T H E S I S

Design and Construction of a Small Single Phase Commutator Induction Motor.

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1 9 1 4

THESIS

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List of Drawings.

I N T R O D U C T I O N

There is an increasing demand for small electric motors. Like large motor practice, there should be motors with characteristics, suited to the work they are to do.

The Shunt and Series Motors in D. C. will do about all that is required, but D. C. is not very extensively used on lighting circuits where the small motor is naturally connected.

Small A. C. motors are generally of the single phase induction type with squirrel cage motors and a split phase starting winding which is thrown out of service when full speed is reached, by a centrifugal device.

These motors run at only one speed and have a very small starting torque. Plain A. C. series motors are also used especially on vacuum cleaners. Such motors have a very bad power factor and small capacity for the iron used.

The writer made a number of tests on a small series motor and tried a compensating winding, but still the power factor was low and sparking bad.

Series characteristic is hardly what is wanted in a small motor, the shunt being greatly preferred. The writer's attention was next turned to the shunt induction motor for single phase.

These have a good starting torque and a wide speed variation, with a power factor near unity. The overload capacity is also higher than the plain induction motor. It is true that the efficiency is low, but this is not such an important item in a small motor for intermittant use.

Therefore since the writer could find nothing concerning small motors of this type, it was thought worth while to experiment along this line.

T H E O R Y

The theory of the single phase shunt commutator motor and the sommon single phase squirrel cage induction motor is exactly the same.

The shunt motor consists essentially of a status with a distributed single phase winding similar to the common induction motor and an armature and commutator similar to a D. C. machine. On the commutator are four brushes (speaking of a two pole machine for simplicity) one set parallel to the primary winding and the others at right angles. (See Fig. 1).

At stand still the motor is essentially a transfer under short circuit, stator winding primary and rotor winding secondary, shorted across y y.

Thus the stator current must supply flux enough to generate a counter E.M.F. equal to the impressed E.M.F. less the local stator impedance and balance the M.M.F. of the rotor current in the transformer axis.

The stator circuit is highly inductive thus the current I_o the Magnitizing current will lag almost $90°$ behind the impressed E.M.F., E_1. I_o causes the flux ϕ_t which is nearly in phase with it.

ϕ_t generates an E.M.F. E_t in both the stator and rotor, laging $90°$. The magnitude of these E.M.F!s varies according to the ratio of transformation.

E_t causes a current I_t to flow across axis y y, determined both in magnitude and phase by the local impedance of

the rotor. The primary current I_1 will then be the resultant of I_0 the magnetizing current, and I_t reversed, or the vectorial difference, (assuming 1 to 1 ratio of transformation). The impressed E. M. F. E_1 will be the resultant of a component equal and opposite to E_t and of a component $i_1 z_1$ to over come the local stator impedance and $i_1 r_1$.

Now if the motor is brot up to speed, there will be in E.M.F. E_t' (Fig. 3) of line frequency along axis x x, due to the conductors cutting Φ_t. E_t is proportional to Φ_t and the speed and is either in time phase withor in time-phase opposition to flux Φ_t depending on the direction of rotation. Assuming it to be in time-phase with . The rotor current I_t along the transformer axis sets up a leakage field ϕ_t in phase with itself. ϕ_t also generates an E.M.F. e_t' in the speed axis, it is in phase with I_t. Thus E_f is the vectorial sum of E_t' and e_t'. The conditions along the speed axis are those of a transformer on open circuit since the Counter E.M.F. allows only exciting current to flow. Thus E_f causes a current I_s laging heavily, this produces a flux Φ_s nearly in quadrature with E_f. Φ_s has line frequency and is along x x or right angles to Φ_t mechanically. Φ_s by it alternations induces an E.M.F., E_s along x x, 90° behind Φ_s in phase which brings it nearly in opposition to E_f. The vectorial difference between E_s and E_f is the E.M.F. required to drive I_s thru the local impedance and resistance. The motion of the rotor conductors thru the speed field Φ_s generates an E.M.F. E_s' in the transformer axis, which is in time-phase opposition to Φ_s and proportional to Φ_s and the speed. Thus E_s' is nearly in opposition to E_t

E_t. E_s is the counter E.M.F. of the motor. Φ_s also produces a leakage flux ϕ_s coaxial with Φ_s and in phase with I_s. This with the speed generates e_s' in the transformer axis in phase opposition to I_s. The vector sum of E_t, E_s' and e_s' give E_r, which drives I_t thru the local rotor impedance.

The limiting speed will be when the counter E.M.F. E_s' ~~and~~ E_r e_s' and E_t vectorily balance. E_t is constant while E_s' depends upon the speed. Now if an external E.M.F. in phase with E_t or opposition such as from line or taps from stator, is introduced across y y, E_t will be either increased or decreased and the speed will have to increase or decrease to keep up the balance. This method is used for speed variation and is used over wide ranges. See Fig. 4.

Again if the speed field can be increased or weakened, E_s' will be changed and the speed will have to change to again give equalibrium. This can be done by inserting a inductance or capacity along x x. A capacity increases I_s, thus Φ_s and E_s' and reduces speed; an inductance decreases I_s thus raises speed. (Fig. 5).

If I_s be made to pass thru stator coils along axis x x which will either boost or buck Φ_s, E_s' can be changed, thus the speed. (Fig. 6).

\# Power factor Compensation.

The power factor may be improved by introducing an E.M.F. from the line or stator in the speed axis. This E.M.F. E is in phase with I_s and Φ_s approximately and at right angles with E_f and E_s. Thus we have three E.M.F's in speed axis. (Fig. 8) E_c causes I_c and Φ_c nearly at right angles to it. Φ_c generates E_c'

\# The Induction Motor--Bayley.

