

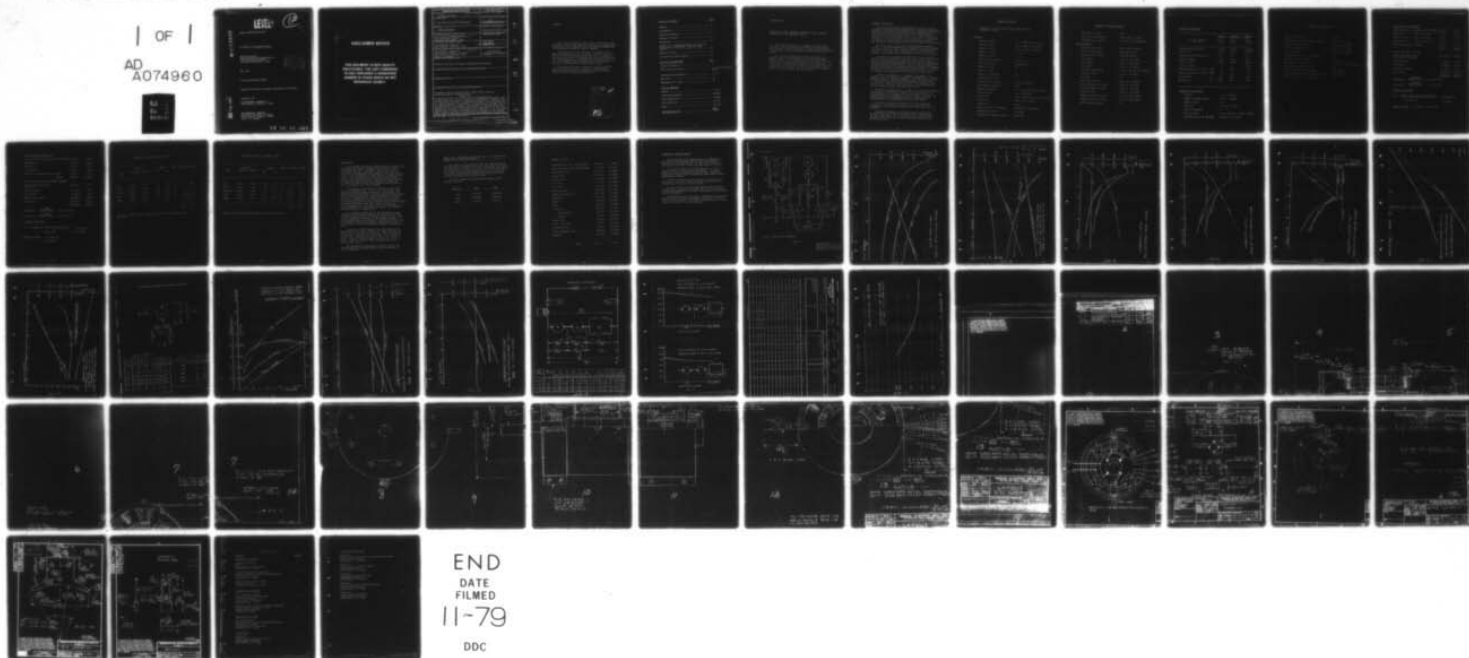
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DC TEST RIG PROPULSION MOTOR.(U)
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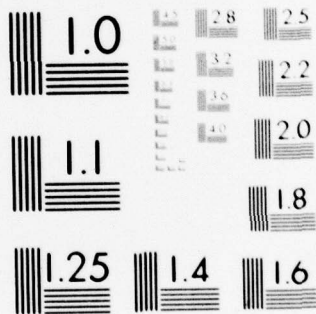
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Report DAAK70-78-C-0044

DC TEST RIG PROPULSION MOTOR

Sylvain Garnett
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100 Pennsylvania Avenue
Paterson, New Jersey 07509

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May 1979

Final Engineering Report

Approved for Public Release; Distribution Unlimited

Prepared for

USA MERADCOM, DRDME-PE-1
Fort Belvoir, Virginia 22060

USA MERADCOM, DRDME-EA
Electrical Equipment Division
Fort Belvoir, Virginia 22060
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) DESIGN, CONSTRUCT AND EVALUATE TWO HIGH SPEED DC PROPULSION MOTORS WITH A NOMINAL RATING OF 10HP @ 6000 RPM AND AN INTERMITTENT RATING OF 20HP @ 3000 RPM AT A MOTOR WEIGHT OF 95LBS/UNIT. THE MOTORS ARE DESIGNED FOR USE IN CONJUNCTION WITH EITHER A CONVENTIONAL DC CHOPPER MOTOR CON- TROLLER, OR AS A DUAL MOTOR DRIVE IN CONJUNCTION WITH A TWO PHASE, SEQUENTIALLY SWITCHED DC CHOPPER MOTOR CONTROLLER. THE AUXILIARY SHUNT FIELD IS USED TO SYNCHRONIZE SPEED BETWEEN THE TWO MOTORS AND TO ASSIST THE SERIES FIELD DURING THE REGENERATIVE BRAKE MODE.			

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SUMMARY.

This report describes the design, construction, and evaluation of two high speed D.C. motors for a propulsion application with a nominal rating of 10HP at 6000RPM and an intermittent rating of 20HP at 3000RPM.

The objective of the work done by Boque Electric Manufacturing Company was to design, construct, and test two D.C. propulsion motors which were to be compatible with a multiphase D.C. chopper-motor drive, described in the IEEE Transactions On Industry Applications, Vol. IA-8, No: 2, March/April 1972, pp 136-144, entitled "Design Analysis of Multiphase DC Chopper Motor Drive".

The motors also had to interface with an existing electric propulsion test rig design, originated by Barber-Nichols Engineering Company, Arvada, Colorado, which limited its envelope dimensions.

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INTRODUCTION.

DESIGN OF A 10HP, 6000RPM, CONTINUOUS 20HP, 3000RPM INTERMITTENT DUTY TRACTION MOTOR.

The design is based on a compromise between good efficiency and low weight-two conflicting requirements. Any reduction in electro-magnetic weight causes a decrease in efficiency and any increase in efficiency increases weight.

The electric loading and current densities are based on values extrapolated from previous designs of similar units. As it turned out after testing, the limit in the design was not temperature or efficiency but commutation. Considerable difficulty was experienced due to the fact that only two commutating poles were used in order to save weight. We will discuss this in greater detail in a later section of this report.

GENERAL DISCUSSION.

The solid state control methodology utilized in conjunction with these motors requires that each motor contains a series field which is supplanted by an auxiliary shunt field. The auxiliary shunt field assists in the recuperation of energy during braking, whereby the series field usually remains in circuit and returns energy to the source during the freewheeling operating mode of the controller. In addition, the auxiliary shunt field controls speed balance between the two motors and provides steering angle control if necessary.

As can be seen on the motor interconnection diagram in Fig. 1. the two armatures are connected in series, whereas the series fields of the respective motors are connected in parallel. By sequentially switching the paralleled series fields, the armature current becomes twice the field current.

The special requirement for this motor is to provide a series field winding which furnishes 85 to 100 percent of the required ampere-turns with only half the armature current, while the remaining requirements for magnetic flux excitation is provided by the shunt field. Since it was necessary to pretest this motor as a conventional series motor, the series field was arranged in two parallel circuits making it possible to operate in a series connection under electronic control or in parallel connection as a conventional series motor.

Another requirement is to minimize its weight. The nominal rating of the motor is 10HP at 6000RPM with an intermittent rating of 20HP at 3000RPM. A goal of 90 lbs. was set for this motor by extrapolating from similar motors built in the past. Because of the relatively low voltage of this motor the currents are high and require a large commutator, a large brush, rigging, and heavy lead wires.

We had a choice between a 4 pole or a 6 pole configuration. For reasons of economy, we adopted the 4 pole design. To reduce weight, we provided only two interpoles which also provided space to accommodate the large number of leads. We also reduced weight by fabricating the end brackets of aluminum and the brush-holders of thin gauge brass.

We investigated the possibility of using Vanadium-Permendur for the magnetic structure but found the cost prohibitive for the small reduction in weight that could be realized.

Vanadium-Permendur contains 50% cobalt and the price of cobalt has risen from \$5 a pound to \$50 a pound during the last four years. It is also a material that must be imported from unreliable sources providing another reason to avoid its use.

SUMMARY OF DESIGN

THE DESIGN IS BASED ON THE PEAK RATING OF 20HP,
3000RPM, 48 VOLTS.

Armature:

Outside Diameter	$D_a = 5.000 \text{ in. (12.7cm)}$
Inside Diameter	$D_i = 1.500 \text{ in. (3.81cm)}$
Length of Stack	$L_a = 4.00 \text{ in. (10.16cm)}$
Number of Slots	$S = 45$
Number of Poles	$P = 4$
Slots per Pole Pitch	$S/P = 11.25$
Type of Winding	Simplex Wave
Number of Coils	45
Turns per Coil	1
Number of Conductors	90
Conductors per Slot	2
Total Flux in the Gap	$2.69 \times 10^6 \text{ lines}$
Distribution Constant	0.66
Magnetic Loading	$Q = 1146 \text{ AN/in (451 AN/cm)}$
Flux per Pole	$4.44 \times 10^5 \text{ lines}$
Conductors	2 No. 10 AWG Square (2.59 x 2.59mm)
Copper Area	$.0197 \text{ in.}^2 (.127\text{cm}^2)$
Insulation	Class H
Current Density at 400 Amps	$10152\text{A/in.}^2 (1574\text{A/cm}^2)$
Resistance at 25°C	.007 Ohms
Frequency of Armature Current	100 Hertz

SUMMARY OF DESIGN-CONTINUED

Amp Turns per Pole	2250
Material of Laminations	M-19, #29Ga. (.035cm)
Rotating Mass Inertia	0.605 Lb.Ft. ² (255Kgcm ²)

Poles and Yoke:

Material-Main Poles	M-19, #29Ga (.035cm)
Material-Interpoles	Low Carbon Steel
Material-Yoke (Frame)	Low Carbon Steel
Pole Height	1.250 in. (3.175cm)
Pole Length	4.00 in. (10.16cm)
Pole Width	1.25 in. (3.175cm)
Interpole Dimensions	.5 x 3.5 in. (1.27 x 8.89cm)
Interpole Shoe	.625 in. (1.58cm)
Pole Arc	60 ^o
Main Pole Air Gap	0.071 in. (0.180cm)
Outside Diameter of Yoke	8.750 in. (22.2cm)
Inside Diameter of Yoke	7.640 in. (19.4cm)
Length of Yoke	5.500 in. (13.97cm)
Magnetic Section of Pole	4.75 in. ² (30.63cm ²)
Magnetic Section of Yoke	5.95 in. ² (38.37cm ²)
Pole Leakage Constant	1.2

Stationary Windings:

	<u>SERIES</u>	<u>INTERPOLE</u>	<u>SHUNT</u>
Size of Conductor AWG (cm)	#7SQ (.365)	#7SQ (.365)	#24 (.051)
Conductor cross section (in ²) (cm ²)	.0199 (.128)	.0199 (.128)	.000317 (.002)
Maximum current/section (A)	210	210	2.7
Current density (A/in ²) (A/cm ²)	10552 (1636)	10552 (1636)	8517 (1320)
Turns per pole	8	17	400
Resistance/section at 25°C (ohm)	.01	.007	40
Resistance/section at 125°C (ohm)	.014	.01	56
Voltage Drop (V)	2.94	2.06	108
Watts Loss (W)	1180	825	292

Commutator and Brushes:

Diameter	4 in. (10.16cm)
Length of brush surface	2.5 in. (6.35cm)
Number of bars	45
Bar pitch	.279 in. (.708cm)
Number of brushes	8
Size of brush	.375 X 1.00 in. (.952 X 2.54cm)
Current density (At 400 AMP)	266A/in. ² (41 A/cm ²)

SUMMARY OF COMMUTATION

Bars covered by Brush	1.342
Commutating Zone on Armature Surface	0.73 in. (1.85cm)
Width of Neutral Zone	1.335 in. (3.39cm)
Width of Interpole Shoe	0.625 in. (1.59cm)
Gap of Interpole	.045 in. (1.14cm)
Commutating Zone in % of Neutral	54%
Reactance Volts at 400A	0.7 volts
Interpole Gap Density	12732 L/in. ² (1974 Gauss)
Amp. Turns for Gap Density	148
Armature Reaction (At 400 AMP)	2250 AT/Pole
Total Amp Turns Required (Approx. 125%)	3400 AT/Pole
Turns per Int. Pole (2 Par. Circ.)	17

LOSS PROFILE AT OVERLOAD.

