the field system.

To find the length of the path c:

50"—2(1+5.5)—3 equals 34" mean diameter of wheel rim, where 50 equals diameter of revolving field and 5.5 equals height of coil.

$\dfrac{1}{28}$ of pole arc at this diameter equals $\dfrac{\pi\, 34}{28}$

equals 3.82". $\dfrac{\text{Length of path on diameter}}{2}$ equals

$3.82 - \dfrac{3.5}{4} - 1.5$ equals 1.44. $\dfrac{\text{Length of path}}{2} = e$

e equals $1.44 + \frac{3+\pi}{4}$ equals 3.81" length of path through the wheel rim.

u_r equals Permeability of wheel rim equals 350

u_p " " " pole " 1600

d " distance from wheel rim to pole shoe.

b " thickness of pole equals 3.5"

g " width of wheel rim " 19"

h " thickness of wheel rim equals 3"

f " length of pole " 15.2"

r_1 " $.313\left(\frac{5.5}{3.5 \times 15.2 \times 350} + \frac{3.8}{38 \times 3 \times 1600}\right)$

equals .0000992

K_s equals $1 + \frac{.00102}{.00745} + \frac{.0000992}{.00745} + \frac{.0000992}{.004}$

K_s " $1 + .137 + .0133 + .0248$ equals 1.175 Effect of leakage on short circuit current.

$2\ P \times A_1$ equals $K_s \times 2.12 \times \frac{z}{2} \times c$.

2 P equals 14 poles, K_s equals effect of leakage on short circuir current, A_1 equals 5000 ampere turns necessary for shunt field to supply; this was taken from curve, one of the curves *drawn*.

Z equals 210 Conductors per phase, 2.12 equals constant.

14 x 5000 equals 1.175 x 2.12 x 105 C

C equals 268 Short circuit current.

CALCULATION OF SHUNT FIELD.

100 volts used in D.C. exciter for shunt field.

Table of Flux and Cross sectional areas of different parts for different loads. Ampere turns per paths. etc.

E. M. F.				3000		2300		1600		1000	
ARMATURE FLUX				5.3×10^6		4.07×10^6		2.83×10^6		1.77×10^6	
FIELD FLUX				6.7×10^6		5.14×10^6		3.58×10^6		2.24×10^6	
Material and sectional area in sq. in. of:	Wheel Rim.	Cast iron 57	Magnetic densities and corresing amp. turns per in. of length.	58600	250	45000	125	31300	60	19600	25
	Pole Core	.04" Sheet 50.4		133000	700	102000	100	71000	24	44400	11
	Teeth	.02" Sheet 58		91300	50	70000	22	48700	12	30400	8
	Arm. Core	.02" Sheet 58		45600	12	35000	9	24300	73	15200	6
Length of magnetic path in inches.	Wheel Rim	3.8"	Ampere turn of paths	950		475		228		95	
	Pole Core	6.5"		455	0	650		156		71.5	
	Teeth	1.42"		71		31.2		17		11.4	
	Arm. Core	6.86"		82		61.7		50.1		41.2	
	r_0	.00102		5410		4150		2890		1805	
Total ampere turns per pole.				11063		5372	9	3341.1		20241	

Allowing 22% drop in the rheostat we have 78 volts delivered to the shunt winding. It takes 70000 ampere turns to excite the shunt field at no load and 2200 volts. Sectional area of conductor equals

$$\frac{\text{Ampere turns} \times \text{length of a turn} \times \frac{8}{10^7}}{E}$$

Length of one turn of the field winding:

Mean diameter equals 3.5+1.75 equals 5.25" where 3.5 equals width of pole and 1.75 equals depth of winding

Length equals 14.45 x 2+5.25Xπ equals 45.4" Mean length of turn, where 14.45 equals straight part of pole and 5.25 equals mean diameter.

q equals $\frac{70000 \times 45.4 \times 8}{78}$ equals .0325 Sectional area of conductor, where 70000 equals shunt ampere turns 45.4 equals mean length of turn $\frac{.0325 \times 10^6}{7854}$ equals 41615 circular mils.

Sq. in. equals .0326.

This corresponds to a No. 4 B & S wire.

Using a current density of 1300 amps. per sq. in. 1300 x .0326 equals 42.4 amperes that must be delivered to the shunt field.

$\frac{\text{Ampere turns}}{\text{amperes used in shunt field}}$ equal $\frac{70000}{42.4}$ equal 1650 turns in shunt field.

R equals $\frac{\text{Turns} \times \text{length in inches} \times 8}{\text{Sectional area of conductor} \quad 10^6}$

$1650 \times \frac{45.4}{.0326} \times \frac{.8}{10^6}$ equals 1.83 Ohms resistance of shunt winding.

CALCULATION OF SERIES WINDING.

Ampere turns necessary to excite field to 2200 volts at no load equals 70000. Ampere turns necessary to excite the field at 2300 volts or at full load equals 102000. Then the compensating winding should supply 32200 ampere turns at full load.

Use 1500 amperes per sq. in. in series winding.

A - 3 to 1 transformer gives 39.4 amperes.

$\frac{39.4}{1500 \times .7854}$ equals 33124 Circular Mils.

This corresponds to a No. 5 B & S wire.

$\frac{32200}{39.4}$ equals 58.4 use 59 turns per pole.

R equals $\frac{\text{Length of a turn x turns}}{\text{Area of conductor}} \times \frac{8}{10^7}$

R " $\frac{45.4 \times 59 \times 8}{.026 \times 10^7}$ equals 1.15 Ohms resistance of series field.

CALCULATION OF WIDTH AND DEPTH OF SHUNT & SERIES WINDINGS.

1650 -÷- 14 equals 118 Shunt turns per pole where 1650=series turns per pole. Allow 55" on each end of coils for iron plates.

Diameter of No. 4 wire equals .216"

" " " 5 " " .194"

8 x .216 equals 1.73" depth of shunt winding.

Since the winding is 15 turns wide and 8 deep:

15 x .216 equals 3.24" width of shunt winding.

The series winding is 6 turns wide and 9 deep.

6 x .194 equals 1.16" width of winding.

9 x .194 equals 1.74" depth of winding.

Total width of windings equal 3.24 + 1.16 equal 4.4".

CALCULATION OF LOSSES.

Hysteresis loss equals W_h equals A x V x f

Mean diameter of the armature core equals 50.6 + 2.82 + 4.4 equals 57.82. Width equals 15.5" and depth equals 4.4"

V equals 57.82 x 11 x 15.5 x .85 equals 10500 cu. in. in armature, where .85 is a factor to correct for laminations.

Mean thickness of a tooth equals .763. Length equals 15.5".

Depth equals 1.42" and number equals 126.

V equals .763 x 15.5 x 1.42 x .85 x 126 equals 1800 cu. in. in teeth.

a equals Hysteresis factor corresponding to 35000 lines equals .0054.

f equals 60 cycles.

W_h " .0054 x 10500 x 60 equals 3400 watts lost in armature due to hysteresis.

Hysteresis factor for 70000 lines equal .00164

W_h equals .00164 x 1800 x 60 equals 1770 watts lost in teeth due to hysteresis.

CALCULATION OF EDDY CURRENT LOSS.

W_e equals E V f^2

E " Eddy current factor for 3500 lines equals .000021.

W_e equals .000021 x 10500 x 3600 equals 794 watts lost in armature due to eddy currents, where 10500 equals cu. in. in armature and 3600 equals cycles squared.

Eddy current factor for 70000 lines equal .000082

W_e equals .000082 x 1800 x 3600 equals 531.5 watts lost in teeth due to eddy currents where 1800 equals cu. in. in teeth and 3600 equals cycles squared.

Total iron loss equals 3400+1770+794+531 equals 6496 watts where 3400 equals hystersis loss in armature, 1770 equals hystersis loss in teeth, 790 equals eddy current loss in armature, and 531 equals eddy current loss in teeth.

DATA FOR CALCULATING EFFICIENCY.

Load	Kilo Watts	Iron Loss	Friction and Windage loss	I	1^2r Loss in Armature	1^2r loss shunt field.
$\frac{1}{4}$	100	6496	6300	29.5	247.5	4240
$\frac{1}{2}$	200	6496	6300	59	990	4240
$\frac{3}{4}$	300	6496	6300	88.5	2232	4240
$\frac{4}{4}$	400	6496	6300	118	3966	4240
$1\frac{1}{4}$	500	6496	6300	147.5	6204	4240
$1\frac{1}{2}$	600	6496	6300	177	8925	4240

continued.

1^2 r loss in series field	total loss	Eff. in %
447.25	17731	82.26
894.5	18920	90.5
1340	20608	93
1789	22791	94.3
2236.25	25416	94.9
2683.5	28644	95.2

TABLE OF WEIGHTS.

Parts	Cubic inches	Weight in Lbs.
Teeth	1800	500
Body of armature	10500	2910
Poles	3880.8	1080
Pole shoes	1551	432
Wheel rim	8070	2105
Hub	3720	968
Frame	11900	3100
Ribs	2000	520
Bearing	3064	800
Armature key stays	1200	313
Supports	872	227
Winding guard	780	203
Base of machine	12620	3290
Shaft	5890	1670
Coupling	530	150
Spokes	4017.34	1044
Armature wire (length inft	3880	525
(width per ft)	.126	
Wire on shunt field	6270 (ft. long)	788
" " series "	3130 " "	313
Postes for holding brushes	456	118
Pole rings	206.4	57
Copper in commutator	340	108
" " slip rings	170	54
Iron in commutator	250	71
" " slip rings	160	45
	Total	21391

DIAGRAM OF RECTIFIER FOR SERIES FIELD.