Laging 90° which is a counter E.M.F. to the E introduced. Thus along axis x x, we have two fluxes Φ_s and Φ_c 90° out of phase with each other, therefore they cannot react together to give torque and change the speed. The conductors cutting Φ_c generates another speed E.M.F. E_c'' along the transformer axis in phase with the flux. E_c'' being at right angles to the main speed E.M.F. E_s' in the y y axis, they combine to form a new resultant E.M.F. Taking the action of this E.M.F. E_c'' causes I_c' in y y axis to flow laging heavily, thus causes flux Φ_c' on this axis 90° behind E_c''. This flux generates E_c''' in both the rotor and the stator, which lags 90° behind Φ_c' or 90° behind the counter E.M.F. in the stator equal and opposite to E_t. Thus E_1 and E_c''' combined to give the stator resultant E.M.F. $\mathcal{E}_1$ which can be made to either lead or lag behind the primary current I_1.

All of the theory connected with Fig. 3 holds for a squirrel cage rotor, the end rings at all times keep the rotor bars shorted across the respective axis, thus equivalent to commutator and shorted brushes.

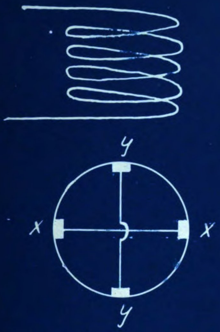


Fig. 1.

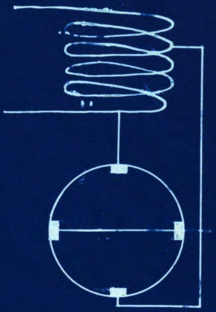


Fig 4

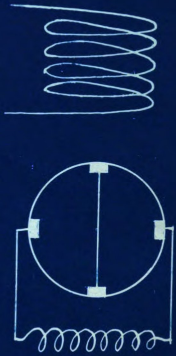


Fig. 5.

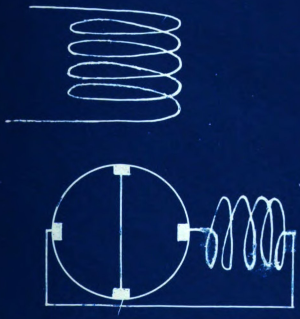


Fig. 6

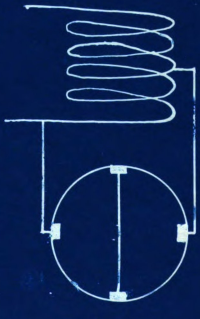


Fig 7.

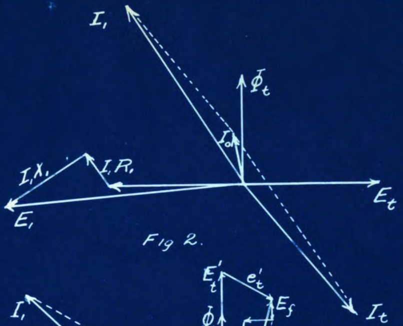


Fig 2.

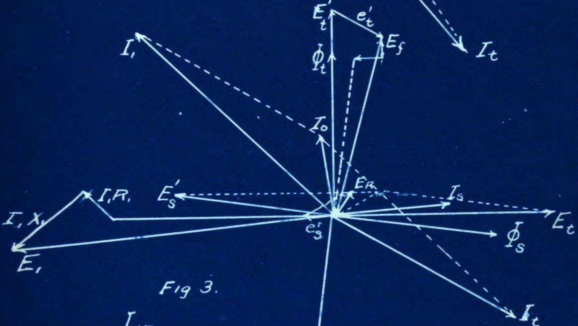


Fig 3.

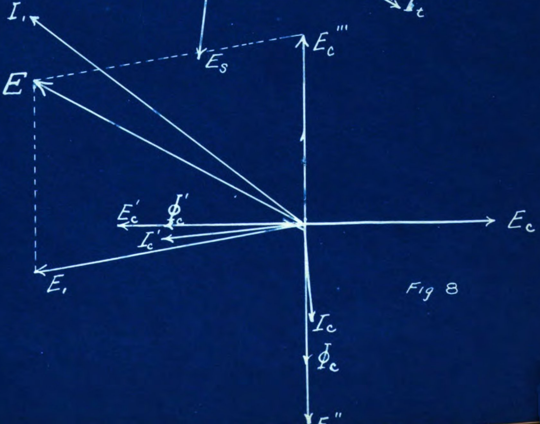


Fig 8

S P E C I F I C A T I O N S

Out put about $\frac{1}{10}$ H. P.

Voltage 110 60 cycles

Single Phase

Speed near 3600 R.P.M.

D E S I G N

Armature

From small motor practice an armature about $2\frac{1}{4}$" diam. and 2" long was selected. Standard punchings can be purchased 2 5/16" diam. 12 round slots 3/8" diam.

Standard practice of motors of this size calls for a 5/16" shaft.

For mechanical detail, see drawing. Allowance was made for winding by examining armatures of similar size.

Stator

The stator used is the same as that of any single phase induction motor of two poles.

The area of the air gap is the area of one-half the armature surface minus the slot area.

$A = \frac{1}{2}(2x.5x12) = 6$ sq. in.

Air gap density 22,500 lines per sq. in.

(Standard Hand Book 13,000 lines to 26,000 lines)

Thus 6 x 22500 = 135000 or total flux

Number turnes wire

$$S = \frac{E \times 10^8}{2K_1 K_2 \phi_m f}$$

Where E Line voltage

S number conductors in stator

K_1 Form factor

K_2 Distribution constant

ϕ Maximum flux

f Frequency

K_1 for Sin wave 1.11

K_2 for 2/3 pole face distribtors .9 (Fig.52 Sheldon & Mason)

$$S = \frac{110 \times 100,000,000}{2 \times 1.11 \times .9 \times 135000 \times 60} = 630 \text{ turns}$$

Considering 1/10 H.P. as 74 watts and 50% efficiency assumed, the imput should be 158 watts. Assuming Unity Power factor as this type of motor should give, the current would be 1.4 amps. With good ventilation, using 400 cir. mils. per amp. (Standard Hand Book)

1.4 x 400 560 cir. mils. area

This is close to a No.22 wire, so use No. 22 wire.