			(125°C)	(25°C)
Resistance drop at overload (at 420 AMPS and 125°C)				
Armature IR	.008 X 1.4 X 420	=	4.70 V	3.36 V
Series Field IR	.005 X 1.4 X 420	=	2.94 V	2.10 V
Interpole IR	.0035 X 1.4 X 420	=	2.06 V	1.47 V
Brush Drop (Copper Graphite)		=	1.00 V	.71 V
			<u>10.70 V</u>	<u>7.64 V</u>

Losses (at 20HP, 3000 RPM)

Copper and Brush Contact 10.70 Volts X 420 AMPS		4495 Watts	3209 W
Brush Friction		95 Watts	95 W
Iron Losses		160 Watts	160 W
Friction + Windage		90 Watts	90 W
Stray Load		400 Watts	400 W
		<u>5240 Watts</u>	<u>3954 W</u>

$$\text{Efficiency} = \frac{14920}{14920 + 5240} = .74 \text{ (at } 125^{\circ}\text{C)}$$

$$\text{Efficiency} = \frac{14920}{14920 + 3954} = .79 \text{ (at } 25^{\circ}\text{C)}$$

Torque at 3000 RPM

$$T_D = \frac{7.04 \times 2.69 \times 10^6 \times 90 \times 420 \times .66}{2 \times 60 \times 10^8} = 39.4 \text{ LBS. Ft.}$$

$$= 53.4 \text{ N-m)}$$

$$\text{Required Torque} = 35 \text{ LBS Ft. (47.46 N-m)}$$

LOSS PROFILE AT RATED LOAD.

	(at 183 AMPS and 125°C)	(25°C)
Full Load Resistance Drop		
Armature IR	2.04 V	1.46 V
Series IR	1.28 V	.91 V
Interpole IR	0.89 V	.64 V
Brush Drop (Copper Graphite) TOTAL	0.50 V	.50 V
	4.71 V	3.51 V
TOTAL		
Full Load Losses (at 133 AMPS, 6000RPM)		
Copper and Brush Contact 4.71 X 183	862 Watts	642 W
Brush Friction	95 Watts	95 W
Iron Losses	50 Watts	50 W
Windage + Friction	200 Watts	200 W
Stray Load	100 Watts	100 W
	1307 Watts	1087 W

$$\text{Efficiency} = \frac{7460}{7460 + 1307} = .85 \text{ (at } 125^{\circ}\text{C)}$$

$$\text{Efficiency} = \frac{7460}{7460 + 1087} = .87 \text{ (at } 25^{\circ}\text{C)}$$

Torque at 6000 RPM

$$T_d = \frac{7.04 \times 1.47 \times 10^6 \times 90 \times 183 \times .66}{2 \times 60 \times 10^8} = 9.37 \text{ LBS Ft.}$$

$$= 12.71 \text{ N-m)}$$

$$\text{Required Torque} = 8.75 \text{ LBS. Ft.}$$

$$= (11.87 \text{ N-m)}$$

MAGNETIC CIRCUIT AT 3000RPM, 20HP

AREA	DENSITY		LENGTH		AT/IN	OERSTED	AT/POLE
	LINES/IN ²	GAUSSES	IN	CM			
GAP	42500	6589	.071	.180	----	-----	1131
TEETH	102000	15814	.600	1.524	85	42	51
ARM. YOKE	80000	12403	1.500	3.810	10	4.95	15
POLE	106000	16434	1.250	3.175	125	61.84	159
FRAME	90000	13953	3.22	8.179	40	19.79	129

TOTAL = 1485

BECAUSE OF ARMATURE CROSS MAGNETIZATION THE ACTUAL TOTAL AT/POLE ARE 1600.

MAGNETIC CIRCUIT AT 6000RPM, 10HP

AREA	DENSITY		LENGTH		AT/IN	OERSTED	AT/POLE
	LINES/in ²	GAUSSES	IN	CM			
GAP	23200	3596	.071	.180	----	-----	609
TEETH	55300	8573	.600	1.52	3.5	1.73	2.1
ARM.YOKE	26000	4031	1.50	3.81	1.5	0.74	2.3
POLE	57600	8930	1.25	3.18	4	1.98	5.0
FRAME	47200	7317	3.22	8.18	10	4.95	32.2
TOTAL =							650.6

BECAUSE OF CROSS MAGNETIZATION THE ACTUAL AT/POLE ARE 732.

DISCUSSION.

The purchase description for this motor specifies two points for the Speed - Torque Characteristic. 10HP at 6000RPM and 20HP at 3000RPM. By careful choice of saturation levels, air-gap and series field turns we were able to accommodate both points at the same voltage level. This relegates the shunt field to balancing the speed of the two motors, to angle control and intermittent regenerative braking. There is no need any more to maintain a large shunt field on the low speed end in order to reach top speed by weakening this field as was envisioned in the Interim Report.

As mentioned previously we encountered some difficulty with commutation. In order to save weight, this motor has only two commutating poles. Therefore, the commutating pole flux has to return through the main pole. But the main pole becomes highly saturated at overloads and cannot accommodate the additional interpole flux. For proper operation of the interpoles it is necessary to maintain linearity between flux and current which cannot be accomplished while the main flux is subject to large fluctuations. Therefore, we had to compromise in the calibration of the interpoles in order to achieve a tolerable degree of commutation.

As a further consequence of our difficulties with commutation we could not achieve the efficiency during overload that was predicted in the interim report. This is due to parasitic torques in the conductors undergoing commutation and is buried in the loss profile under the heading of Stray Load Losses. Nevertheless, the efficiency is still as good as on machines weighing much more.

In order to further improve the efficiency of the motor under solid state control, one could laminate the entire field structure of the motor. This may produce a measurable reduction in iron losses. The additional cost of the laminated motor would have to be justified by the possible energy savings over the life of the motor. This is a subject that is beyond the scope of this present study.

The airflow was maintained at 200 CFM during our test program. The pressure drop at this flow rate is 1.0 in. of water.

ANALYSIS OF COMPARABLE WEIGHT AND COST OF A SINGLE MOTOR
RATED 20HP VS. TWO 10HP MOTORS.

We assume in this analysis that the 10HP motors are 48 Volt motors operating in a series connection and that the 20HP motor is rated at 96 Volt. This keeps the current in both ratings the same and permits us to use the same size commutators, brush-riggings, and cables. Based on the above assumptions the 10HP motor will weigh 95 LBS. and the 20HP motor will weigh 163 LBS.

A Cost Breakdown for these motors based on 1979 Dollars follows:

<u>QUANTITY</u>	<u>10HP</u>	<u>20HP</u>
100	\$ 1250.00	\$ 1800.00
1000	\$ 1060.00	\$ 1530.00
10000	\$ 875.00	\$ 1260.00

Weight of Parts:

Bearing Bracket Ext. End Aluminum	3.69 lbs.	(1.67Kg)
Bearing Bracket Comm. End Aluminum	5.57 lbs.	(2.52Kg)
Frame Ring Steel	21.72 lbs.	(9.85Kg)
4 Main Poles	8.57 lbs.	(3.89Kg)
2 Int. Poles	1.25 lbs.	(0.57Kg)
M.P. Coils	3.7 lbs.	(1.68Kg)
I.P. Coils	2.75 lbs.	(1.24Kg)
Armature Coils	5.00 lbs.	(2.27Kg)
Armature Laminations	16.10 lbs.	(7.30Kg)
Commutator	9.35 lbs.	(4.24Kg)
Cables	2.00 lbs.	(0.91Kg)
Shaft	6.31 lbs.	(2.86Kg)
2 Bearings	1.00 lb.	(0.45Kg)
Brush Holders	1.12 lbs.	(0.51Kg)
Brushes	.45 lb.	(0.20Kg)
Rocker Ring	.24 lb.	(0.11Kg)
Cover - Ext. End	.91 lb.	(0.41Kg)
Bearing Inserts	.36 lb.	(0.16Kg)
Cover Commutator End	3.00 lbs.	(1.36Kg)
Hardware	1.91 lbs.	(0.86Kg)

TOTAL

95 lbs.

43 Kg

ALTERNATIVE CONCEPT MOTORS .

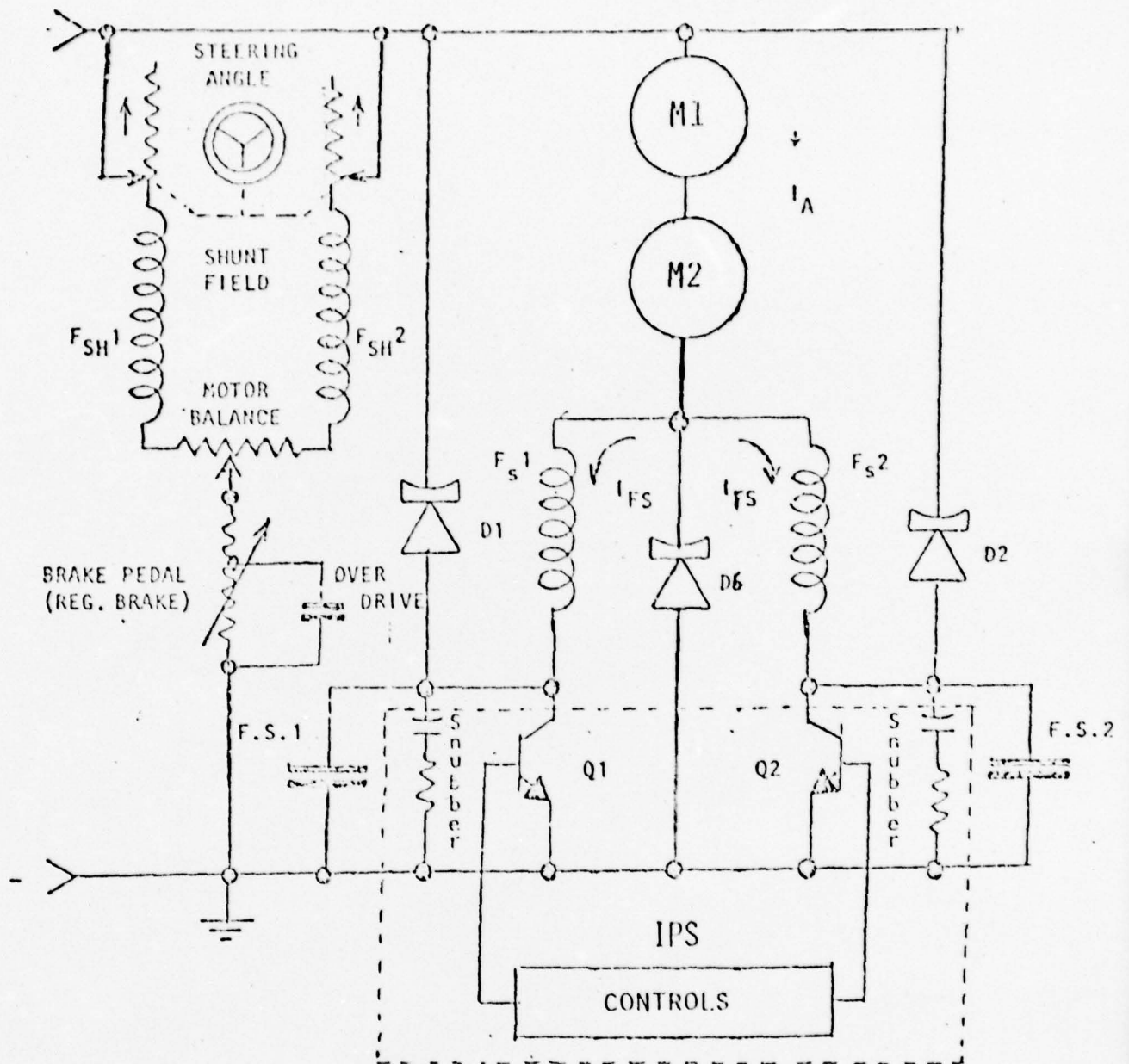
In discussions with representative of MERADCOM it was agreed that endurance testing and environmental testing as prescribed by Par. 4.4 and Par. 4.5 should be cancelled and that instead two more motors be built.

The original motors had radial brushes in order to insure complete by-directional capability. A radial brush is not very stable and under certain conditions, especially under very high speed, may cause chatter with simultaneous arcing.

Brushes in trailing configuration or reaction type brushes are much more immune to chatter but have one disadvantage; they are unidirectional.

In view of the fact that propulsion motors operate in one direction most of the time, we will take advantage of this characteristic and build these motors with trailing type brushholders.

The original motors had only 2 interpoles which caused some difficulties with the interpole flux due to saturation of the main poles. Therefore it was decided to incorporate 4 interpoles in the new motors.