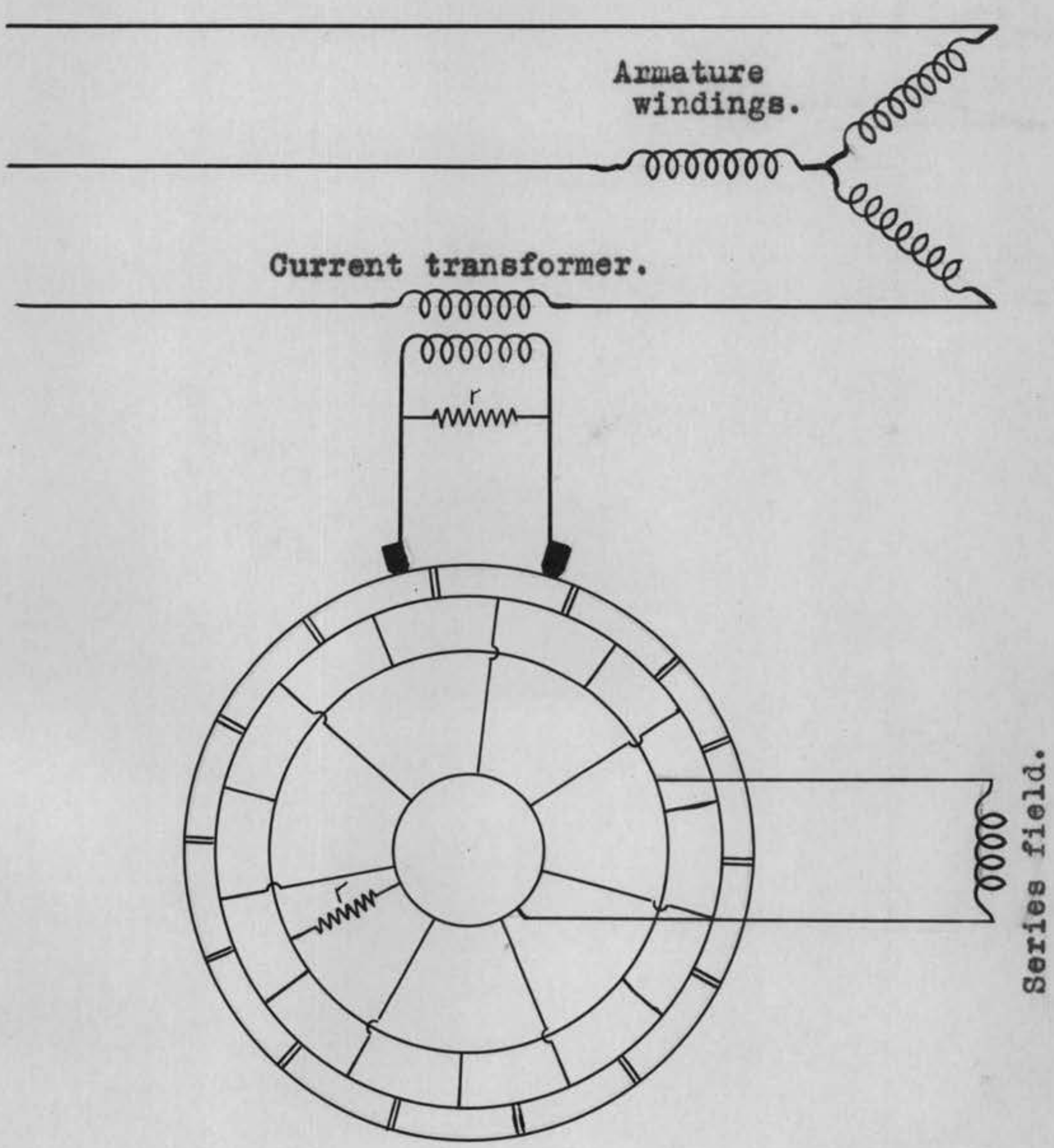


Plate 1 gives end and side elevation of the field.

Plate 2 gives elevations of wheel rim and spider, and end and side elevations of field poles.

Plate 3 gives shaft, commutator, slip rings, and coupling.

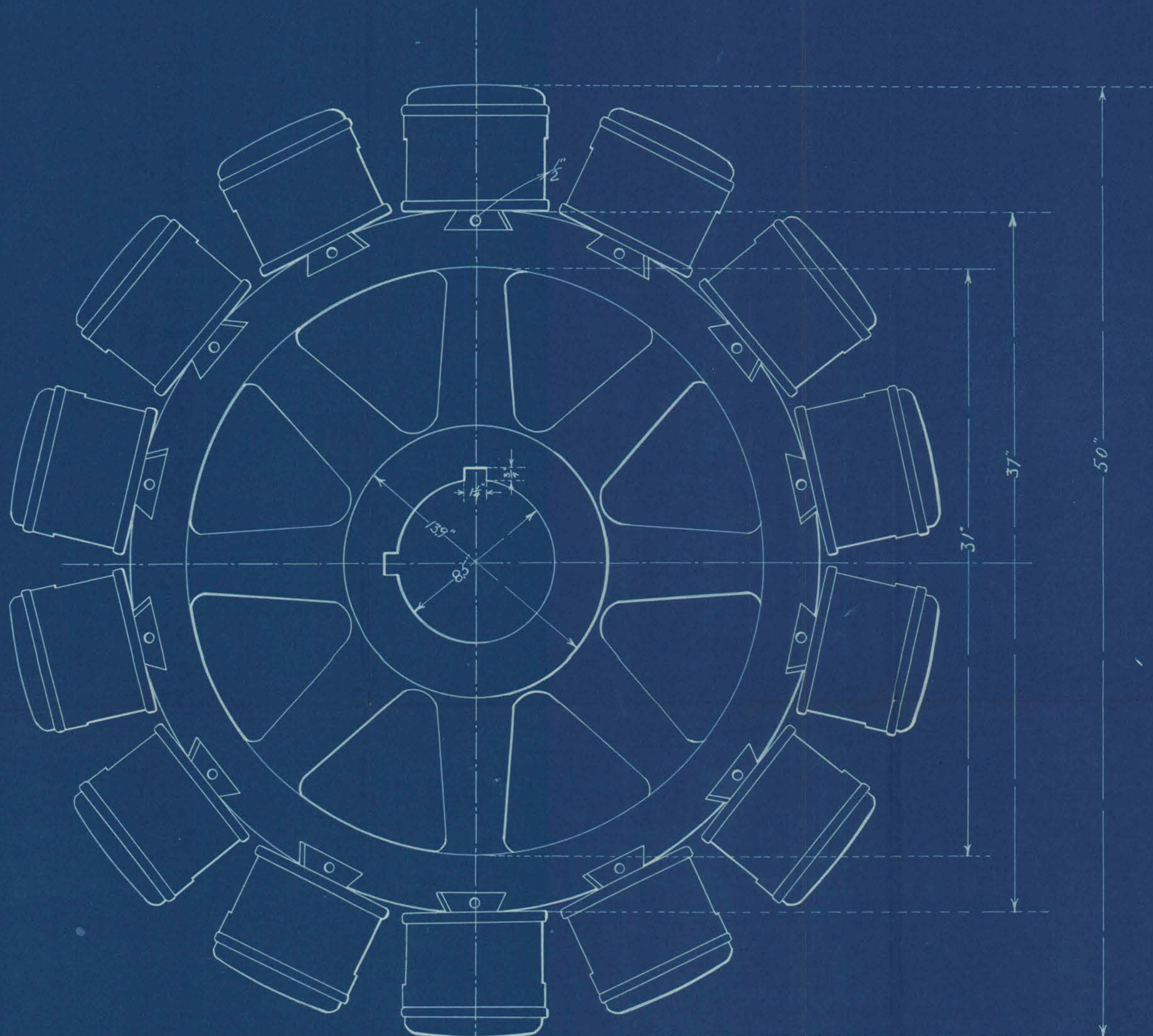
Plate 4 gives side and end elevations of armature.

Plate 5 gives section of armature, armature ring and bearings.

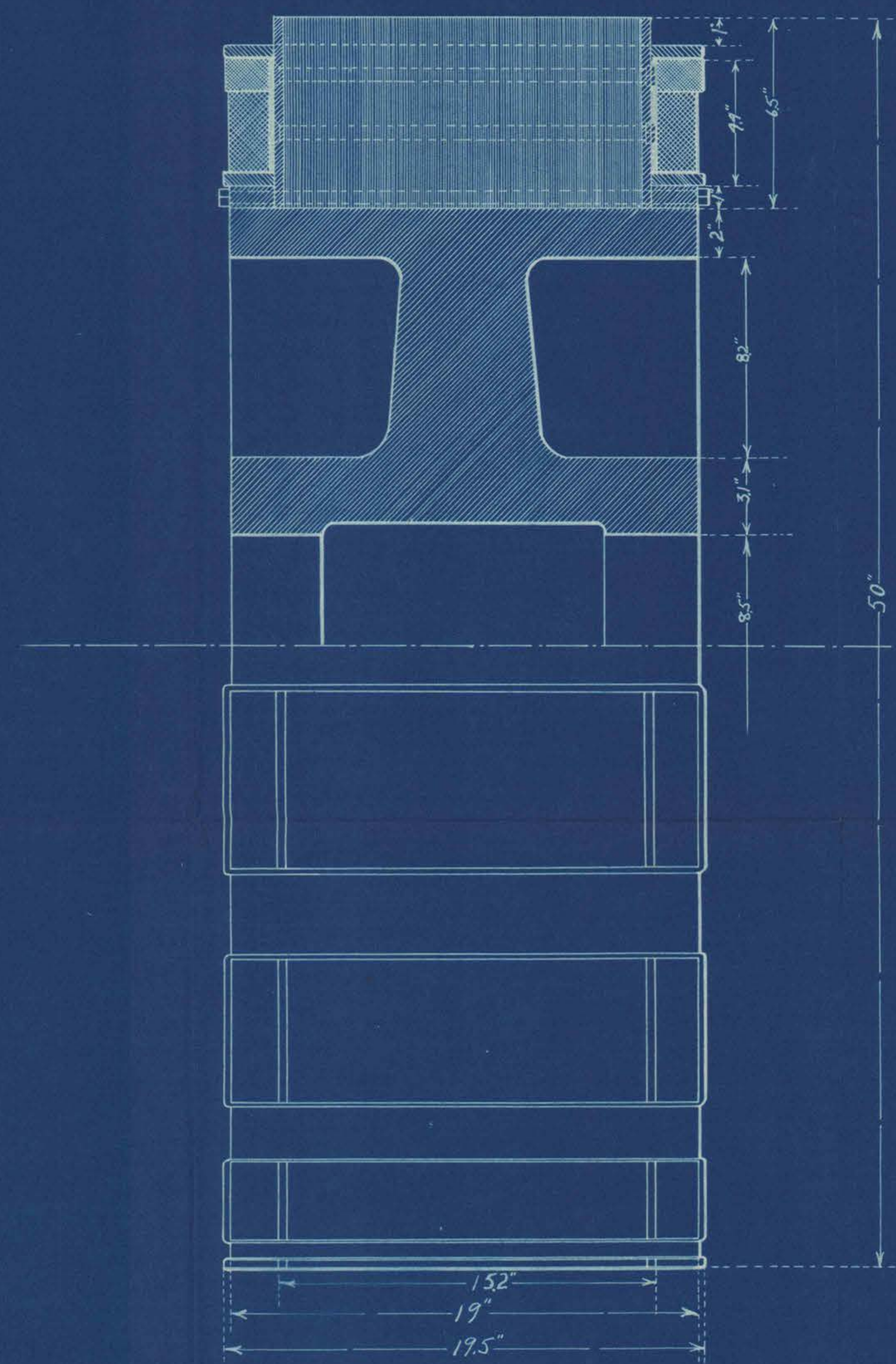
Plate 6 gives plan of the alternator.