With 8 slots, each slot must contain

$$\frac{680}{8} = 85 \text{ conductors}$$

D.C.C. wire No. 22 will run 876 turns per sq. in.

$$\frac{85}{876} = .1 \text{ sq. in. approximately}$$

.1 sq. in corresponds to a 3/8" hole.

Allowing 1/16" for insulation of slot and extra room for winding, makes diameter of slot 7/16".

Round slots are used since they are easier to make and give greater air gap area thus greater capacity.

The inside diameter of stator is determined so as to give 1/32" air gap (Standard Hand Bock).

Outside diameter is determined by end room for coils and castings.

The punching are clamped by a 3/16" bolt.

(See drawing for details.)

Armature Winding

Designing the armature winding according to the transformer E.M.F. N_e actual number of conductors on the armature, the actual number turns is $\frac{N_e}{2}$. Since they are distributed around the armature, the E.M.F. in each coil is equal to the Cos. of the angle of displacement from the position of Max. E.M.F. Thus the E.M.F. is the resultant as vectorial sum of E.M.F. around a circle.

$\frac{N_e}{2}$ number turns in one-half the armature or from brush to brush, thus the effective turns would be $\frac{N_e}{2}$

Thus, $E_t = \frac{N_e \phi f}{\sqrt{2}\ 10^8}$

Assuming 40 volts for the transformer E.M.F.

$$N_e = \frac{E_t \sqrt{2}\ 10^8}{\phi f} = \frac{40 x 1.41 x 100,000,000}{135,000 x 60} = 700$$

700 Conductors on armature

$\frac{700}{12}$ =57.5 conductors per slot use 60 conductors

3/8" round slots give an area of .11 sq. in. Allowing 1/32" for insulation gives a net area of about .1 sq. in. Thus, 60 x .1 600 turns per sq. in. allowable

D.C.C. wire of this size is between No. 21 and No.22. Use No. 22 wire.

With 12 slots and 24 commutator segments, makes 4 coil per slot of 15 turns each.

(See winding diagram and drawings for details.)

This motor was built as designed, but did not operate at all satisfactorily. Sparking at the commutator was at all times very bad, in fact, the commutator was nearly destroyed. The

exciting current was very large, being 2.4 amps. the imput on no load, 100 watts.

The synchroneous speed was 3600 R.P.M., but the speed was only 2400 R.P.M. The motor would carry a heavy load of about 1/10 H.P., but the current was excessive, running up to five amperes.

Standard Squirrel Cage Induction Motor.

Using the same stator with four more slots to make 12 slots and with the same flux per pole 135000 lines. With 6 slots per pole with winding distributed over five slots.

$E = 2.22 \times k_1 S \phi f \, 10^{-8}$

where E line E. M. F.

S = number conductors

ϕ = flux per pole

f = frequency

$$S = \frac{E \; 10^8}{2.22 K_1 \phi f} = \frac{110 \times 100000000}{2.22 \times .74 \times 135000 \times 60} = 830 \text{ turns}$$

Minimum tooth area of stator.

Width of slot $\frac{1}{4}$", 6 slots per pole face

$6 \times \frac{1}{4}" \times 2\ 1/16 = 3.1$ sq. in. area

Core area of stator depth $\frac{1}{2}$" x 2.1/16" = 1 sq. in.

Apparent gap area per pole stator tooth $\frac{1}{2}$"

$6 \times \frac{1}{2} \times 2\ 1/16 = 6.2$ sq. in area

Maximum core density. The stator flux divides half going around each way.

$$\frac{135000}{2 \times 1} = 67{,}500 \text{ lines}$$

Minimum tooth area per pole of rotor

11 conductors or $5\frac{1}{2}$ per pole face

$5\frac{1}{2} \times \frac{1}{4}" \times 2\ 1/16" = 2.85$ sq. in.

Maximum tooth density of stator

$$\frac{\pi}{2} \times \frac{\phi}{\text{tooth area per pole}}$$

$$\text{Stator density} = \frac{135000 \times \pi}{3.1 \times 2} = 74{,}500$$

$$\text{Rotor density} = \frac{135000 \times \pi}{2.85 \quad 2} = 74{,}000$$

830 turns in 12 slots gives

$\frac{830}{10}=83$ Condustors per slot or 83 turns per coil

The slots will easily hold this amount of No. 22 wire. (See first Calulation)

Squirrel Cage Rotor.

Air gap clearance 1/64"

External Diameter 2 9/32"

Length 2 1/16"

Number slots 11

In order for the rotor not to lock on starting the rotor slots must be prime to the stator slots.

Rotor current I per condutor at full load.

I for full load will be 1.6 amps. No. 22 wire has an area of 642 cir. mils at 400 cir. mils per amp.

$\frac{642}{400}=1.6$ amps. carrying capacity with good ventilation.

Rotor amps. $= .85\ I \times \frac{\text{total stator conductors}}{\text{total rotor conductors}}$

$I = .85 \times 1.6 \times \frac{830}{11} = 103$ amps.

Ampere conductors per inch $\frac{11 \times 103}{\times\ 2.23} = 160$

Cir. mils per amp. allowable 500 (Standard Hand Book)

103 x 500 = 51500 Cir. Mils.

This area is close to No. 3 B&S wire .229" diameter or Drill slots 15/64" diameter.

DATA FOR CIRCLE DIAGRAM

Magnetizing current.