F.S. = FULL SPEED CONTACTOR

FIGURE 1

Patent Applied
 USAMERADCOM, Elec Power Lab
 Electrical Equipment Division
 Fort Belvoir, Virginia 220

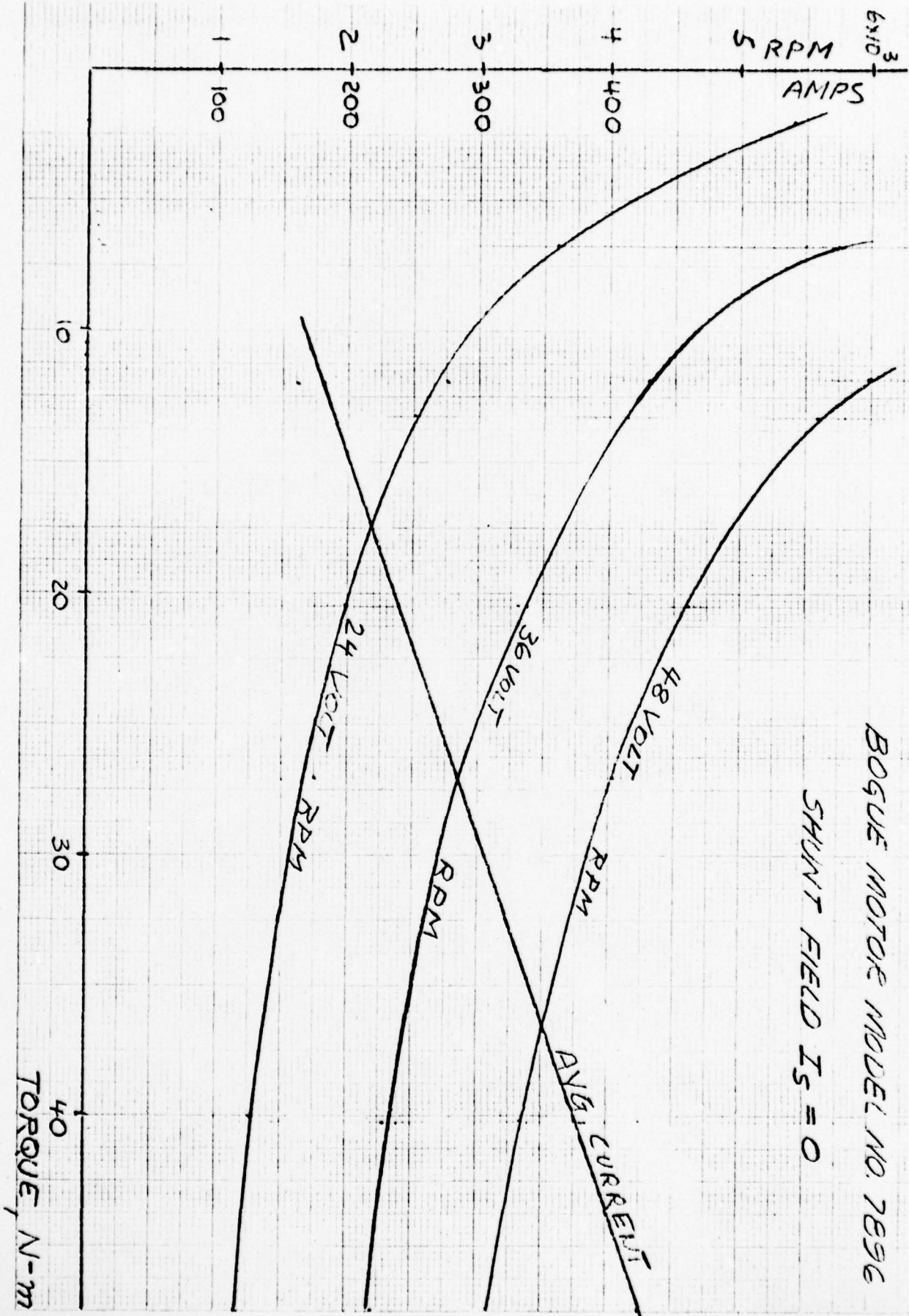


FIG. 2

46 1323

1/2 X 10 TO 1/2 INCH 2 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

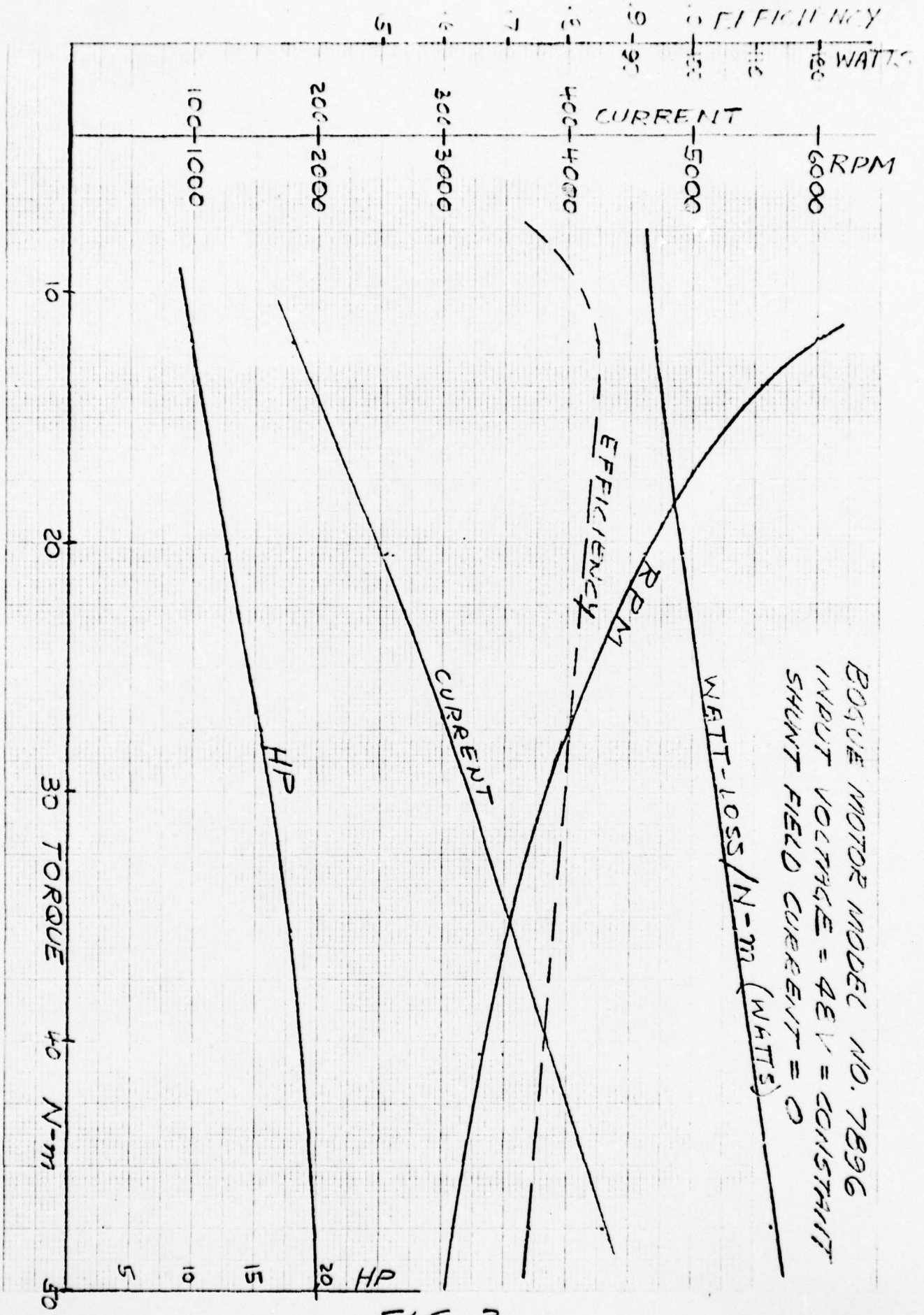


FIG. 3

46 1323

MAX. DISK TO 1.5 INCHES
 REUFFEL & ESSEN CO. MADE IN U.S.A.

BOGUE MOTOR MODEL NO. 7896

5 HP = CONSTANT

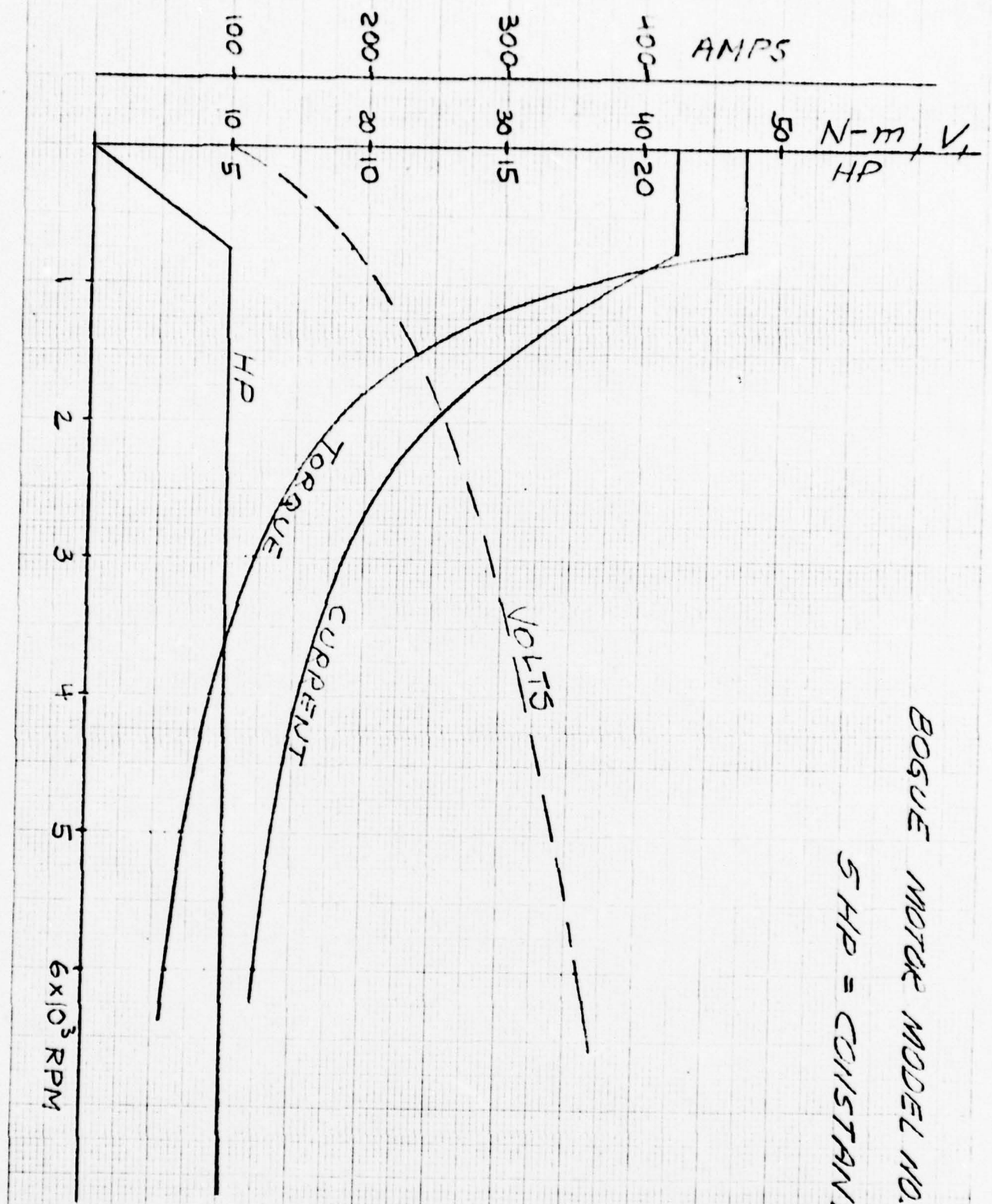


FIG. 4

46 1323

MOORE & CO. ENGINEERS
100 N. 10th St. St. Louis, Mo.