Plate 7 gives excitation, load and compounding curves.

Plate 8 gives loss and efficiency curves.



End elevation of field   Scale 1"=5"



Side elevation of field

THREE PHASE ALTERNATOR

REVOLVING FIELD TYPE

421 K.V.A ~ 60 Cycles ~ No load 2200 Volts ~

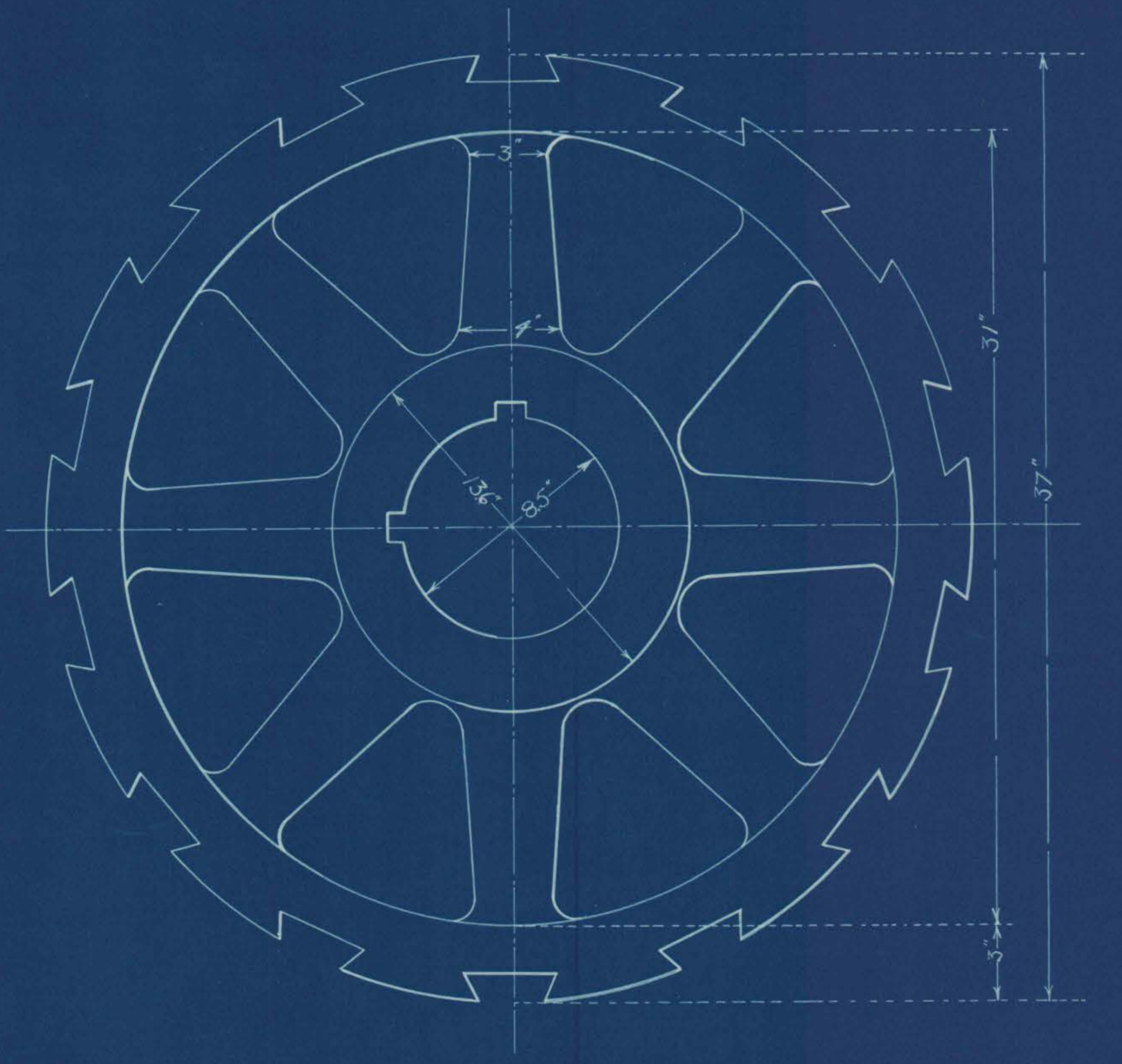
Full load 2300 Volts ~ 14 Poles ~ Speed 514 R.P.M.

Designed by   Date April 4, 1910

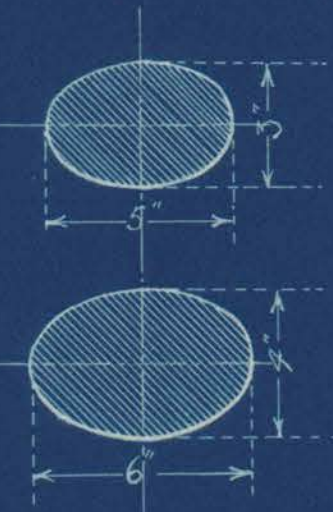
F. J. Williams & R. E. Rawson

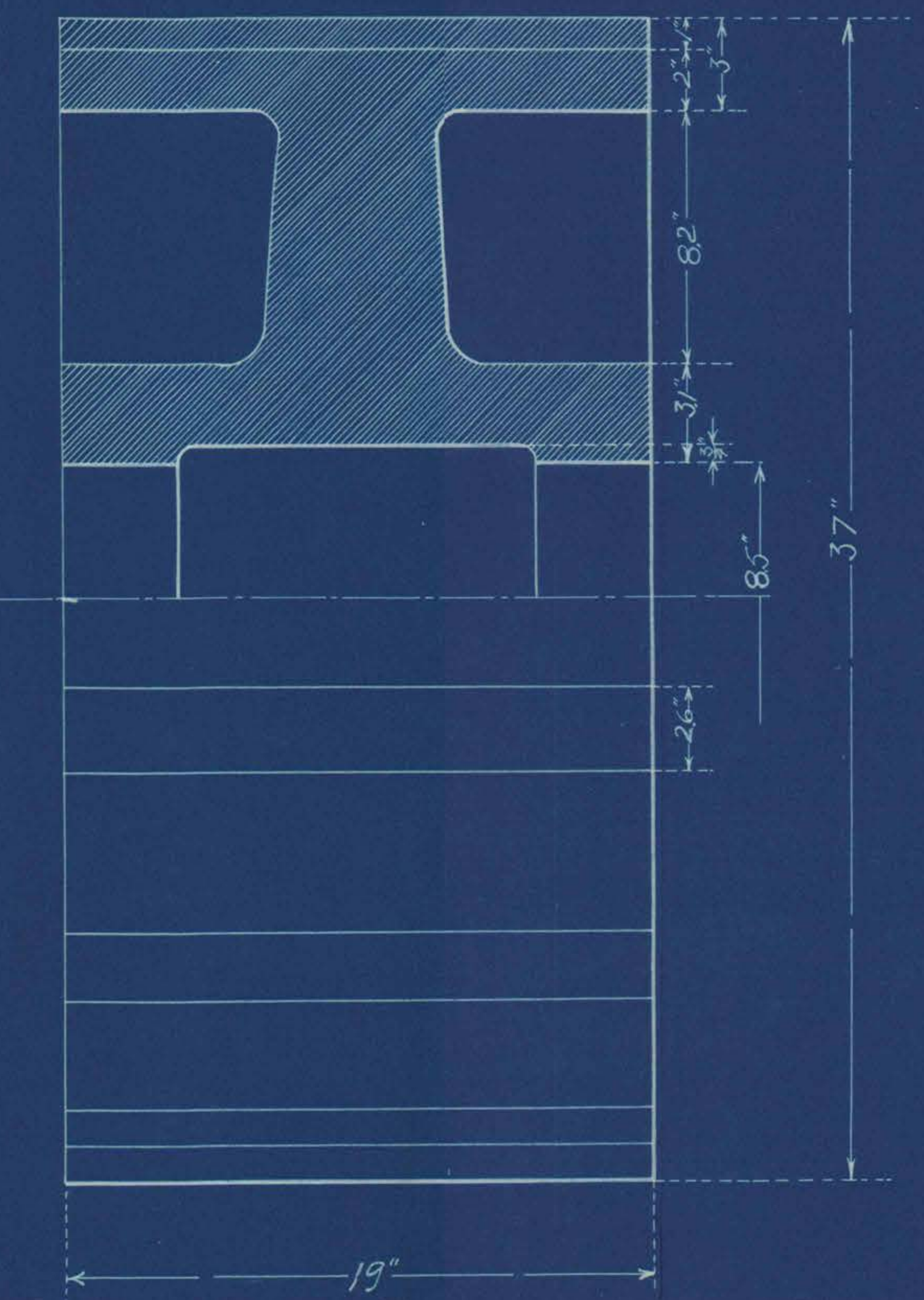
Drawn by Floyd J. Williams

Plate No. 1



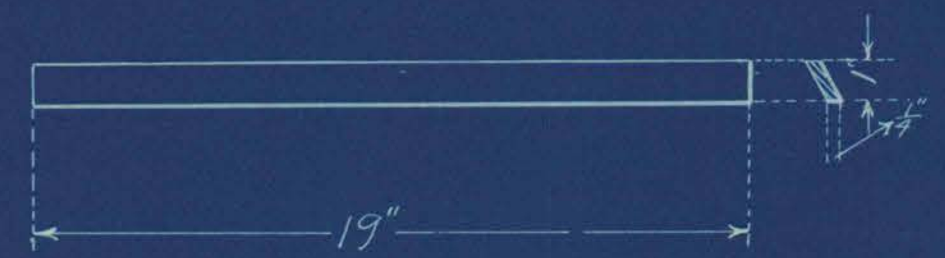
End elevation of wheelrim and spider Scale 1"=5"