C_1=the stator Carter coefficient

$\frac{s}{\delta} = \frac{.125}{.02} = 5.1$

s = slot width = .125

δ = clearance = .02

f = from Curve of Carter fringing constand page 44 Gray's Electrical Machine Design

f = .5

$C_1 = \frac{\lambda}{t + fs}$ slot pitch = .606

$C_1 \; \frac{.606}{.437 \quad .5 \times .125} = 1.21$

C_2 for rotor $= \frac{s}{\delta} = \frac{.062}{.02} = 3.1$

f = .65

$C_2 = \frac{.64}{.635 \quad .65 \times .06} = 1.02$

Pole pitch = 3.64 = τ L_g = Axel length of air-gap

Magnetizing current $I_o = \frac{1}{.87 \text{ (Cond. per pole) } \tau L_g} \Phi_a \times \delta C$

$I_o = \frac{1}{.87(6x80)} \frac{135000}{3.64 \times 2} \times .02 \times 1.02 \times 1.21 = 1.1$ amps. air gap

Allow 20% for iron 1.2 x 1.1=1.3 amps. mag. current

Constant Losses

Weight of stator teeth in pounds

Volume of stator teeth 5.4 sq. in.

1 cu. in. steel .274 #

5.4 x .274 =1.47#

Loss in watts per lb. 7 watts (Fig. 81 pg.102 Gray's Machine Design)

1.47 x 7 = 10.3 watts loss in teeth

Volume of core 13 cu. in.

13 x .274 = 3.56#

Watts per lb. 7

3.56 x 7 = 25 watts loss in core

Disregard rotor iron loss since the frequency is very low.

Total loss 35 watts which remains constant on all loads

Bearing loss = $.81 \times dl\left(\frac{v}{100}\right)^{\frac{3}{2}}$ watts

Where d = bearing diam.

l = length of rubbing surface

v = velocity of rubbing in feet per min.

$.81 \times .31 \times 1.25\left(\frac{3600 \times x \times .31}{12 \times 100}\right)^{\frac{3}{2}} = 1.7$ watts

For 2 bearings 3.4 watts

Assume 1 watt windage

Total loss 40 watts.

Maximum Current

Slot Leakage(Page 330 Sheldon & Mason)

Stator

$X_1 = 2\ f\ l_s N n^2 (.62\ \frac{d_1}{w_0})\ 10^{-7}$ (For round slots)

Where l_s = length of slot in inches

n = number conductors in series per slot

N = number slots per phase

d_1 = depth of saw cut

w_0 = width of saw cut in tooth

$X_1 = 2 \times 60x2x12x6400(.625\ .5)10 = 2.7$ ohms

Rotor

$X_2 = 2x10x2x11x1(.625\ 3)\ 10^{-7} =$

Comes out very small so disregard

Zig Zag Leakage

Stator and Rotor

$$X_2=3.35\ f\ l_s N n_s^2 \frac{\lambda}{\Delta}\left(\frac{t_1}{\lambda_1}+\frac{t_2}{\lambda_2}-1\right)^2 10^{-8}$$

Where t_1 and t_2 are stator and rotor tooth tip widths respectively

λ_1 and λ_2 are stator and rotor tooth pitches

λ average or common tooth pitch

Δ radial length of air gap in inches

$$X_2=3.35\ x60x2x12x6400\ \frac{.687}{2}\left(\frac{.5}{.68}+\frac{.68}{5}-1\right)^2 10^{-8}=.15\ \text{ohms}$$

<u>Resistance Primary</u>

Length of conductors on stator

$$\frac{2(2.5\quad 3.64)x83}{12}=85\ \text{ft.}$$

$$\frac{2(2.5\quad 3)\ x83}{12}=76\ \text{ft.}$$

$$\frac{2(2.3\quad 1.5)\ x\ 83}{12}=52\ \text{ft.}$$

Total = 213 ft.

Resistance per foot of No. 22 wire is .0184 ohms

213 x .0184 = 3.9 ohms stator resistance

$\sqrt{3.9^2+2.85^2}=4.9$ ohms apparent resistance

Maximum current $=\frac{110}{4.9}=22.4$ amps.

$\frac{110}{235}=28.6$ amps. This value is used for diameter of the circle diagram.

22.4 is used to determine the locked position of the rotor in the circle diagram.

<u>Exciting Current</u>

$\frac{40}{110}=.363$ amps. in phase with E.M.F. or a power component

Copper loss $I^2R=1.3^2$ x $3.9=4.9$ watts

$\frac{4.9}{110}=.406$ amps. in phase with E.M.F. or OG in circle diagram

Total amps. in phase with E.M.F. $=.769$

Exciting current $\sqrt{.76^2+1.3^2} = 1.5$ amps. or OI in Circle diagram

Rated Load

Maximum capacity of wire $=1.6$ amps.

Magnetizing current $=1.3$

$1.6 = \sqrt{1.3^2 + x^2}$

$x = .93$ amps.

$.93 \times 110 = 103$ watts power component

103 - 50 watts = 50 watts net power

$\frac{50}{746} = .067$ H.P. or 1/15 H.P.