BOGUE MOTOR MODEL NO. 7B56

10 HP = CONSTANT

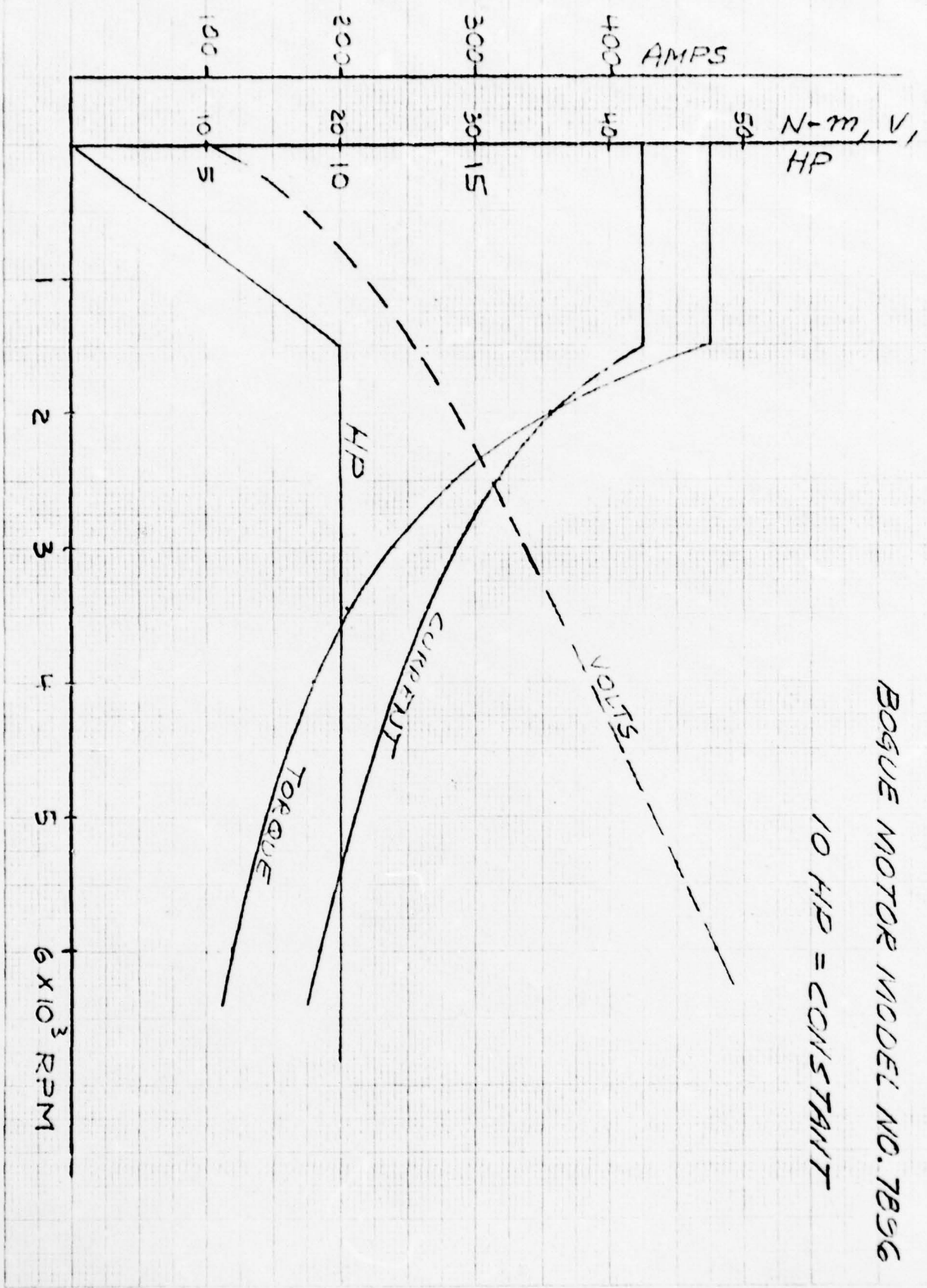
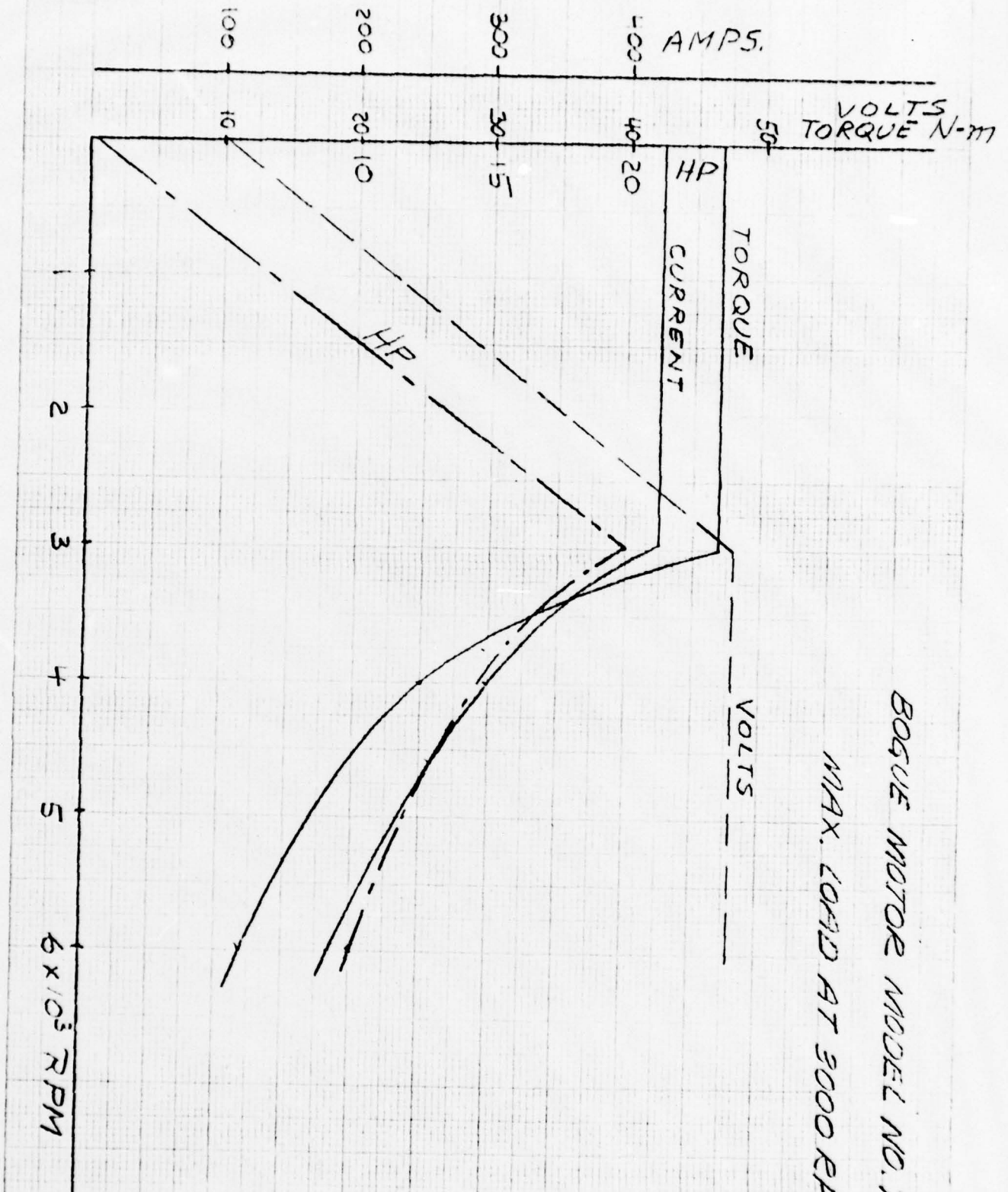


FIG. 5

46 1323

1/2" X 1/8" TO 1/4" X 1/8" HERRICK & LUSK CO. JERSEY CITY, N.J.



BOQUE MOTOR MODEL NO. 7836
 MAX. LOAD AT 3000 RPM

FIG. 6

46 1323

MADE TO ORDER INCH 1 X 10 INCHES
 RECORDER & ASSOCIATED MADE IN U.S.A.

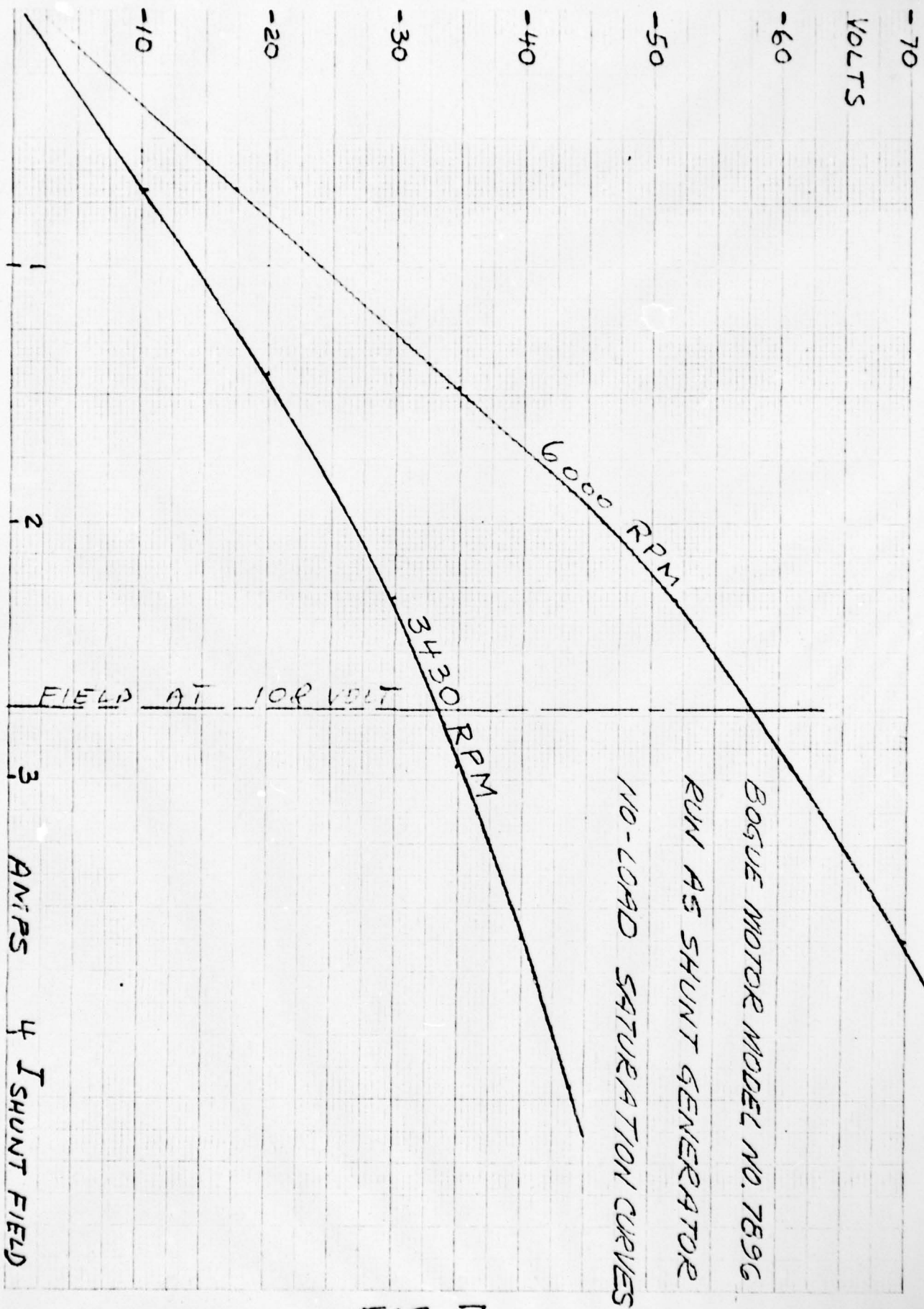


FIG. 7

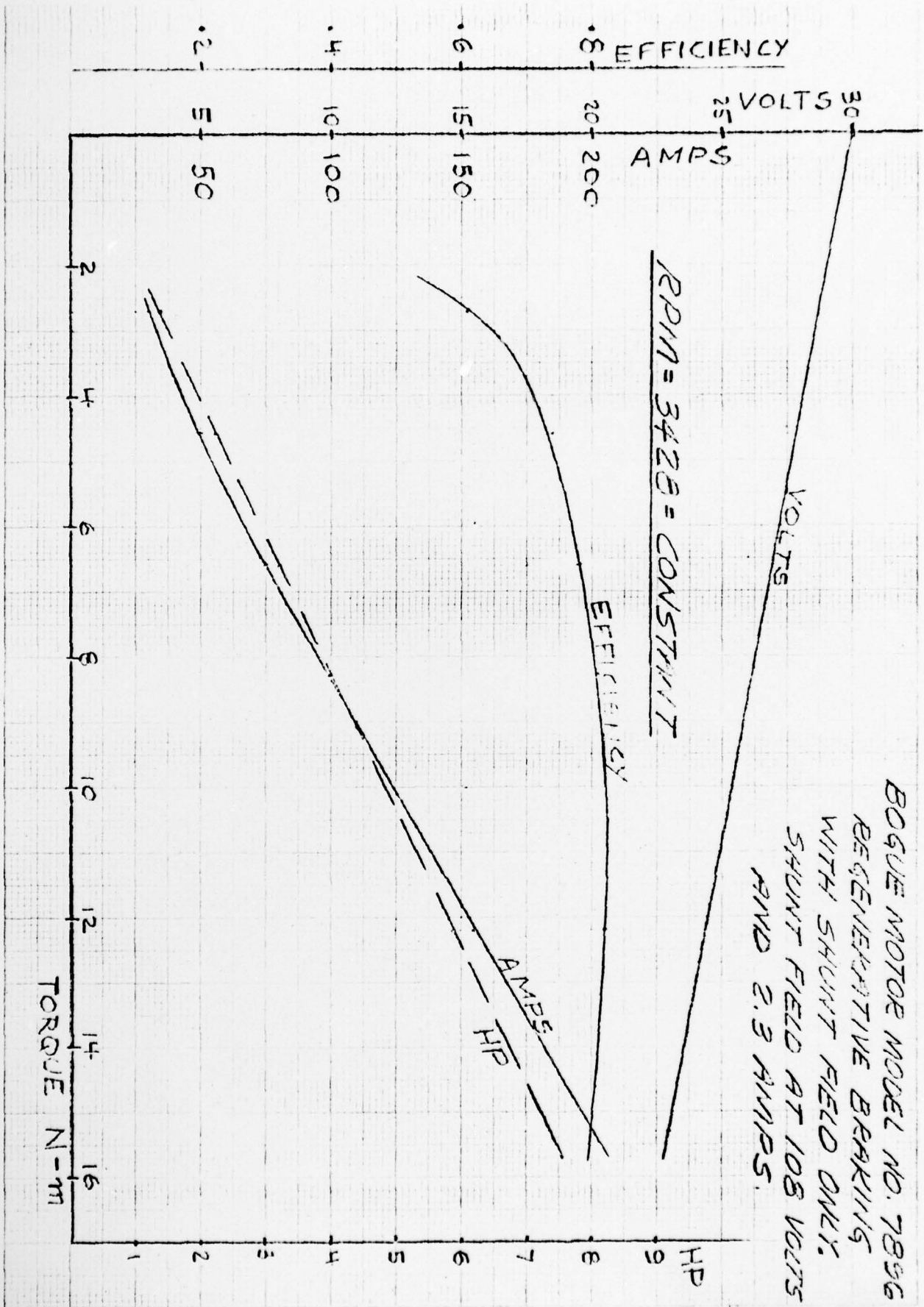
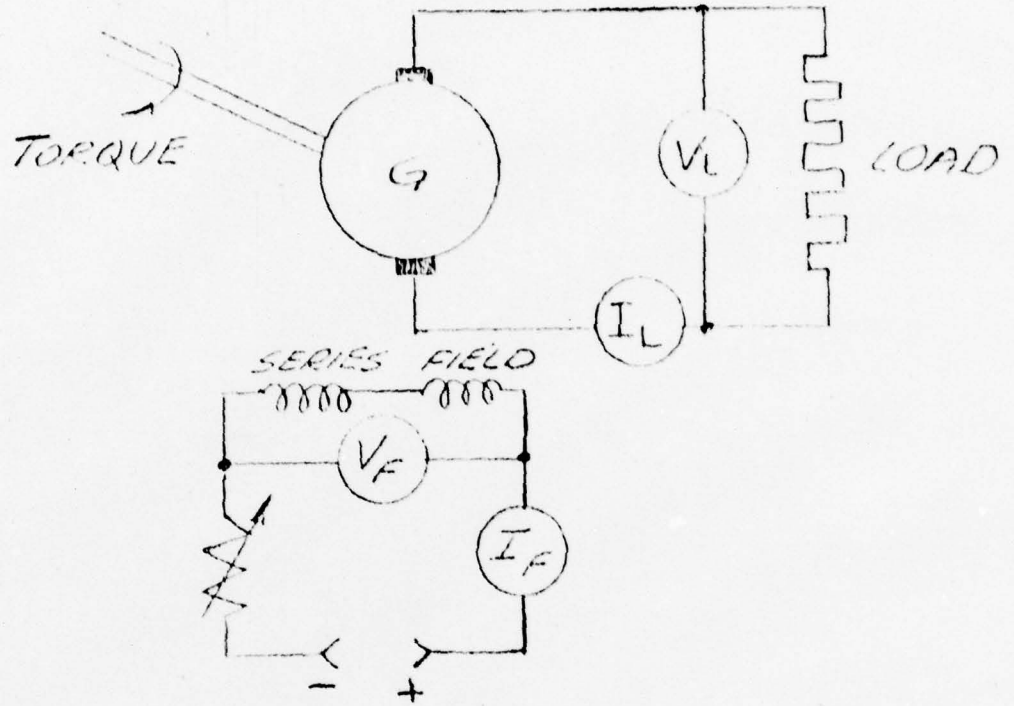