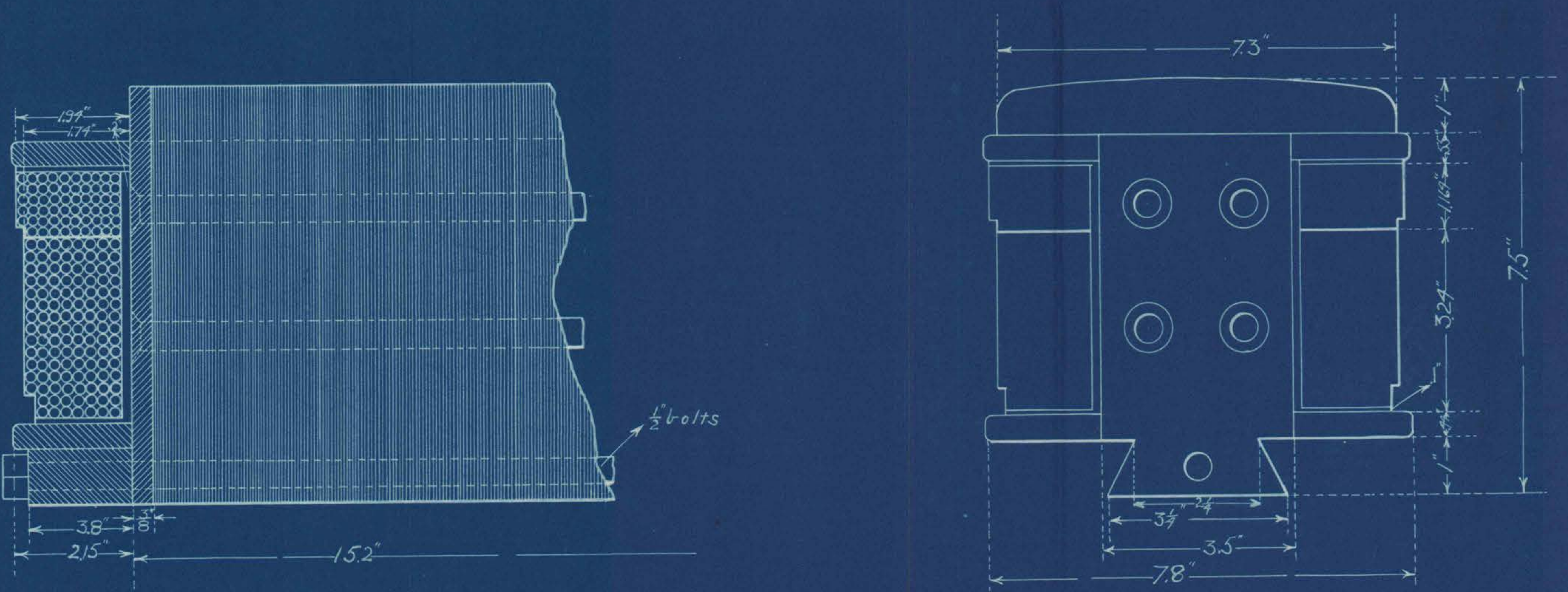


Side elevation of wheelrim and spider

Key. Scale 1"=5"



Wedge for holding poles in place



End and side elevations of field pole Scale 1"=2"

THREE PHASE ALTERNATOR

REVOLVING FIELD TYPE

421 K.V.A. ~ 60 Cycles ~ No load 2200 Volts ~

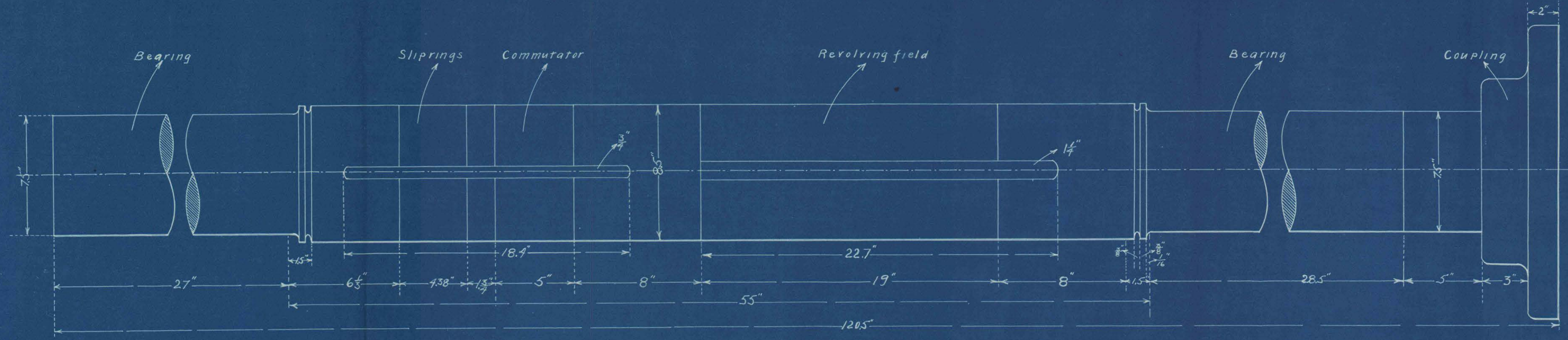
Full load 2300 Volts ~ 14 Poles ~ Speed 514 R.P.M.

Designed by F. J. Williams & R. E. Rawson

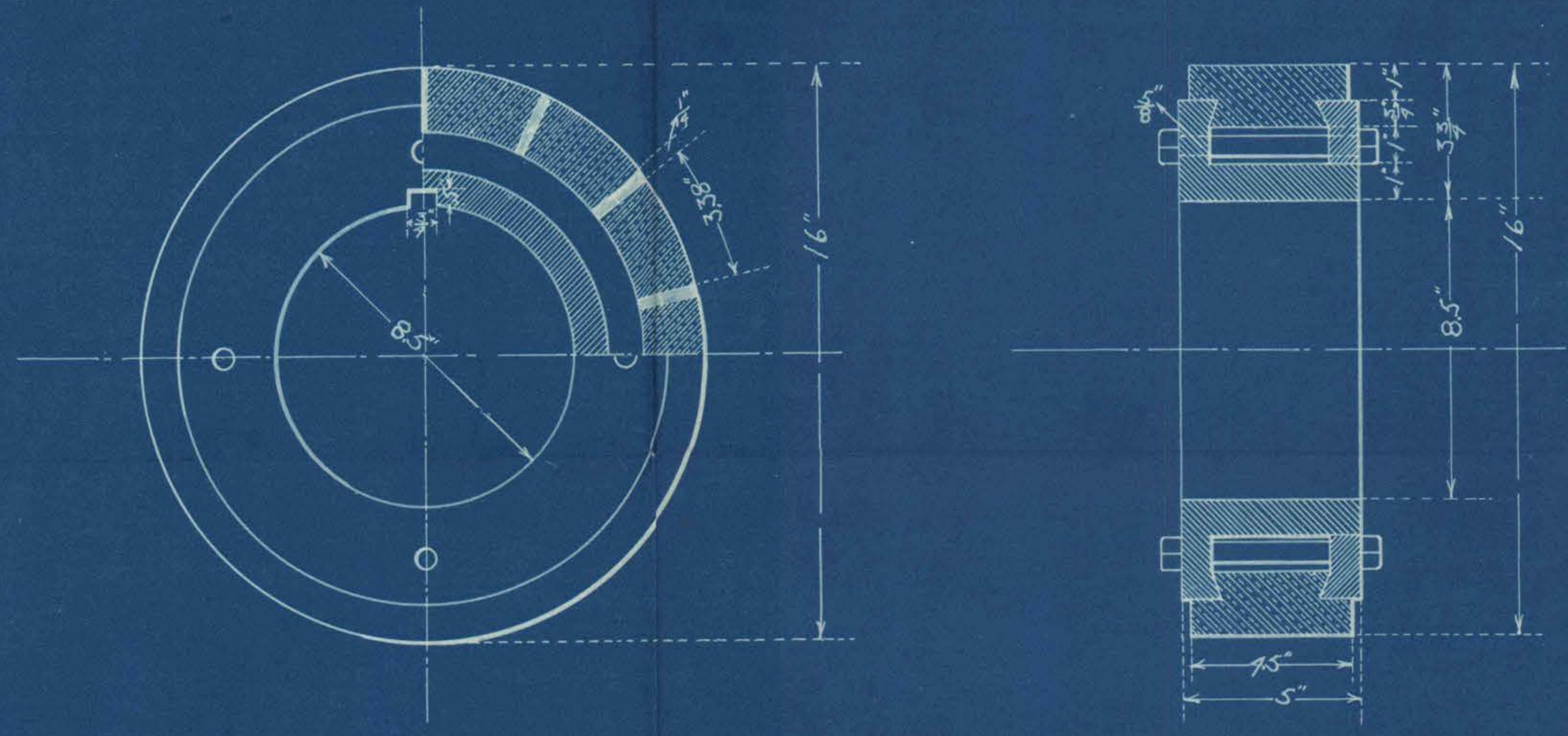
Date April 1, 1910.