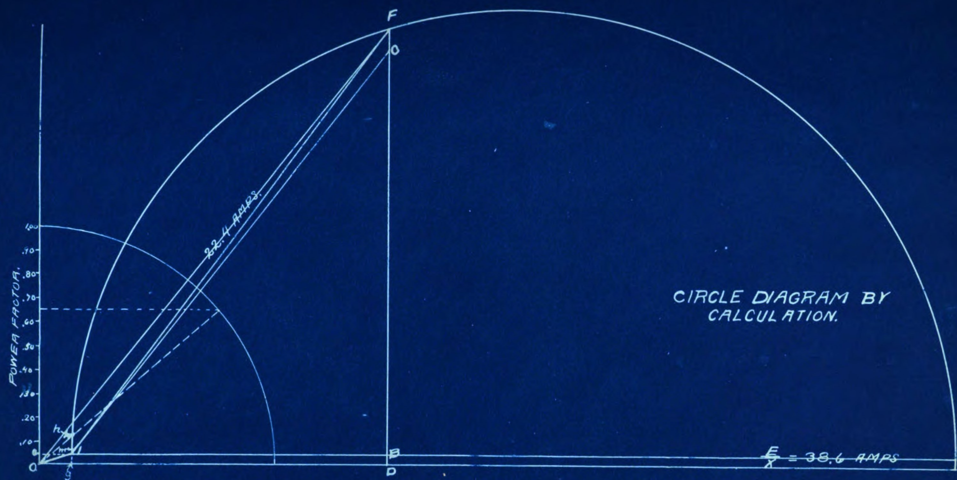
Effieiency $\frac{50}{103} = 48.5\%$

T A B U L A T E D D A T A

	Stator	Rotor
External Diameter	4. 5/16"	2 9/32"
Internal Diameter	2 5/16"	
Frame Length	2 1/16"	2 1/16"
Air ducts	none	none
Net iron	2 1/16"	2 1/16"
Slots number	12	11
Size	7/16" D	15/64"
Conductors per slot	83	1
Size	#22 D.C.C.	#3
Winding type	two coil	squirrel cage
Minimum slot pitch	.606"	.64"
Minimum tooth width	¼"	¼"
Core depth	½"	1
Pole pitch	3.64	
Minimum tooth area per pole	3.1 sq. in.	2.35sq. in.
Core area	1 sq. in.	2 sq. in.
Apparent gap area per pole	6.2	6.2
Flux per pole	135000	135000
Maximum tooth density	69000	74300
Maximum core density	67,500	67,500
Ampere conductors per inch	220	160
Circular mills per ampere	500	500
Apparent gap density	22500	
Air gap clearance	.02	.02
Carter Coefficient	.5	.65
Magnetizing current air gap	1.1	
Total	1.3	
Reactance per phase	2.85 ohms	
Maximum line current	22.4	

	Stator	Rotor
Rating	75 watts	
Horse Power	1/10	
Terninal voltage	110	
Amperes full load	1.9	
Phases	1	
Frequency	60	
Synchroneous R.P.M.	3600	
Poles	2	

CIRCLE DIAGRAM BY CALCULATION.



(OI) = EXC. CURRENT = 1.36 AMPS. (OF) = CURRENT ROTOR LOCKED (OC) = CONSTANT LOSSES.

(DF) = TOTAL LOSS ROTOR LOCKED (BC) = STATOR COPPER LOSS REDUCED TO AMPS. $= \frac{I^2R}{E}$

(CF) = DF − DC = ROTOR COPPER LOSS. TAKE h SO THAT $hm = \frac{H.P. \times 746}{110} = \frac{.1 \times 746}{110} = .67$ AMPS.

(hg) = INPUT = 140 WATTS. EFFICIENCY $= \frac{hm}{hg} =$ 52[illegible] %

THIS DIAGRAM SHOWS THAT THE EFFICIENCY WILL KEEP RISEING.

M E T H O D O F S T A R T I N G .

The Single Phase Motor will not start alone as there is no torque at standstill. For starting purposes a second winding was put on at right angles to the main winding, as in a two phase motor. This winding was of fine wire therefore of high resistance, thus the current was slightly in advance of the main current. This gives the polyphase effect.

DESIGN. The coil is completely in one slot thus no distribution factor is needed

Conductors in main winding 830.

Distribution factor .74

.74 x 830 = 615 conductors. or 307 turns.

$\frac{\pi}{4} \times (7/16)^2 = .15$ sq. in. area of slot.

$\frac{307}{.15} = 2050$ turns per sq. in.

This corresponds to a No. 26 S. C. C. wire.

It was found that the motor would not start with the full voltage on the main winding, so an inductance coil was put in series with it, to reduce the starting current and the locking effect. This also caused the main current to lag still more, giveing a greater difference in phase.

A 40% reduction in voltage was found to be satisfactory the motor would then run up to speed with only 2 amps starting current.

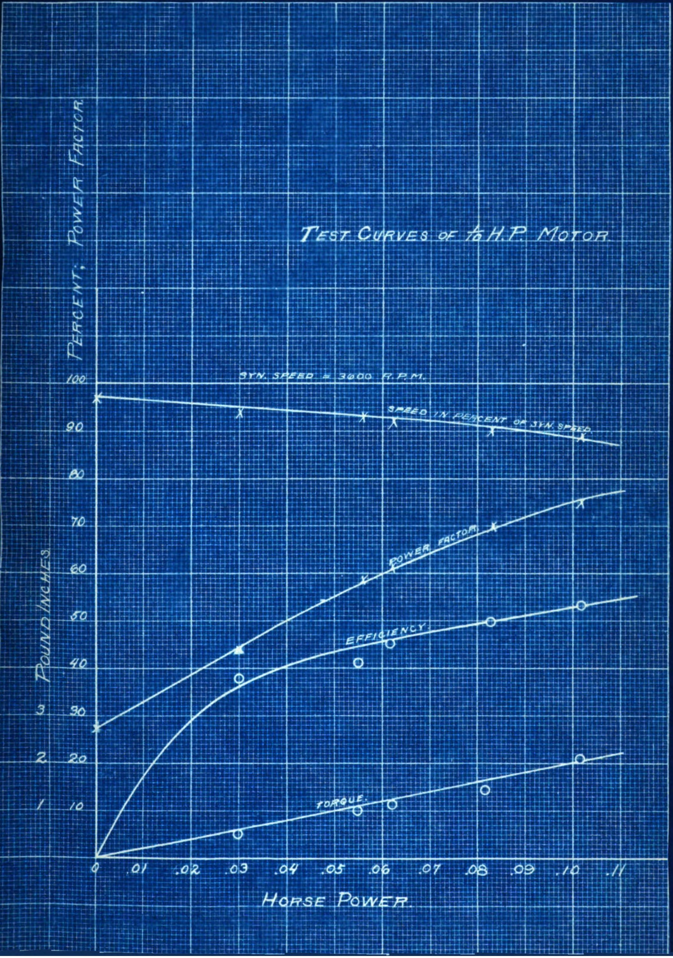
T E S T D A T A .