FIG. 8

46 1323

MADE IN U.S.A. TO 1/8 INCH 7 X 10 INCHES
 METROPOLITAN EDISON CO. MADE IN U.S.A.

REGENERATIVE BRAKING WITH SERIES FIELD ONLY



RPM = 3428

I_L	V_L	I_F	V_F	TORQUE	P_{GEN}	P_{INPUT}	EFFICIENCY
A	V	A	V	N-m	$I_L V_L$	$(359 \times T_q) + V_F I_F$	P_G / P_{INPUT}
				0.81	0	290	0
50	8.8	31	.62	2.17	440	798	.55
100	18.3	70	1.40	6.37	1830	2385	.77
150	27.4	118	2.36	12.88	4110	4902	.84
200	36.5	196	3.92	22.64	7300	8896	.82

FIG. 9

BOGUE MOTOR MODEL 789C
 REGENERATIVE BRAKING
 WITH SERIES FIELD ONLY

RPM = 3428 = CONSTANT

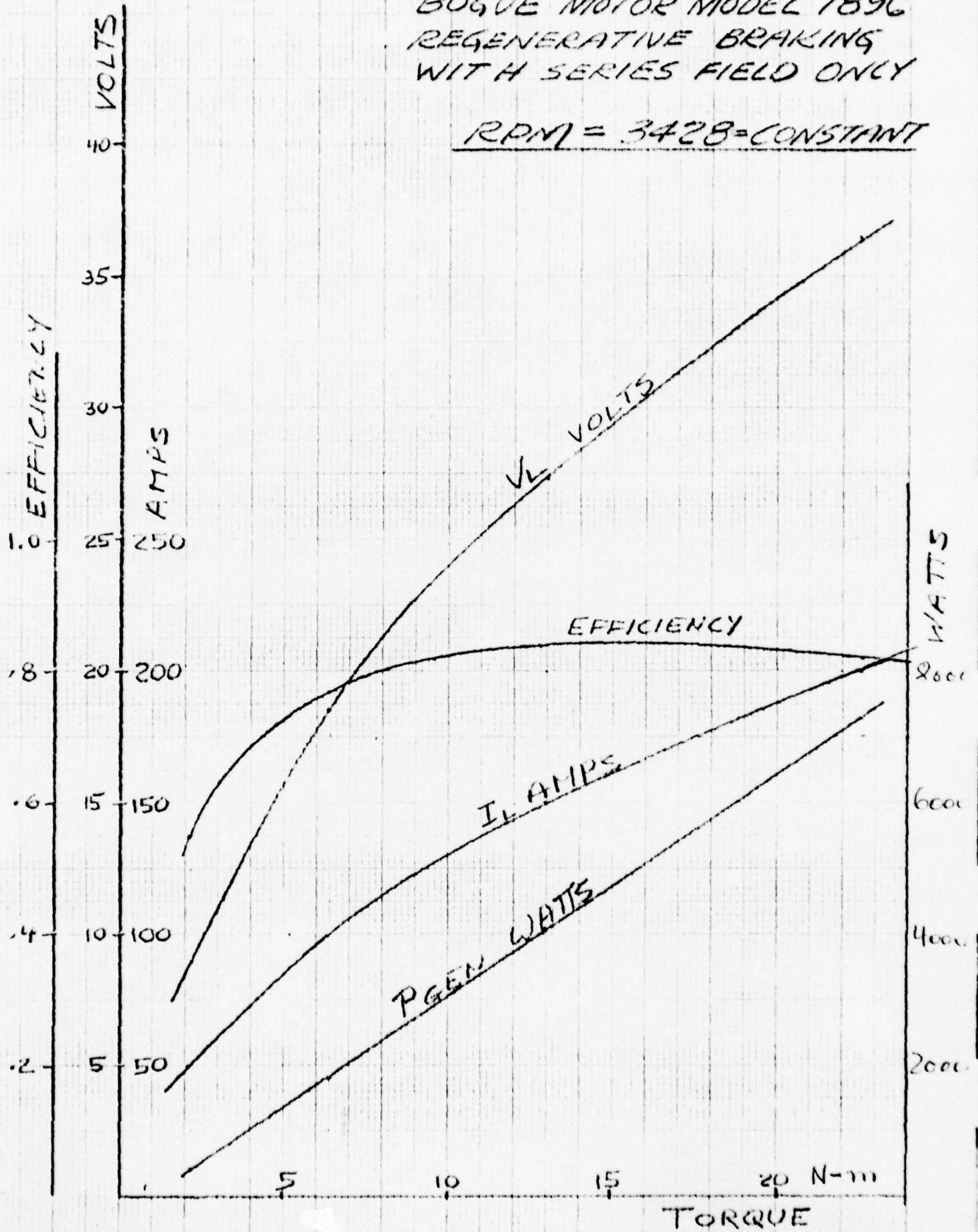


FIG. 10

BOGUE MODEL NO. 7896

VOLTS, AMPS, EFFICIENCY VS. TORQUE

RPM = 3000 = CONSTANT

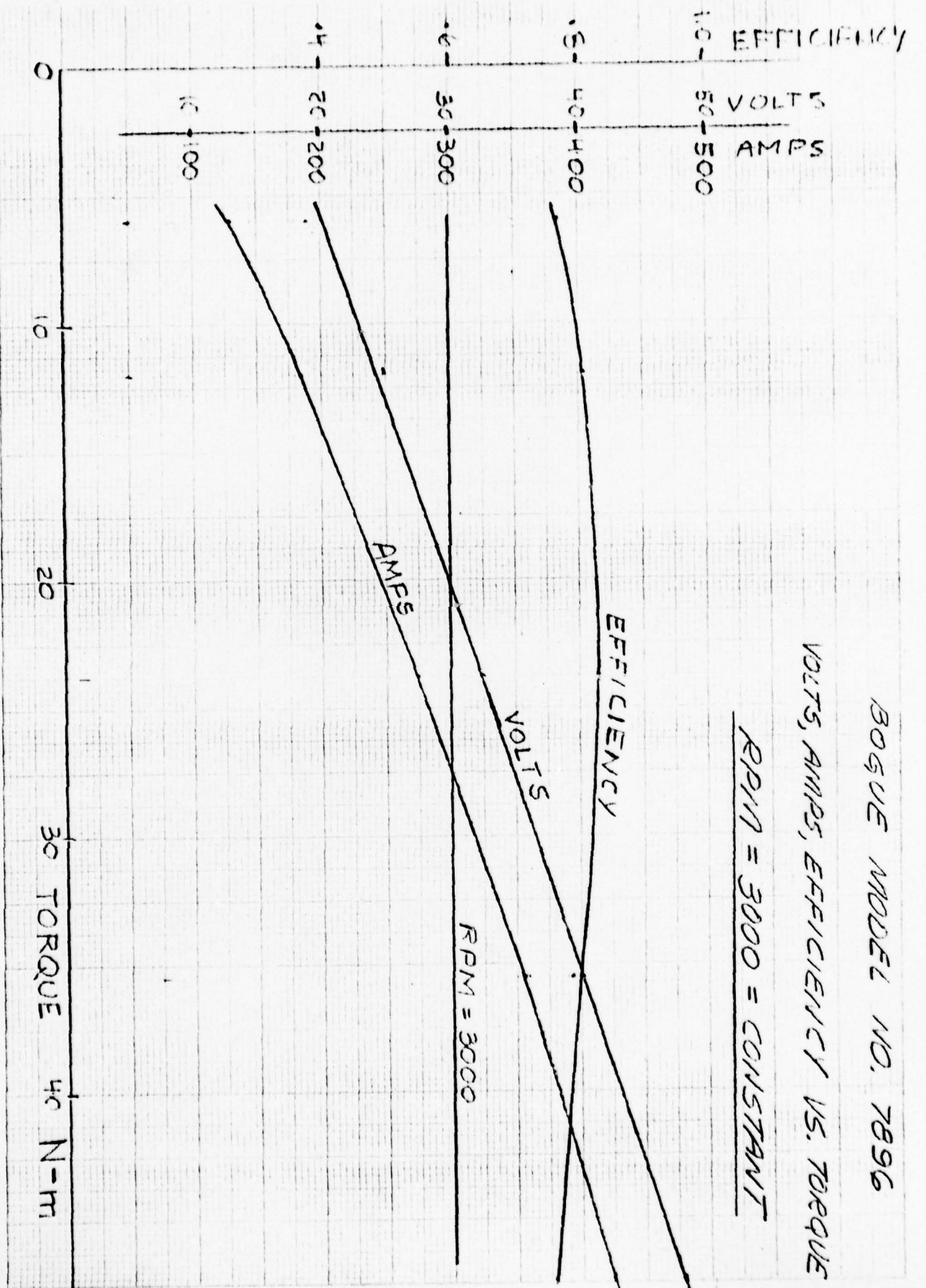


FIG. 11

46 1323

10 X 10 TO 1/2 INCH 7 X 10 LINES
LEOFFEL'S ESSER CO. NEW YORK

BOGUE MODEL NO. 7896

VOLTS, AMPS, EFFICIENCY VS. TORQUE

RPM = 6000 = CONSTANT

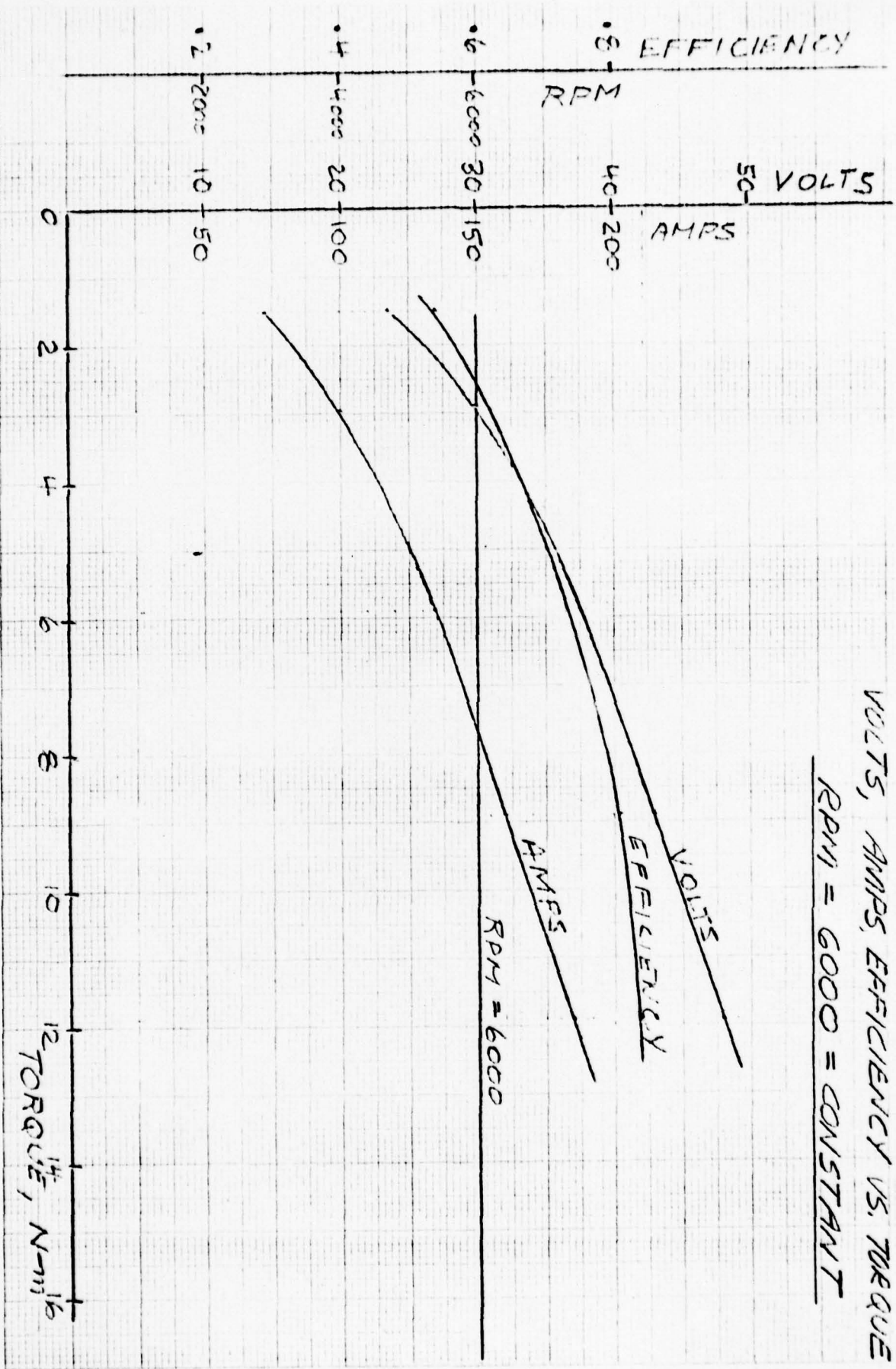
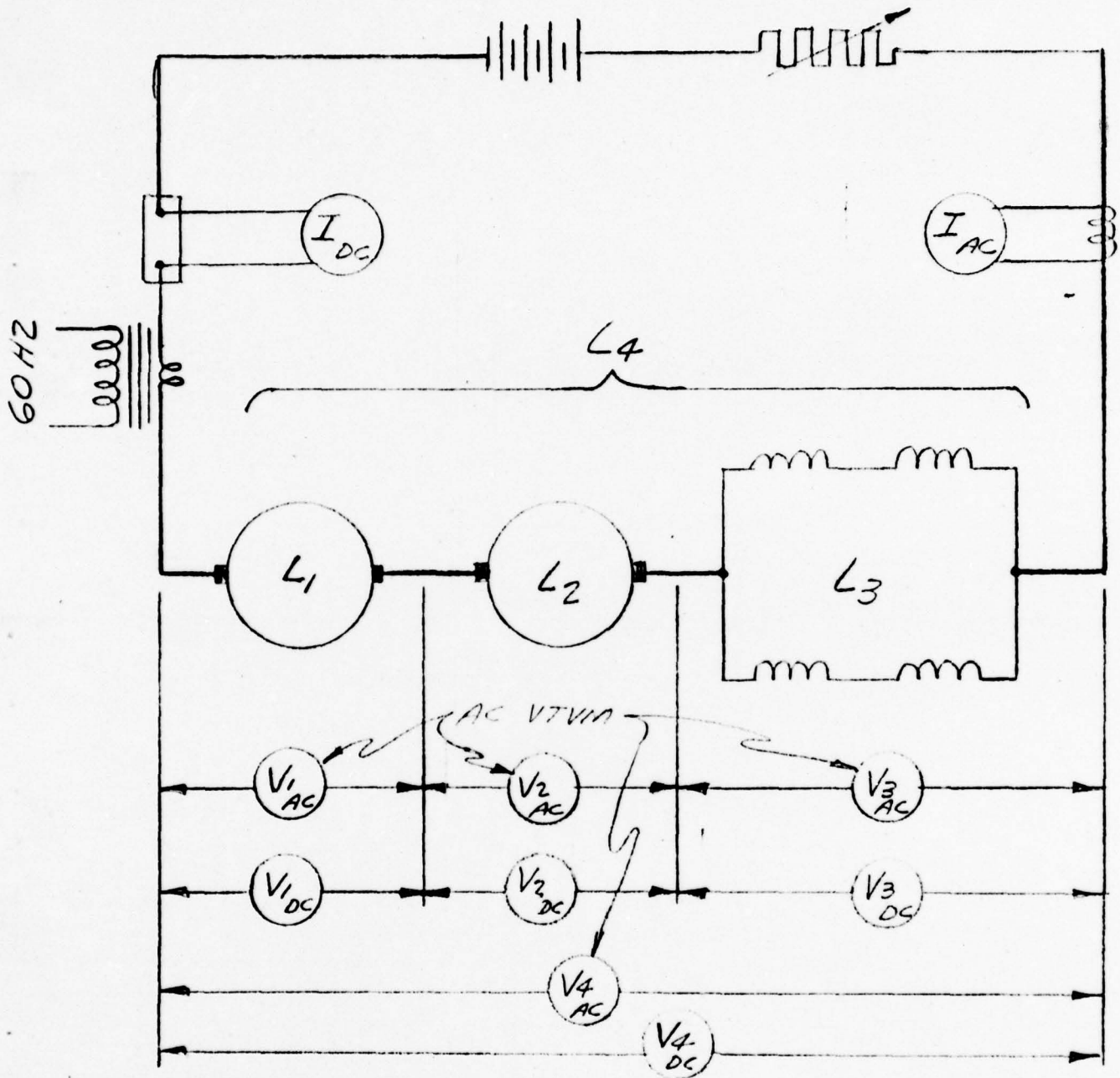