Drawn by Floyd J. Williams

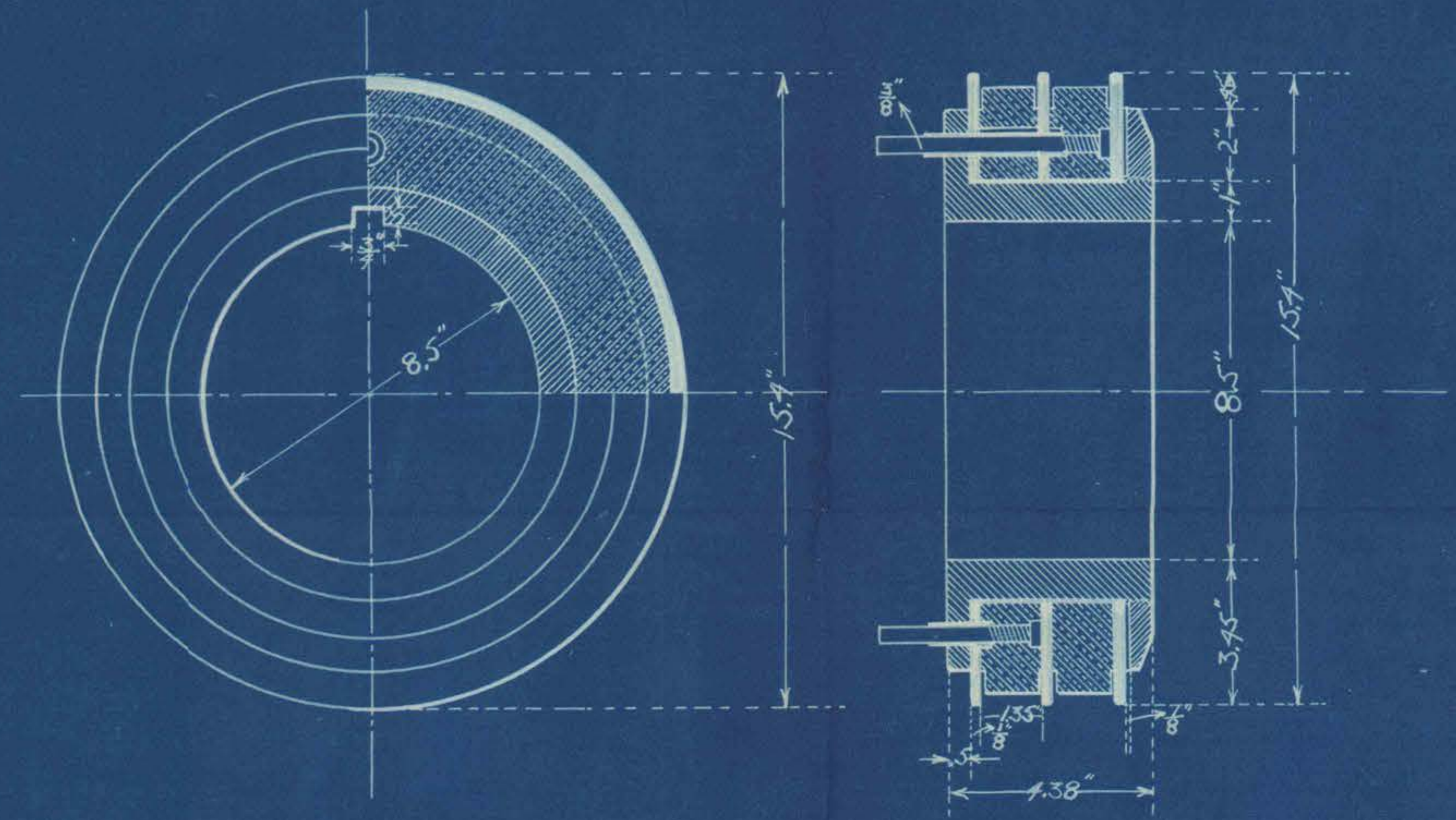
Plate No. 2.



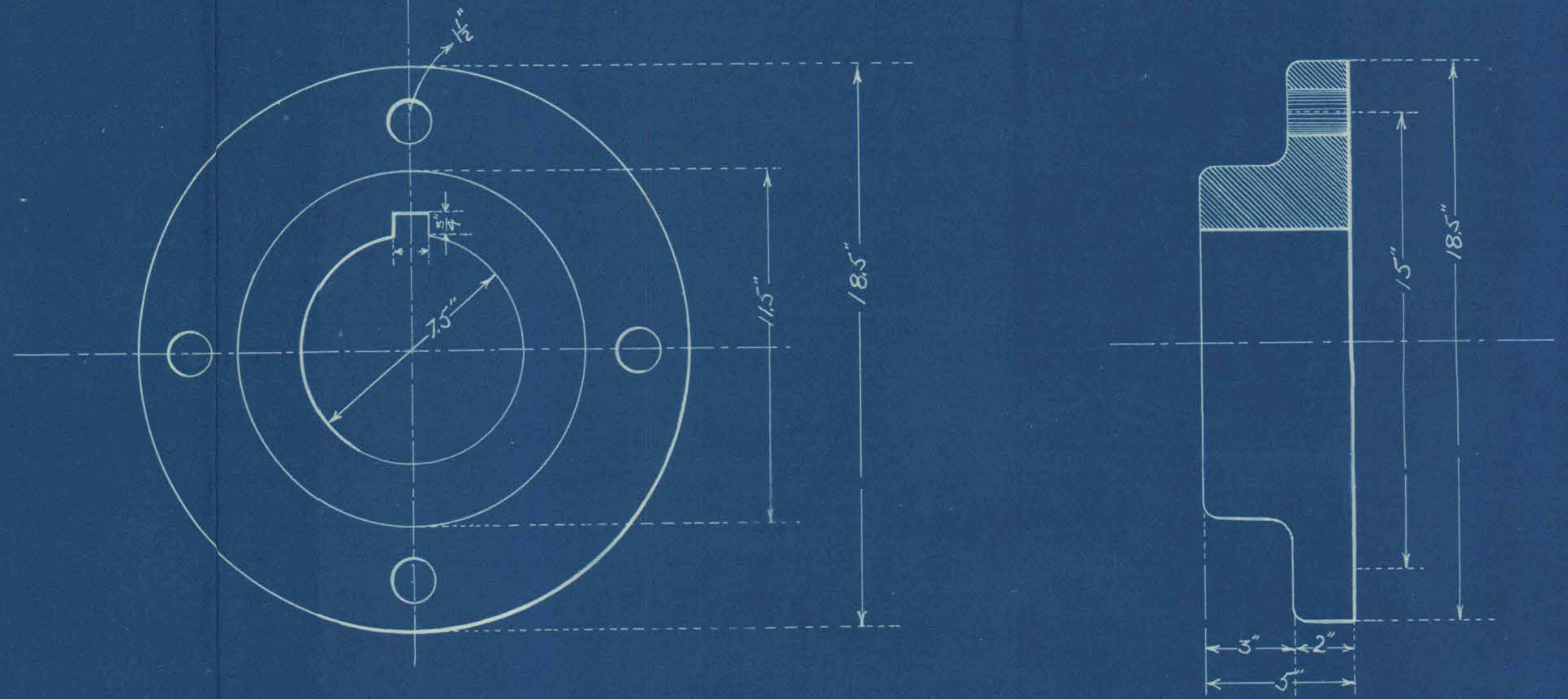
Shaft Scale 1"=4"



End and side elevations of commutator



End and side elevations of slip rings



End and side elevations of coupling

THREE PHASE ALTERNATOR

REVOLVING FIELD TYPE

421 K.V.A ~ 60 Cycles ~ No load 2200 Volts ~

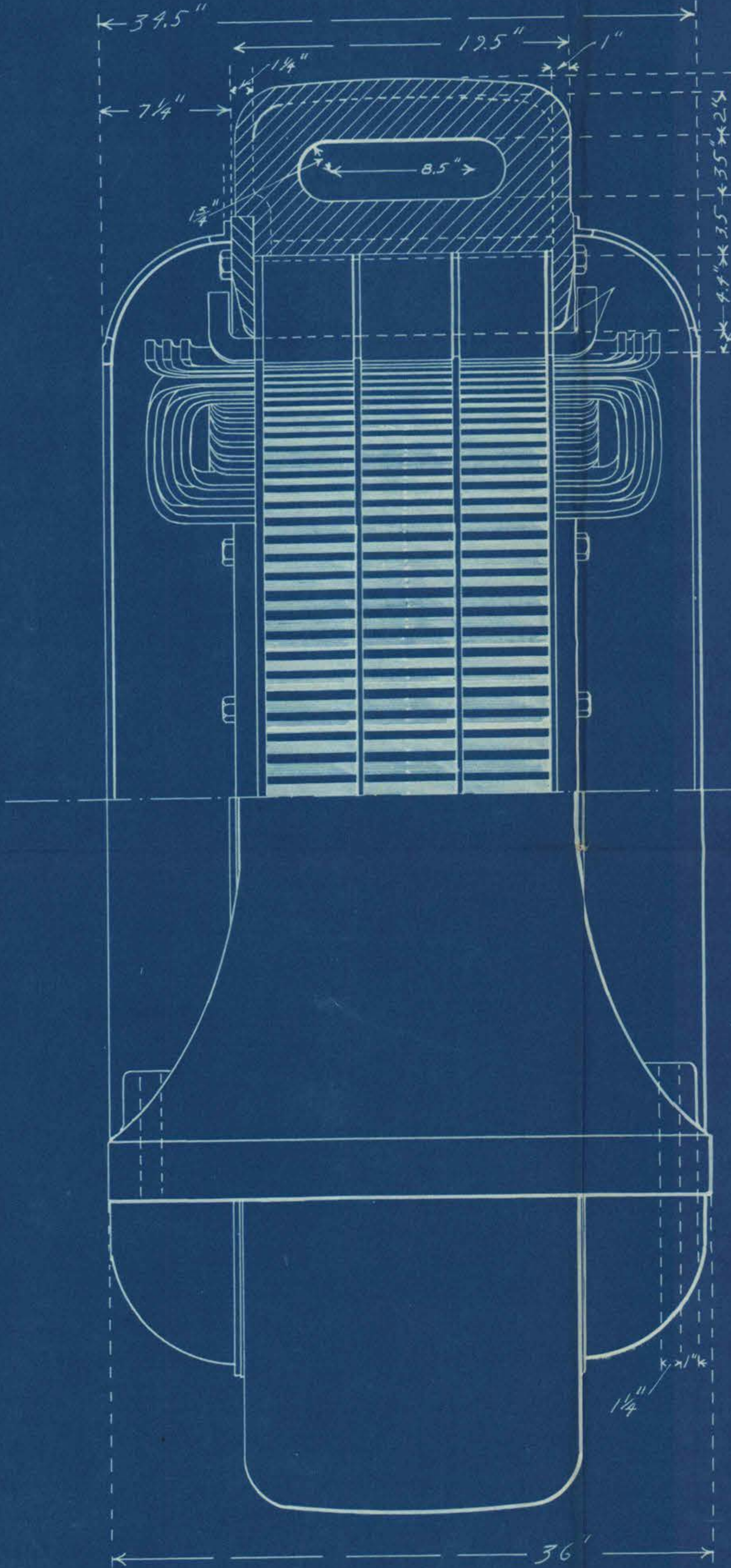
Full load 2300 Volts ~ 14 Poles ~ Speed 514 R.P.M.