Volts	E I	Watts	Power Factor	Speed	Amps.	Load oz.	H P
114	154	44	.286	3500	1.35	0	0
113	158	69	.438	3400	1.4	12	.0302
107	161	95	.59	3400	1.5	22	.0555
110	170	103	.605	3350	1.55	25	.0625
107.5	183	126	.69	3300	1.7	34	.0835
104	203	153	.75	3200	1.95	46	.109

Eff. %	Torque. In. lbs.	Speed. % Syn. Speed
0	0	97.2
30.8	.562	94.5
41.5	1.03	94.5
45	1.17	93.2
49.5	1.6	91.6
53.2	2.16	89

Comparison of calculated data, and test data.

	By Calculation	By Test.
Capacity	1/10 H P	1/10 H P
Exc. Current	1.5 amps.	1.35 amps.
Watts input no load	40	44
Efficiency at 1/10 H P	52%	53%
Power Factor at 1/10 H P	.65	.75
Resistance of primary	3.9 ohms	7.5 ohms
Reactance	2.85 ohms.	



TEST CURVES OF 1/10 H.P. MOTOR.
PERCENT; POWER FACTOR
POUND INCHES
SYN. SPEED = 3600 R.P.M.
SPEED IN PERCENT OF SYN. SPEED.
POWER FACTOR
EFFICIENCY.
TORQUE.
100
90
80
70
60
50
40
30
20
10
3
2
1
0
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11
HORSE POWER.

APPENDIX.

Shunt Motor Drawings.

1 Stator.

2 Armature.

3 End Castings.

4 Commutator and Brushes.

5 Wireing Diagram.

Squirrel Cage Induction Motor Drawings.

1 Stator as above with four more slots, so as to make twelve slots equally spaced.

2 Squirrel Cage Rotor.

3 Bearings and Oil Cups as above.

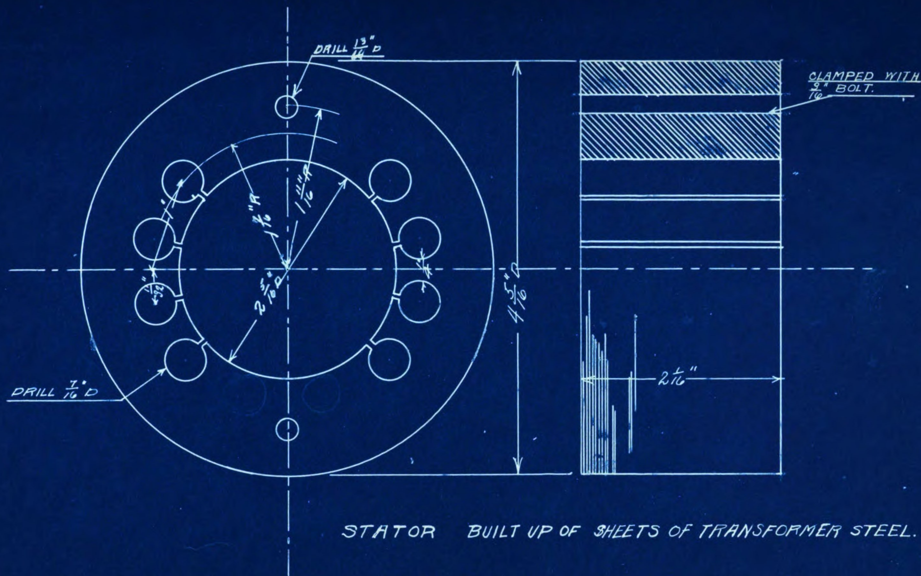
4 End Castings as above, both with the short bearing.

5 Base.

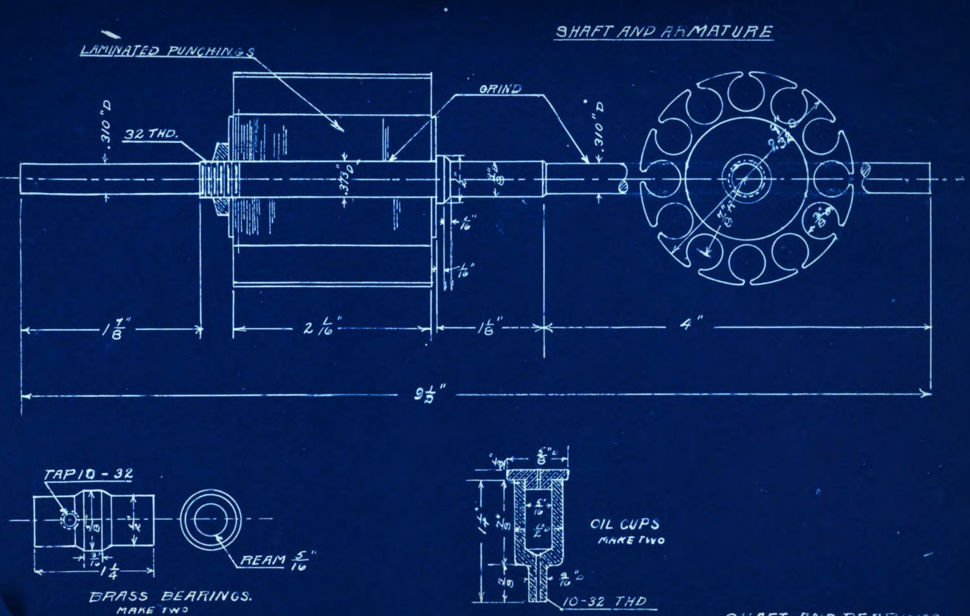
6 Wireing Diagram.