FIG 12

COMPUTATION OF INDUCTANCES



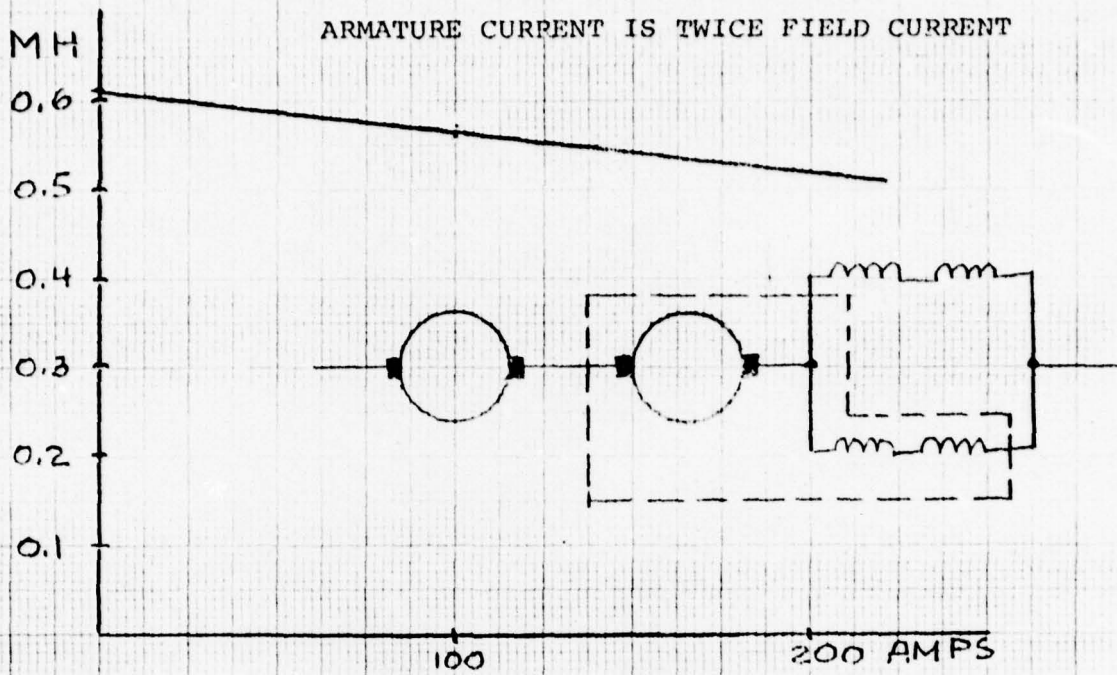
I_{AC}	I_{DC}	V_1		V_2		V_3		V_4		L_1 mH	L_2 mH	L_3 mH	L_4 mH
		AC	DC	AC	DC	AC	DC	AC	DC				
17.5	0	1.15	0	1.15	0	1.5	0	3.8	0	.17	.17	.22	.55
17.5	100	1.05	1.80	1.05	1.80	1.4	1.05	3.5	4.65	.15	.15	.21	.51
17.5	200	1.00	3.10	1.00	3.10	1.3	2.10	3.3	8.30	.145	.145	.19	.48
17.5	400	0.95	5.85	0.95	5.85	1.2	4.20	3.1	15.90	.14	.14	.18	.46

FIG. 13

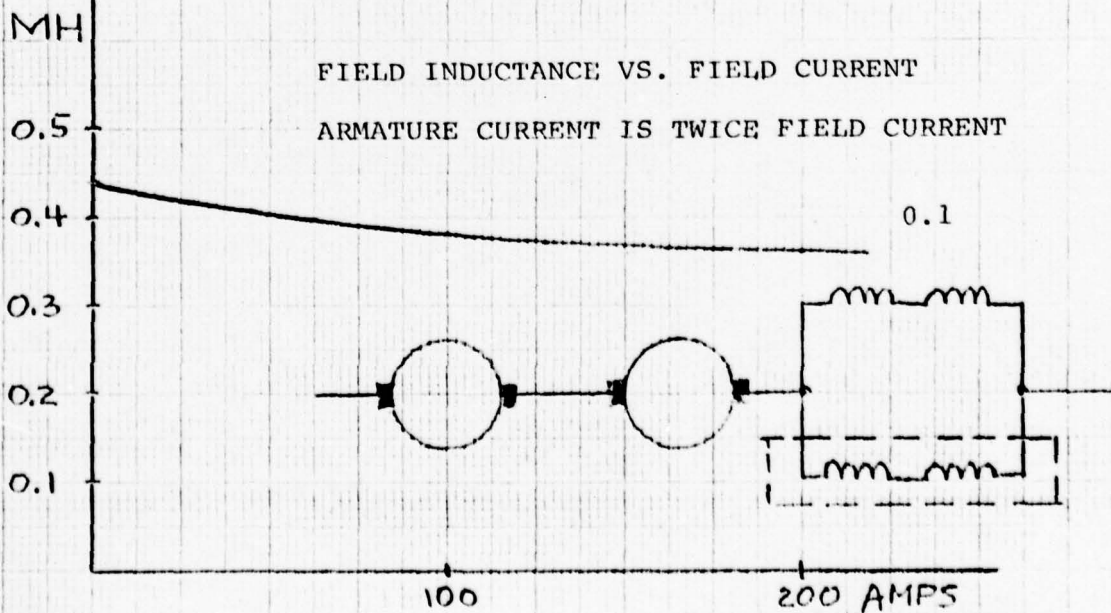
BOGUE MODEL NO. 7896

MOTOR INDUCTANCE VS. FIELD CURRENT

ARMATURE CURRENT IS TWICE FIELD CURRENT



SERIES FIELD CURRENT



SERIES FIELD CURRENT

FIG. 14

46 1323

10 X 10 TO 1/4 INCH
REAFFEL & ESSER CO. MADE IN U.S.A.

BOGUE ELECTRIC MFG. CO.
QUALITY CONTROL
TEST DATA

Contract or Order No. 7896
 Job or Model No. 7896

Serial No. HEAT RUN
 Type of Test

Date 6/6/79

Dept. 15

Page _____ of _____

Description of Equipment: 10 HP, 6000 RPM
 48 V, 183 AMPS.