Designed by F. J. Williams & R.E. Rawson

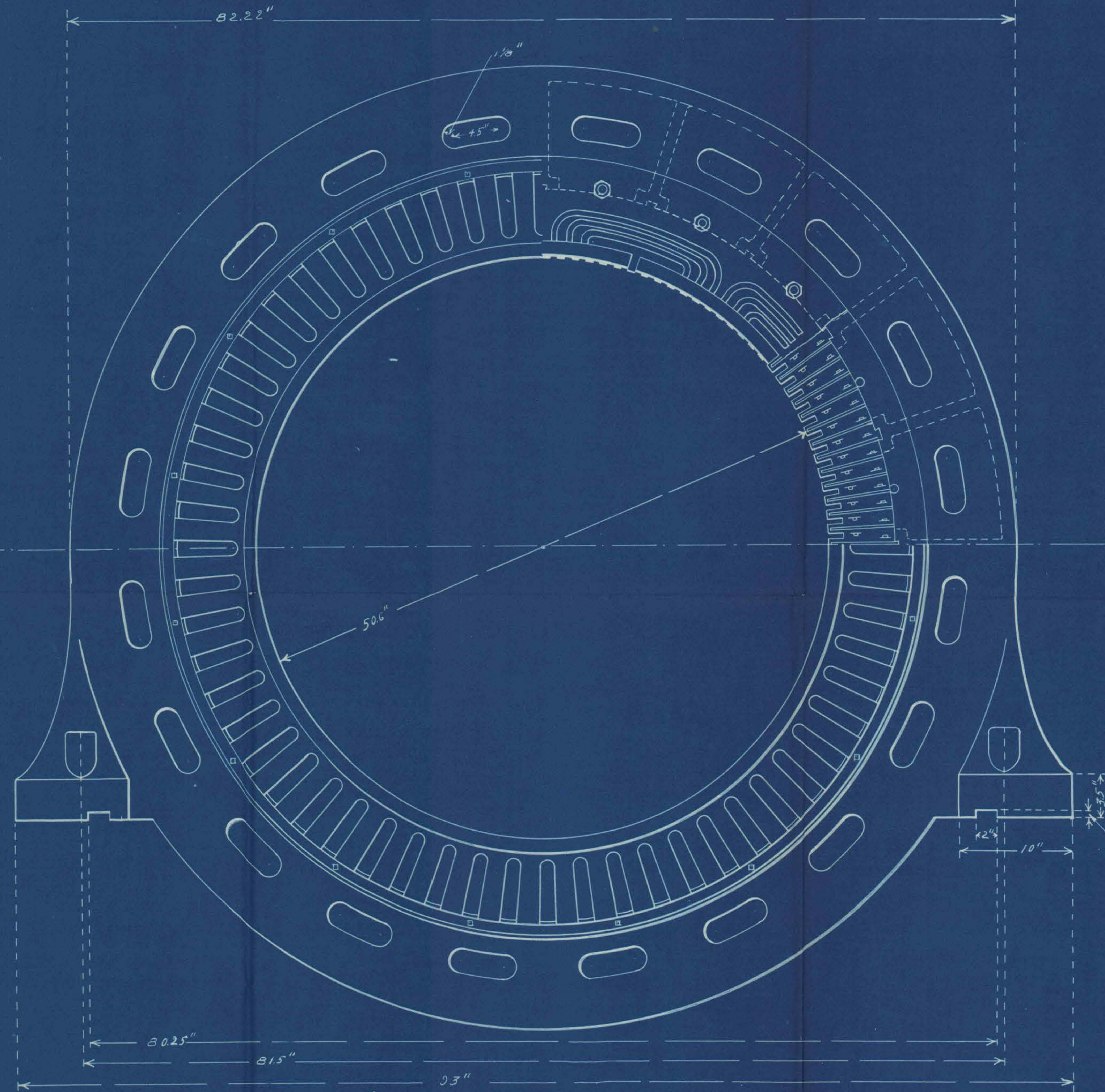
Date April 26, 1910

Drawn by Floyd J. Williams

Plate No 3



Side View of Armature.



End View of Armature.

THREE PHASE ALTERNATOR REVOLVING FIELD TYPE

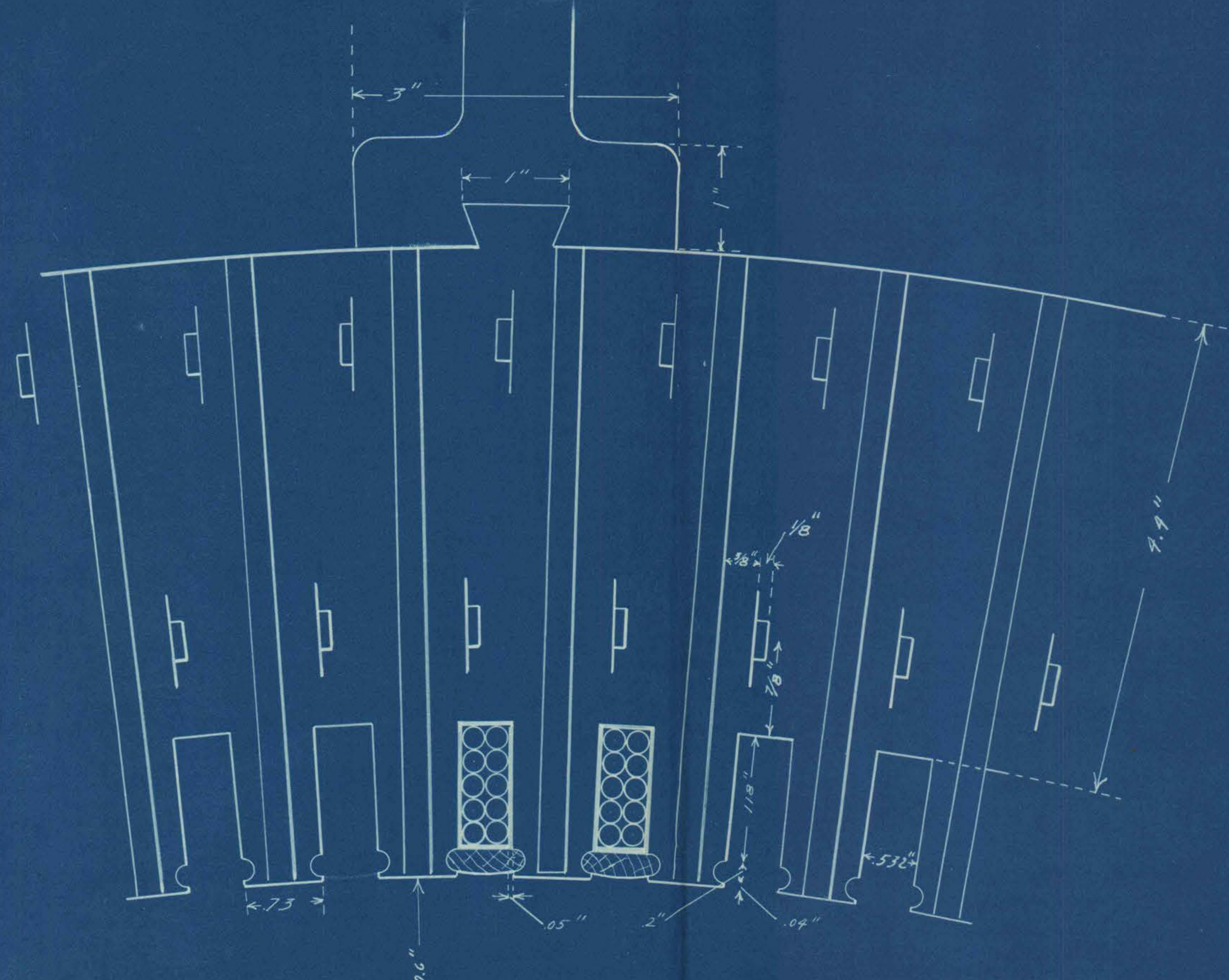
421 K.V.A. 60 Cycles 2200 Volts no load 2300 Volts full load 14 Poles Speed 514 R.P.M.

Designed by F. L. Williams & R. E. Rawson.

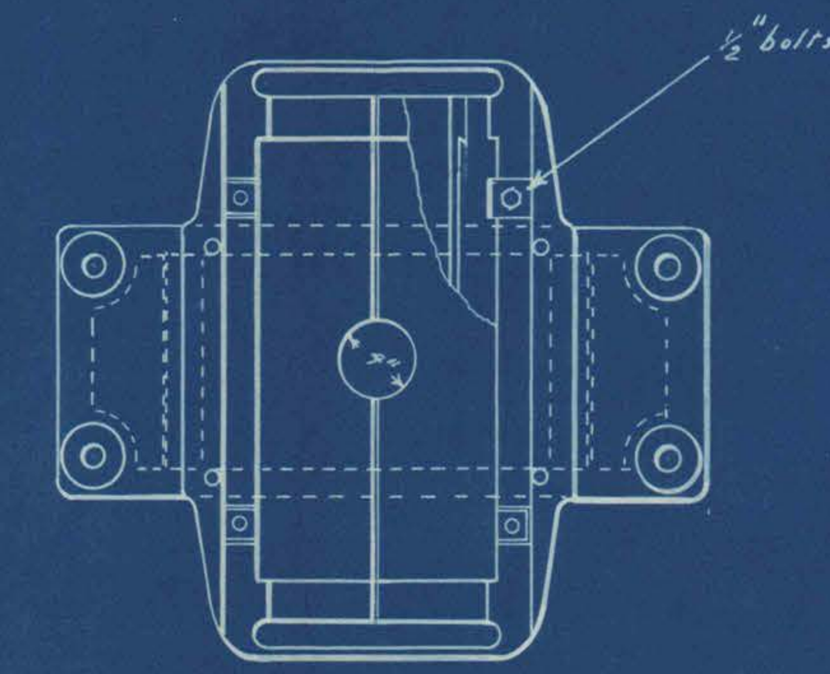
Date May 1, 1910.