7 Photograph of Finished Machine.

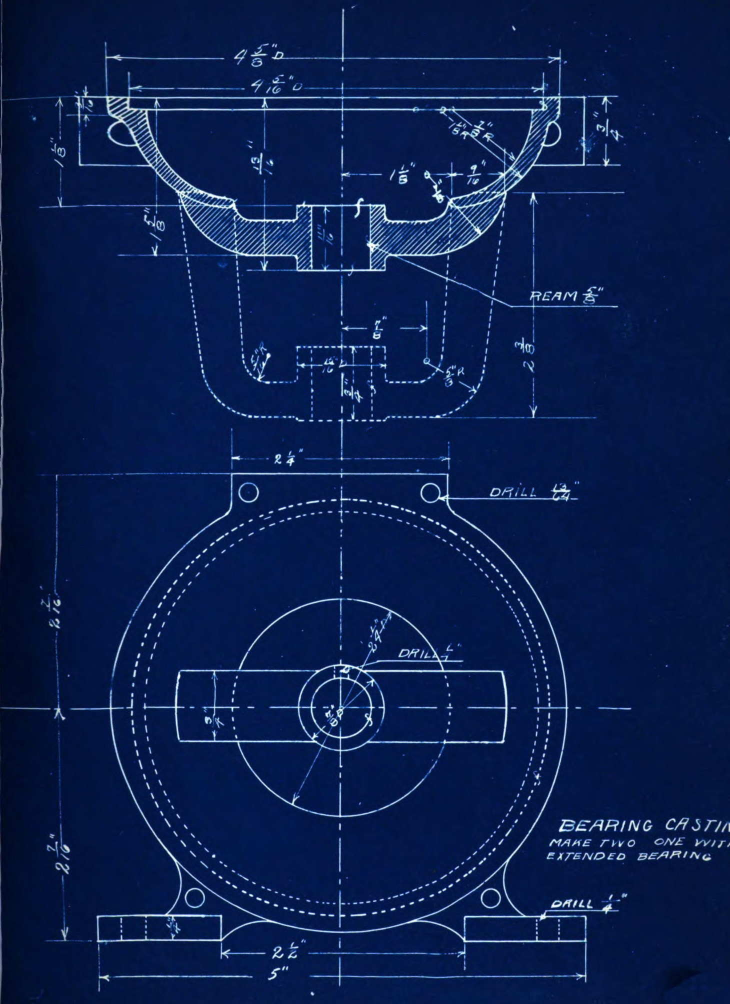
References

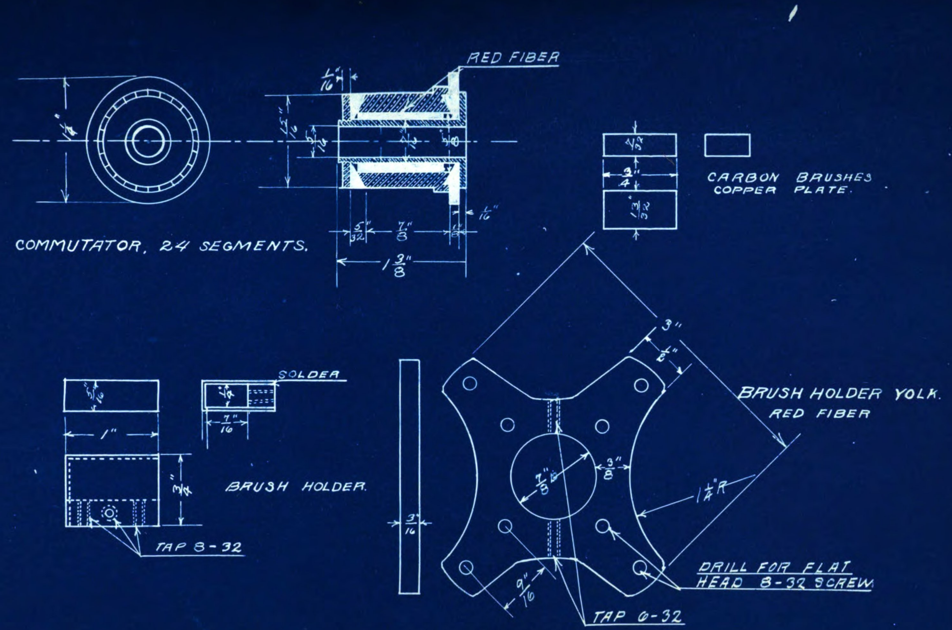


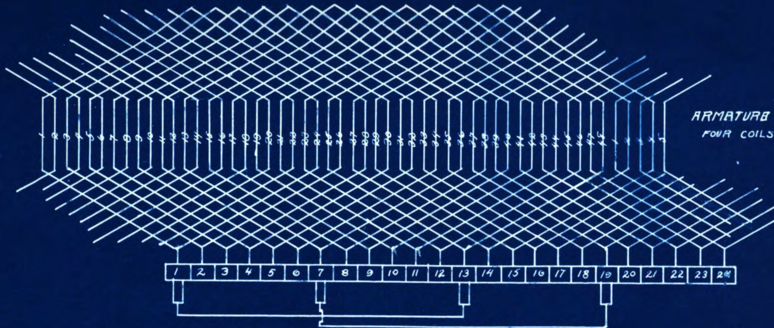
STATOR BUILT UP OF SHEETS OF TRANSFORMER STEEL.



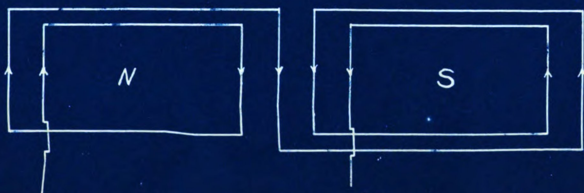
SHAFT AND BEARINGS.