Spec. 4.8
 Paragraph Temperature Rise
 Air Flow

Applicable specification	D	E	F	G
A QC-7896/I				
B				
C				

V	I in	RPM	Torque N-m	THERMOCOUPLES:					Time
				1 Main Pole	2 Main Pole	3 Inter Pole	4 Brush	5 Ambient	
48	183	6100	11.85	41	42	40	61	25	9:40
48	183	6100	11.86	55	58	49	63	26	9:50
48	183	6100	11.86	58	62	52	65	26	10:00
48	183	6100	11.86	59	63	52	68	26	10:15
48	183	6100	11.86	60	63	54	67	27	10:25
48	183	6100	11.86	61	63	54	67	27	10:35
48	183	6100	11.86	61	63	54	67	27	10:45
48	183	6100	11.86	61	63	54	67	27	10:55

AIR FLOW: 200 CFM
 STATIC PRESSURE DROP = 1 inch H₂O

Tester:

Government Inspector:

BOGUE MODEL NO. 7896
MAXIMUM HP VS. TIME
AT 200 CFM AIR FLOW

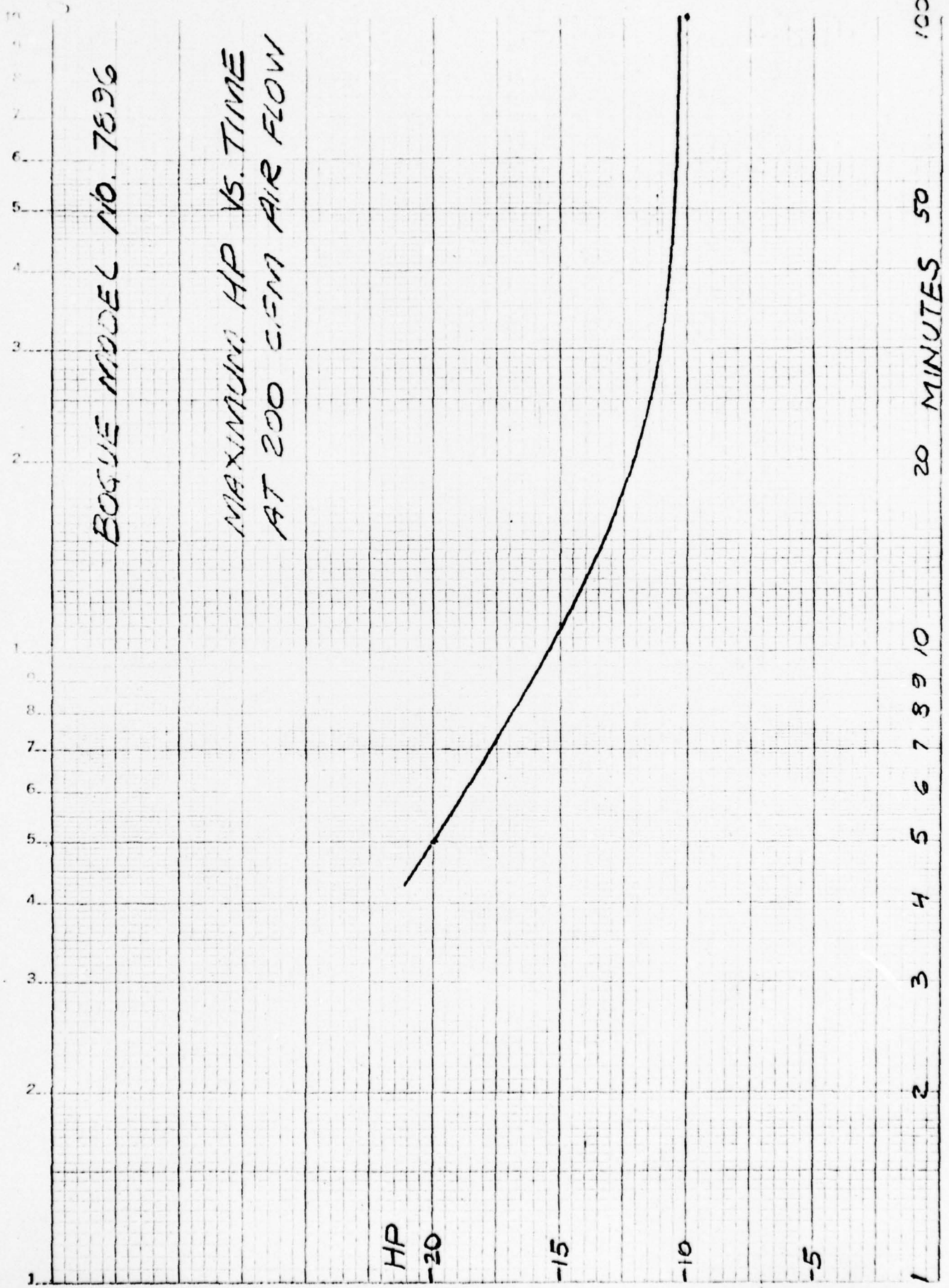


FIG. 16

1

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REVISIONS						
NO.	DATE	DESCRIPTION	BY	DATE	INITIALS	
B		CHANGED POSITION OF AIR INLET. SHOWED ALL LEADS	PLV	9-9-78		PLV
C		DELETED COIL SUPPORT FLANGE.	A.S.	11-1-78		AS
D	39762	ADDED METRIC EQUIVALENTS	RJ	5/2/79		RJ

2

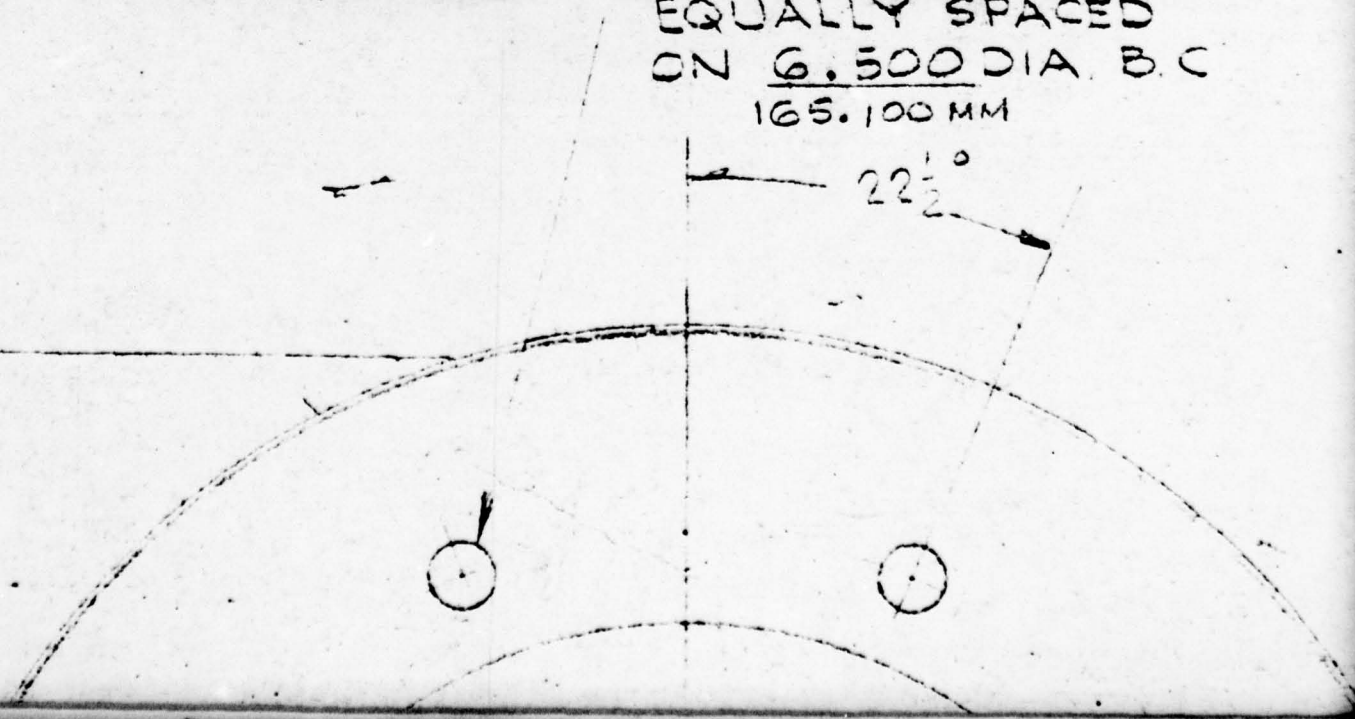
7

3

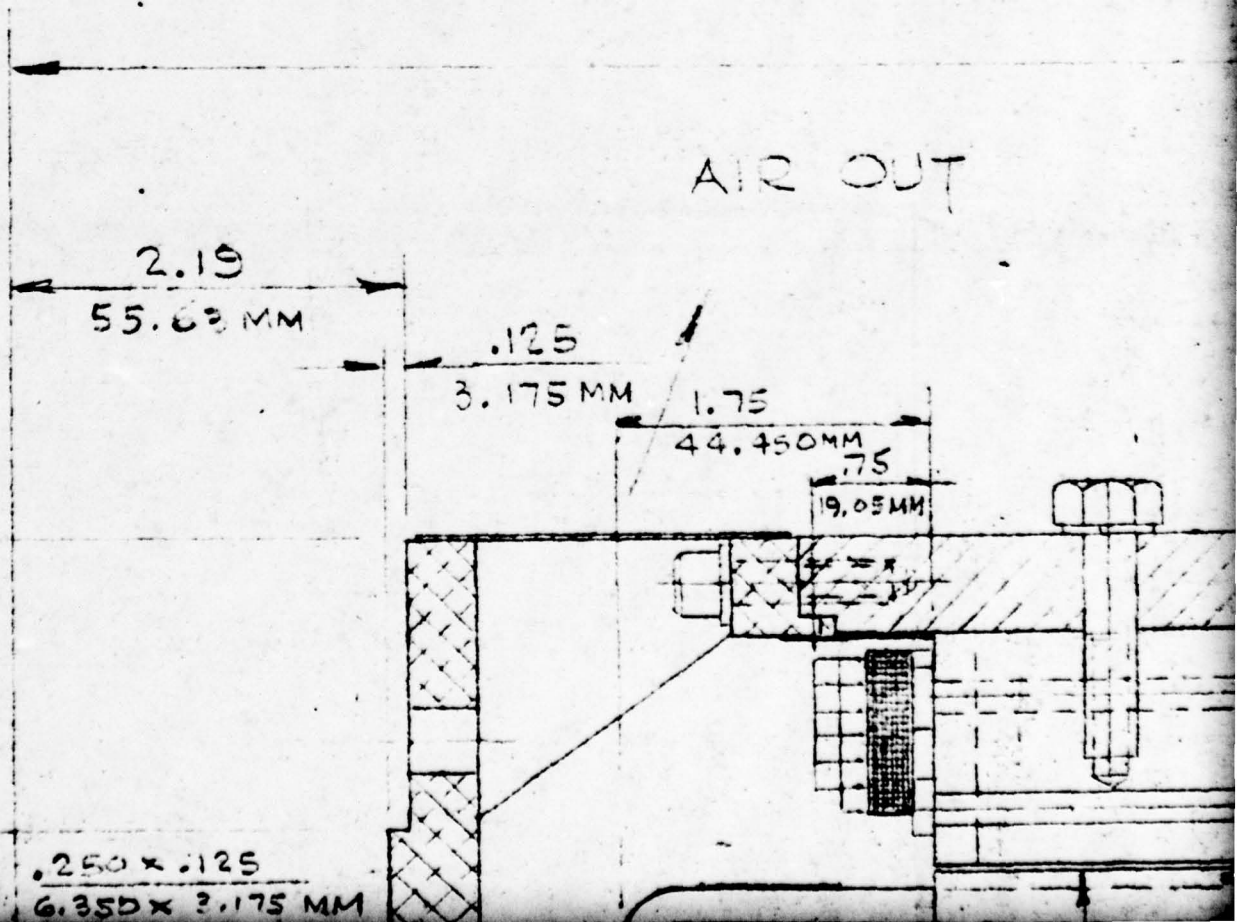
.375
9.525MM

DIA. 8 HOLES
EQUALLY SPACED
ON 6.500 DIA. B.C
165.100MM

22 $\frac{1}{2}$ ^o

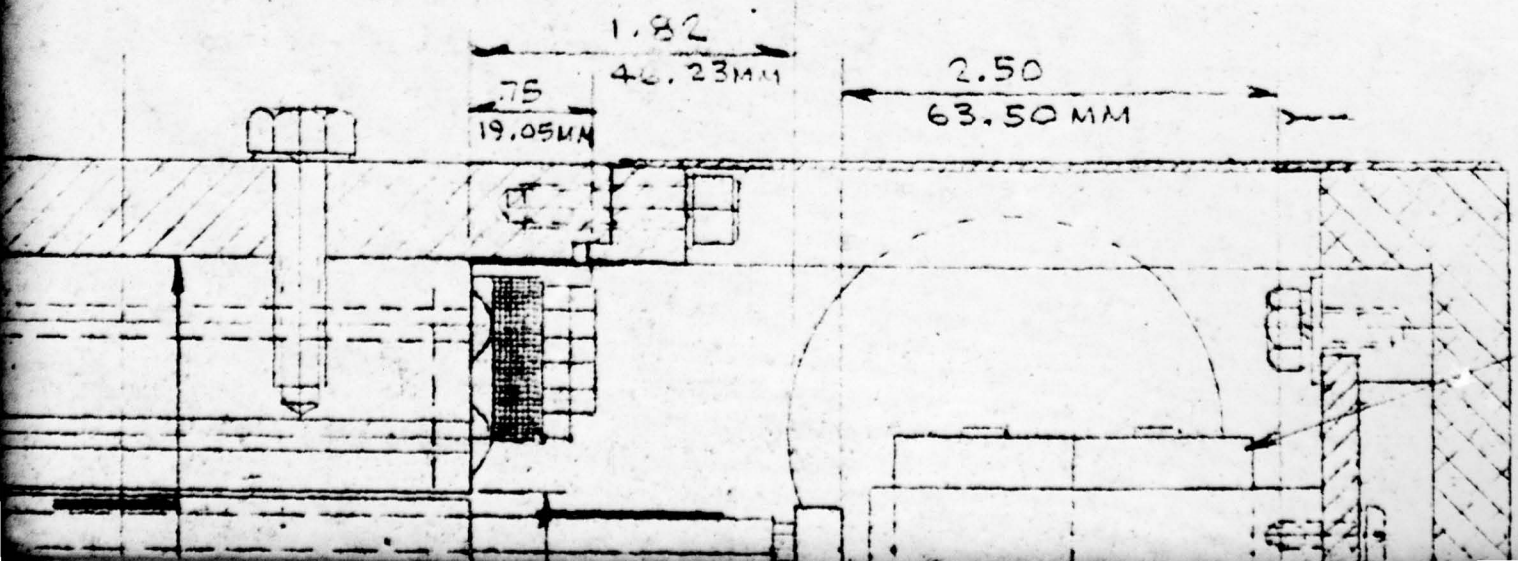


4



5

15.63
397.00 MM



6

BRUSH SIZE

$\frac{.875}{22.225\text{MM}}$ LG x $\frac{1.000}{25.400\text{MM}}$ W x $\frac{.375}{9.525\text{MM}}$ TH.