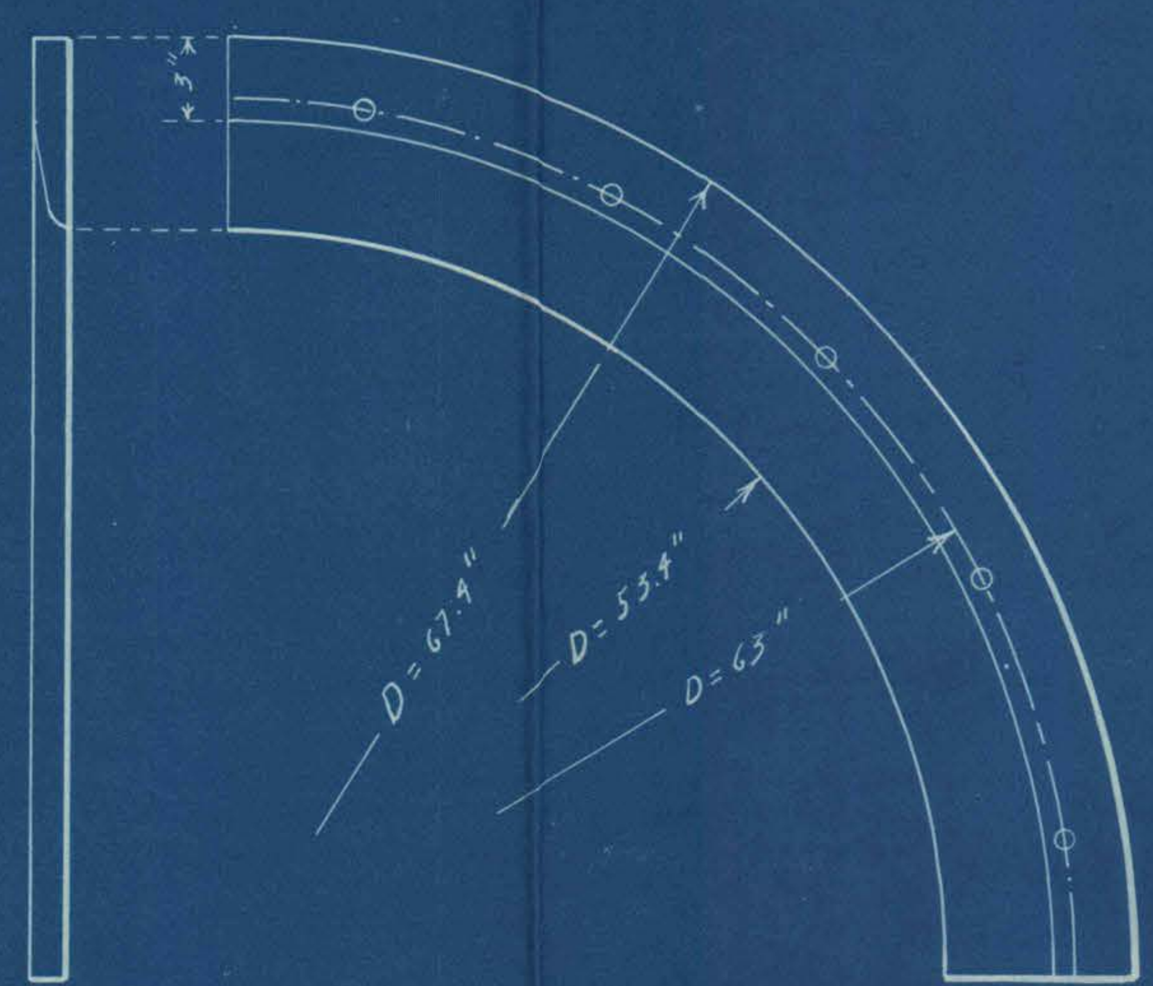
Drawn by Roy C. Rawson

Plate No 4.

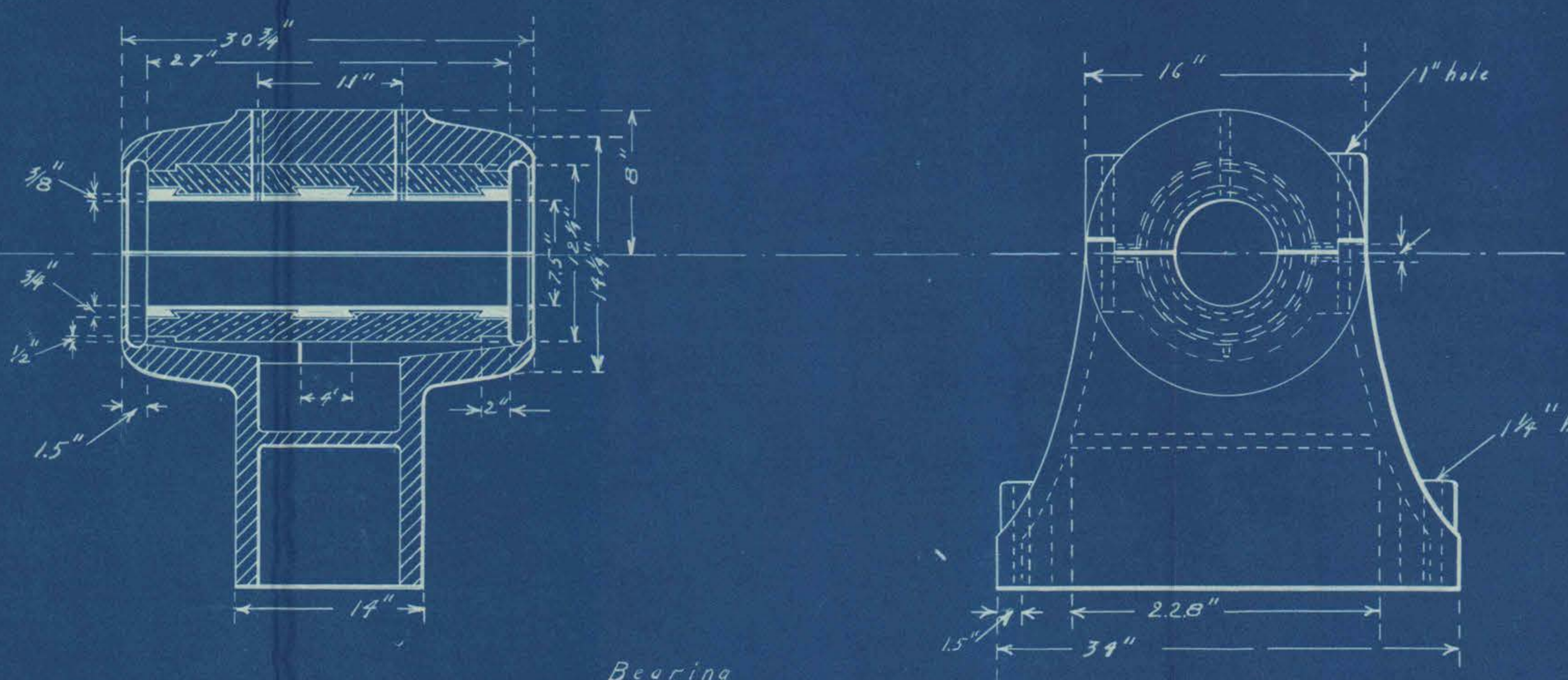


Section of Armature.





Armature Ring



Bearing

THREE PHASE ALTERNATOR REVOLVING FIELD TYPE

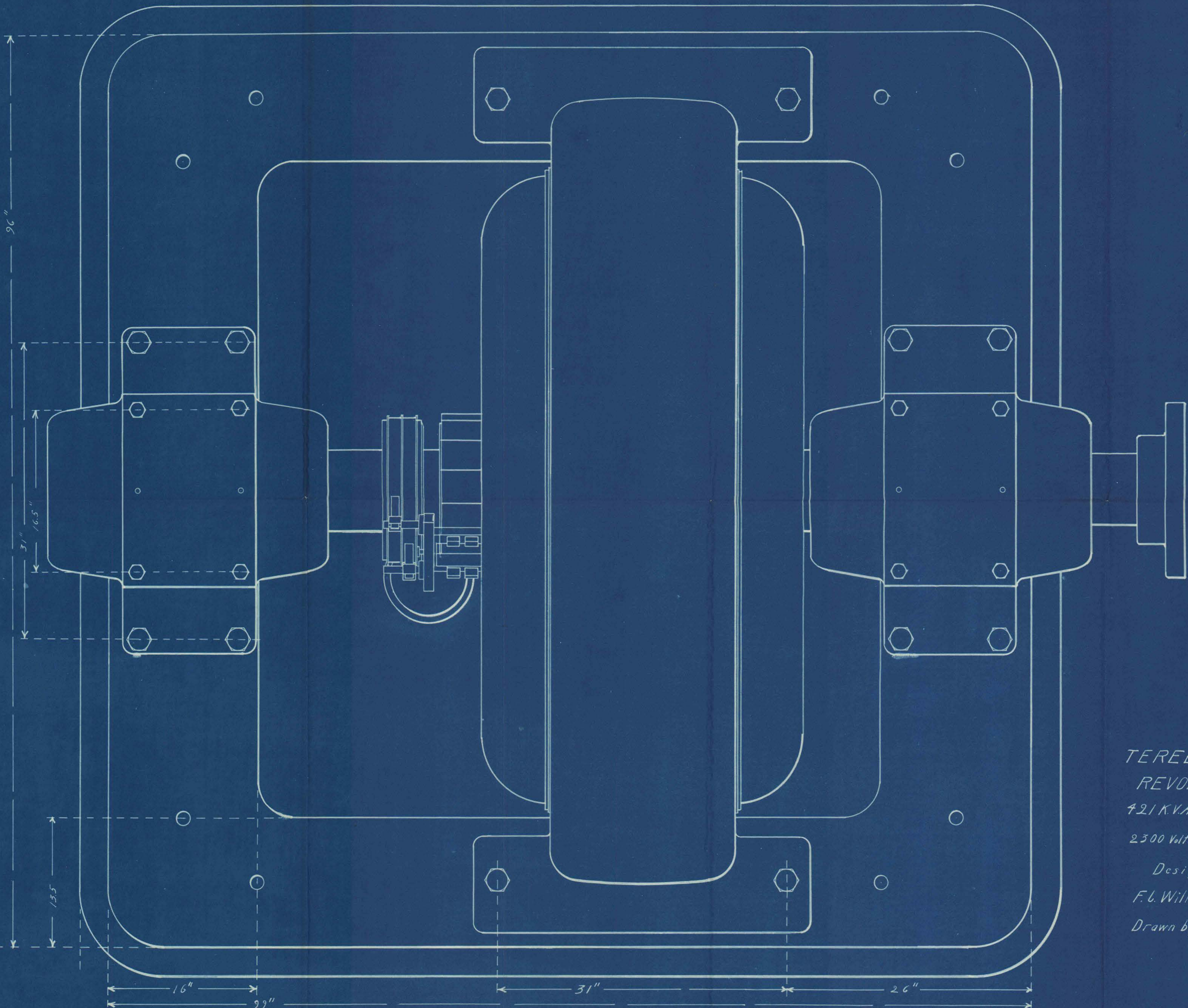
421 K.V.A. 60 Cycles 2200 Volts no load 2300 Volts full load 14 Poles Speed 514 R.P.M.