BEARING CASTIN
MAKE TWO ONE WITH
EXTENDED BEARING
REAM 5/8"
DRILL 13/64"
DRILL 1/4"
DRILL 1/4"
4 5/8" D
4 5/16" D
2 1/4"
2 1/2"
5"

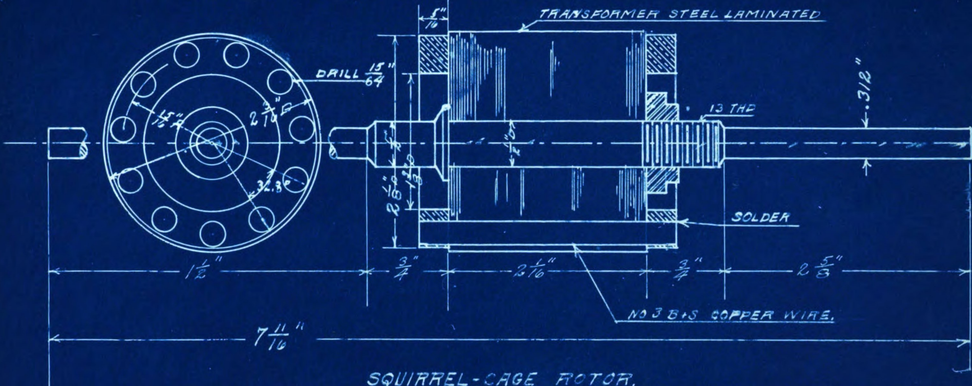

RED FIBER
COMMUTATOR, 24 SEGMENTS.
CARBON BRUSHES
COPPER PLATE.
BRUSH HOLDER YOLK.
RED FIBER
SOLDER
BRUSH HOLDER.
TAP 8-32
DRILL FOR FLAT
HEAD 8-32 SCREW.
TAP 6-32



ARMATURE WINDING.
FOUR COILS PER SLOT.

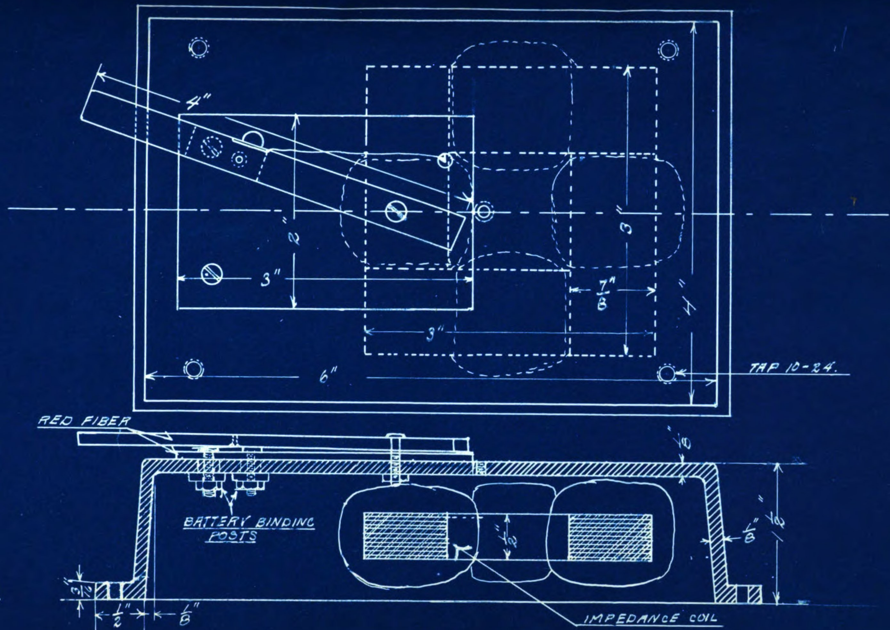


STATOR WINDING

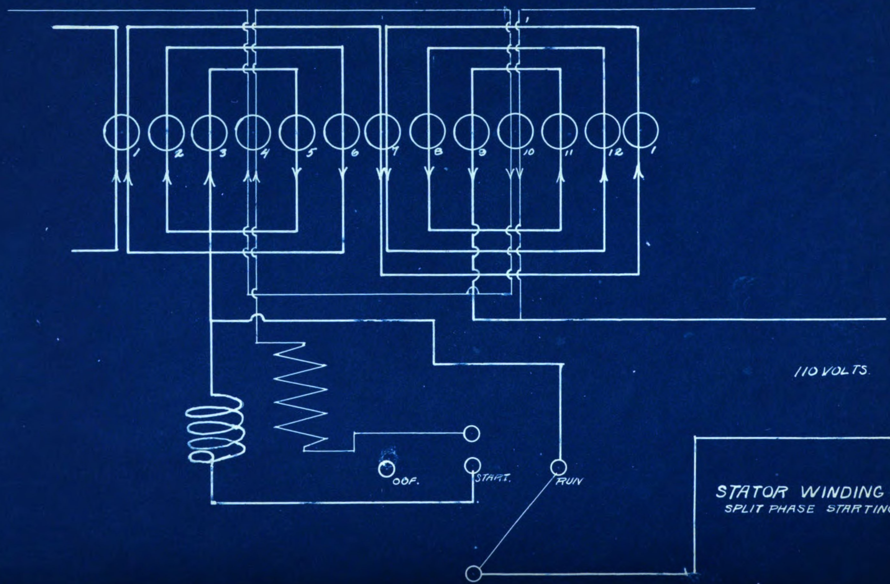


SQUIRREL-CAGE ROTOR.

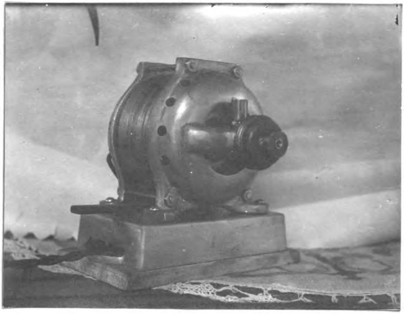
COIL . CAST IRON.



BASE WITH SWITCH AND IMPEDANCE COIL. CAST IRON.



STATOR WINDING
SPLIT PHASE STARTING.



R E F E R E N C E S .

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(b) Repulsion Motor with Variable-speed Characteristics by E. F. W. Alexanderson.

(c) Current Locus of the Single Phase Induction Motor. by A. S. Langsdorf.