Designed by F. L. Williams & R. E. Rowson.

Date May 16, 1910.

Drawn by Roy E. Rowson

Plate No. 5.



Plan View of Alternator.

TEREE PHASE ALTERNATOR
REVOLVING FIELD TYPE

421 K.V.A. 60 Cycles 2200 Volts no load

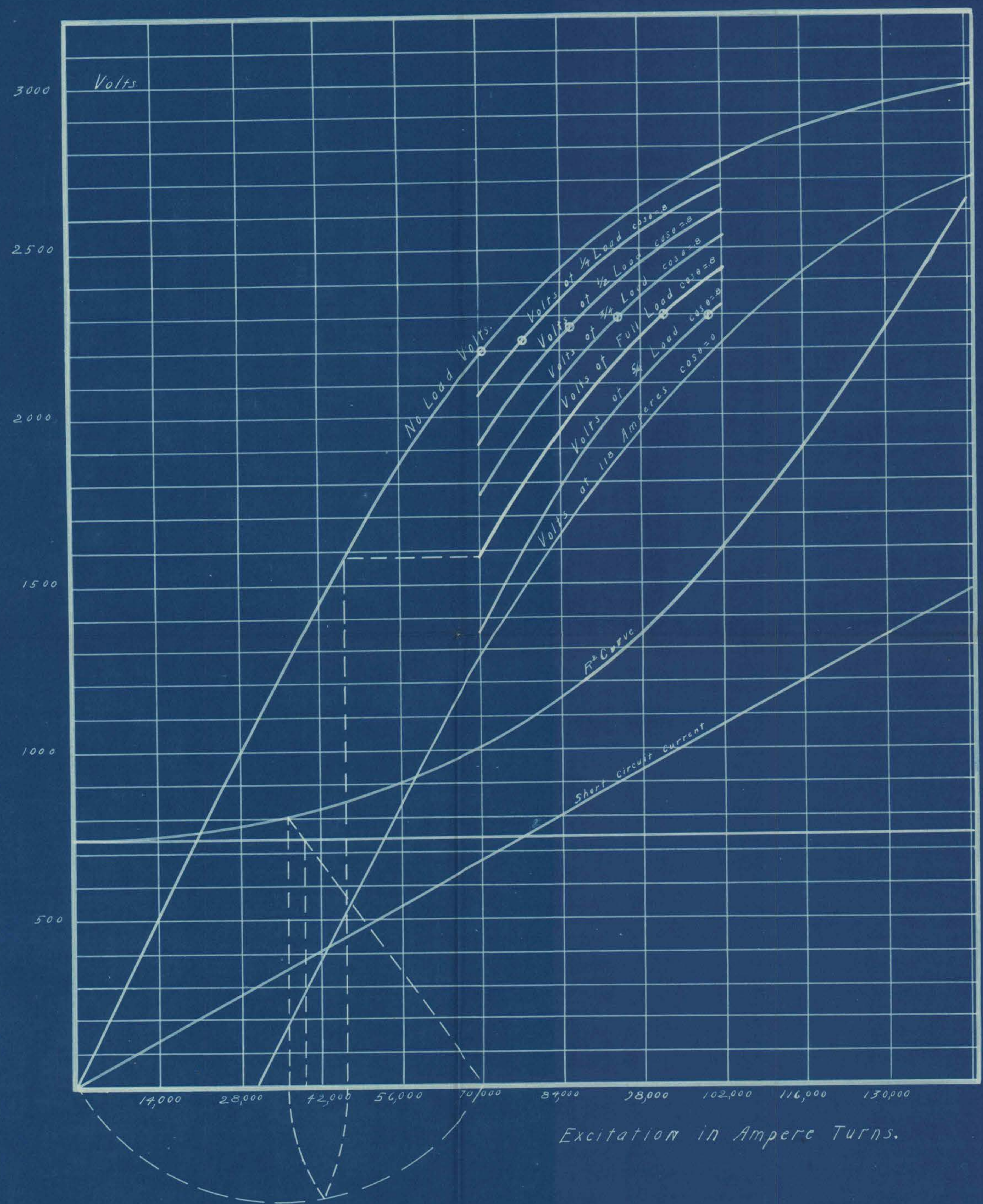
2300 Volts full load 14 Poles Speed 514 R.P.M.

Designed by F. L. Williams & R.E. Rawson.

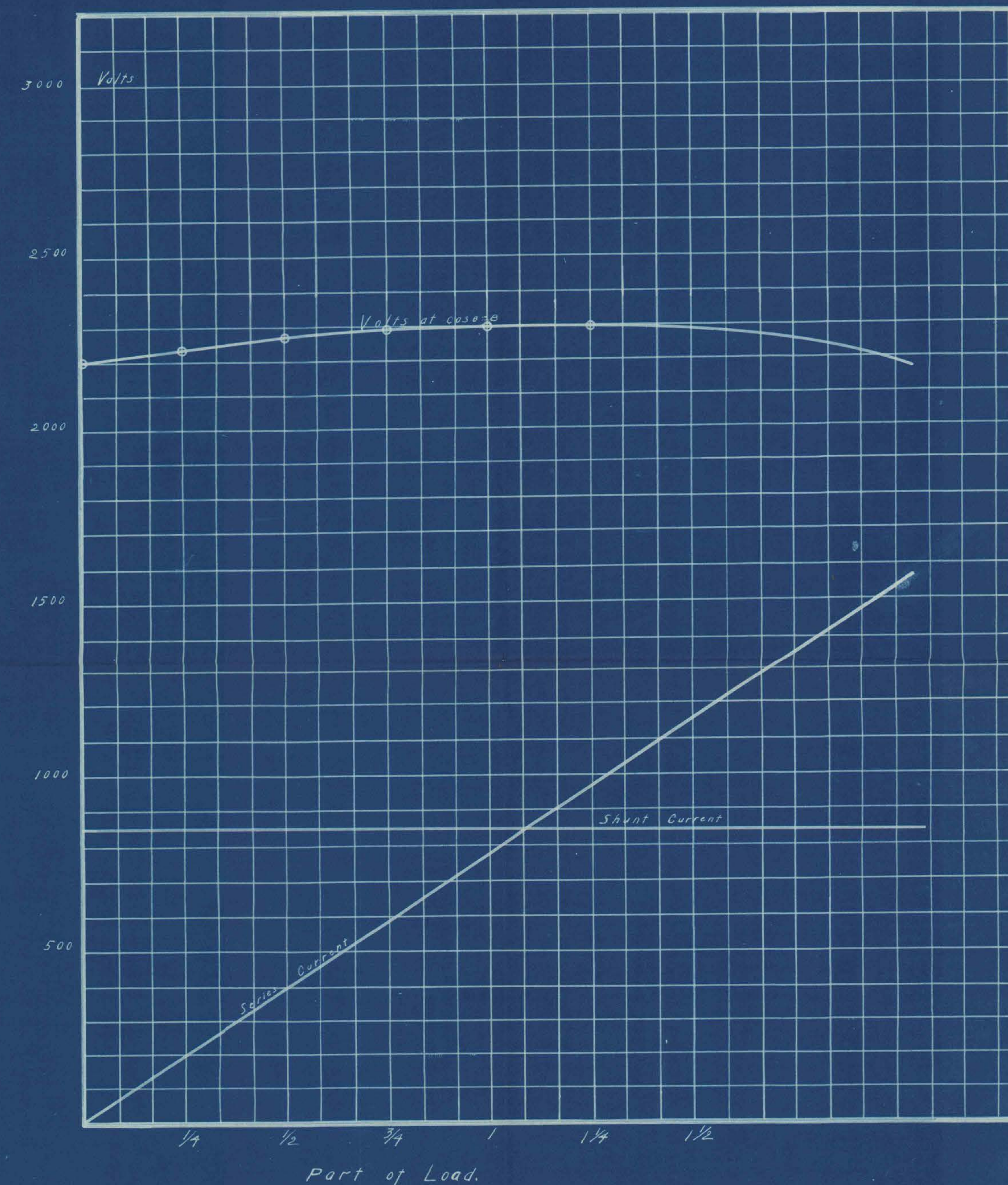
Date May 16, 1910.

Drawn by Roy E. Rawson.

Plate No. 6.



Volts
3000
2500
2000
1500
1000
500
No Load Volts.
Volts of 1/4 Load cos θ=a
Volts at 1/2 Load cos θ=a
Volts at 3/4 Load cos θ=a
Volts at Full Load cos θ=a
Volts at 5/4 Load cos θ=a
Volts at 110 Amperes cos θ=a
Short Circuit Current
14,000
28,000
42,000
56,000
70,000
84,000
98,000
102,000
116,000
130,000
Excitation in Ampere Turns.



Volts
3000
2500
2000
1500
1000
500
Volts at cos θ=a
Shunt Current
Series Current
1/4
1/2
3/4
1
1 1/4
1 1/2
Part of Load.

Plate No 7.


100
80
60
40
20
Efficiency
iron loss
Friction and Windage loss
loss in shunt field
I²r loss in armature
I²r loss in series field
1/4
1/2
3/4
load
4/4
1 1/4
1 1/2

Plate No 8