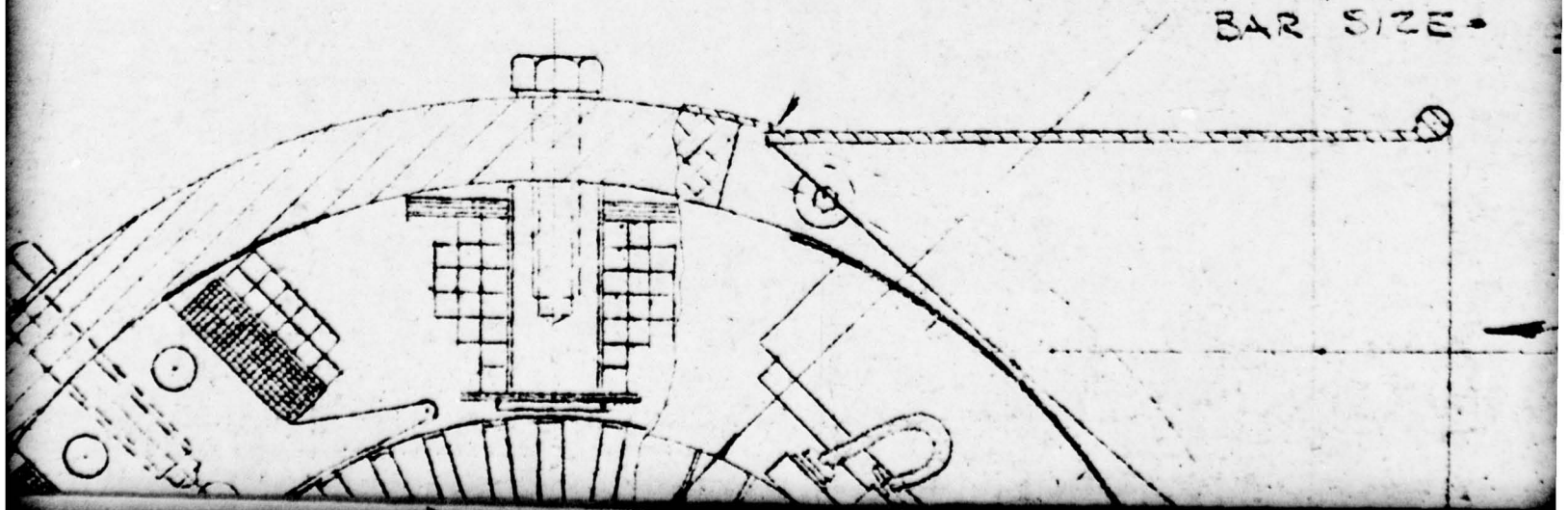
RADIAL BALL
METRIC BALL BEARING



7

THIS END COVER
TUBE CAN BE RO
STEPS OF 90°

45 BAR COMM
BAR SIZE =

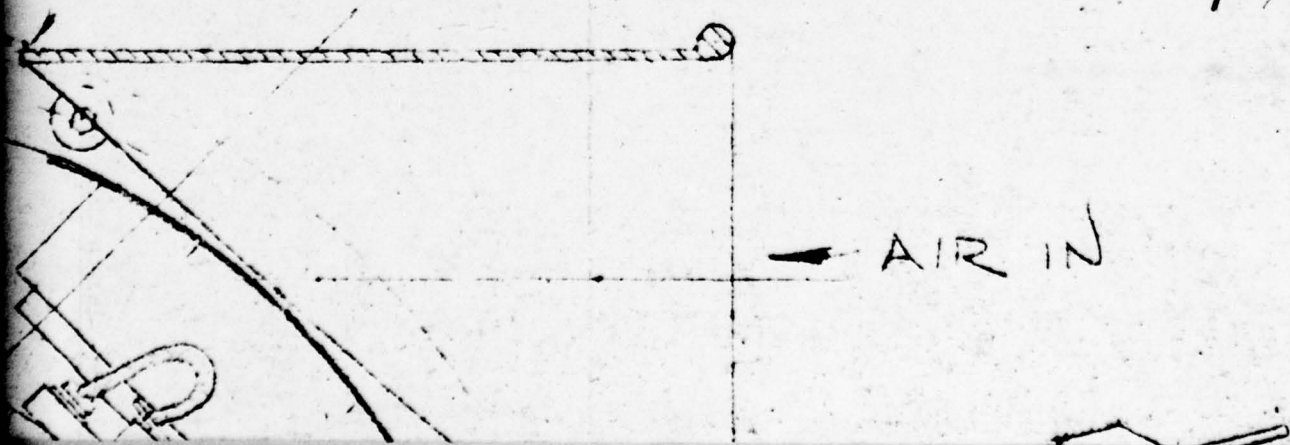


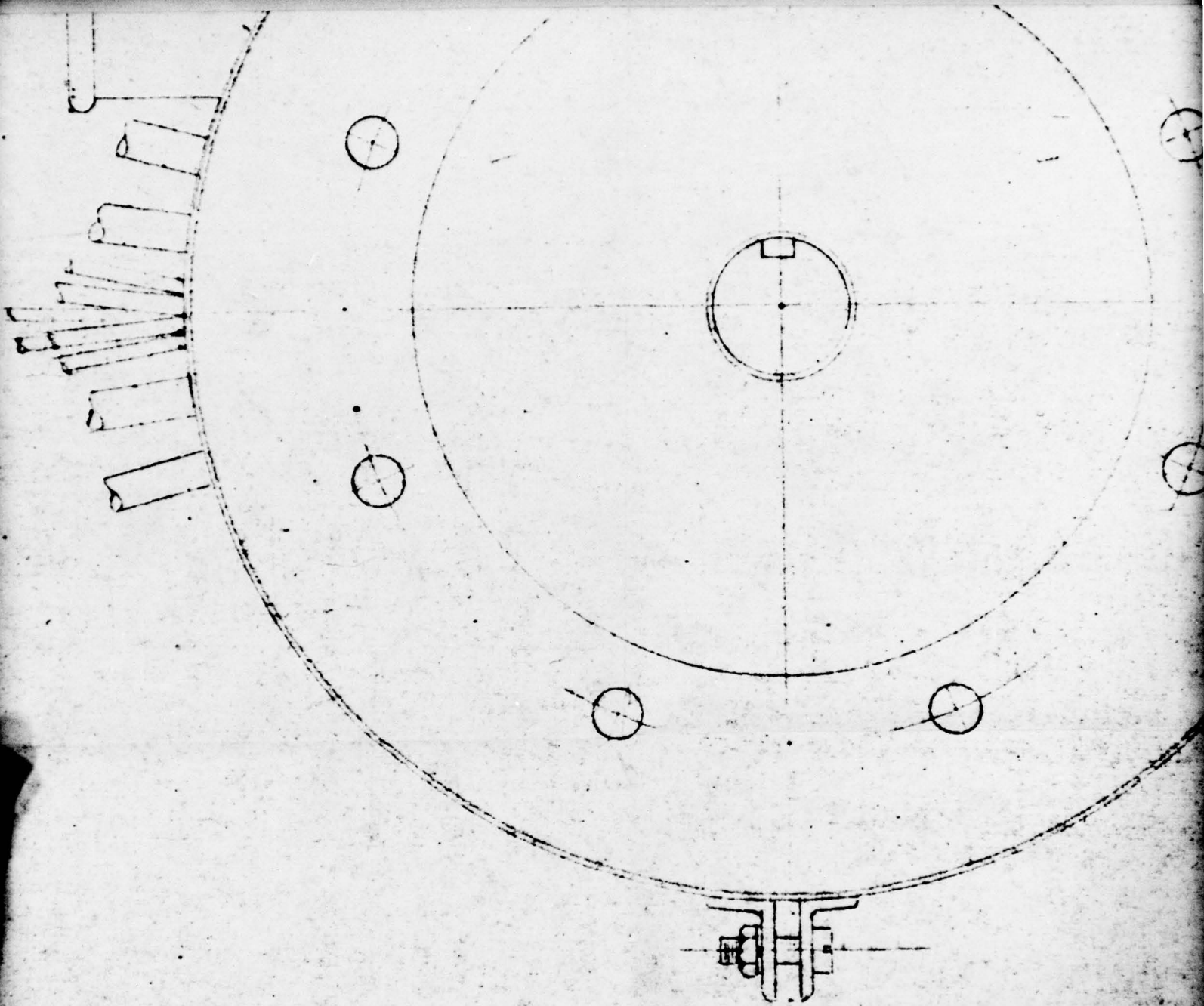
7

THIS END COVER WITH AIR INLET
TUBE CAN BE ROTATED IN
STEPS OF 90°

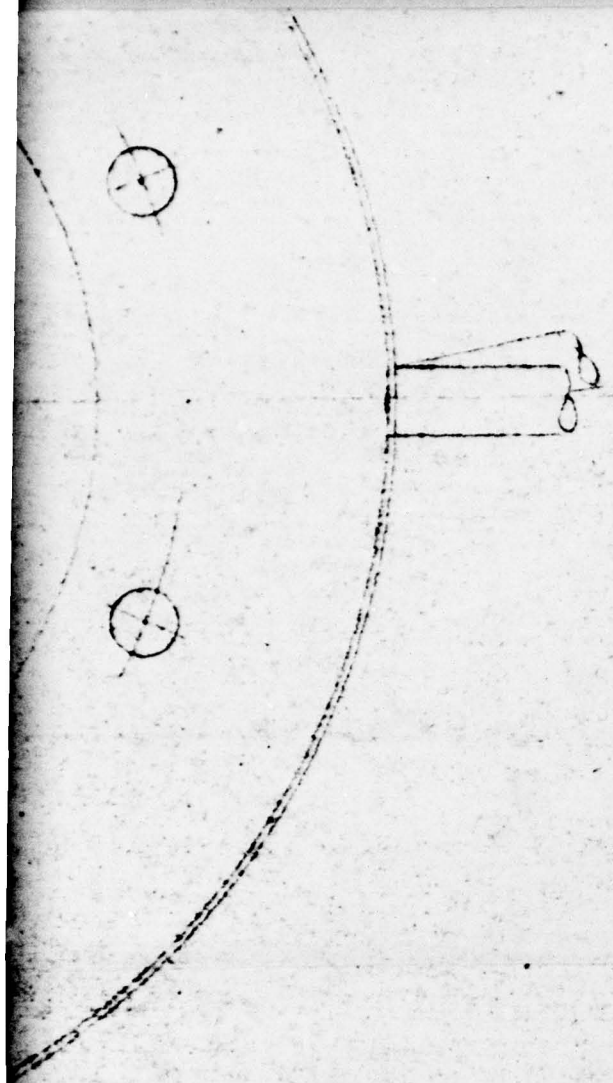
45 BAR COMMUTATOR
BAR SIZE = $\frac{.279}{7.087 \text{ MM}}$

7-A





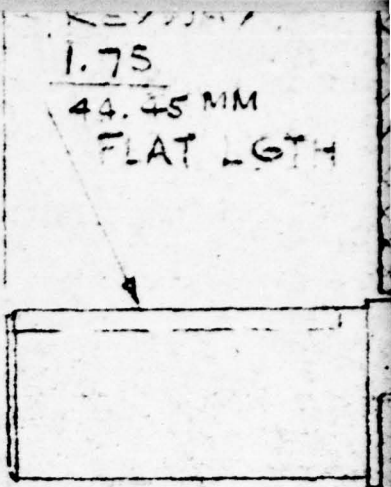
8



8.75 DIA.
222.25 MM

5.500 ± 0.002 DIA
139.700 ± 0.050 MM

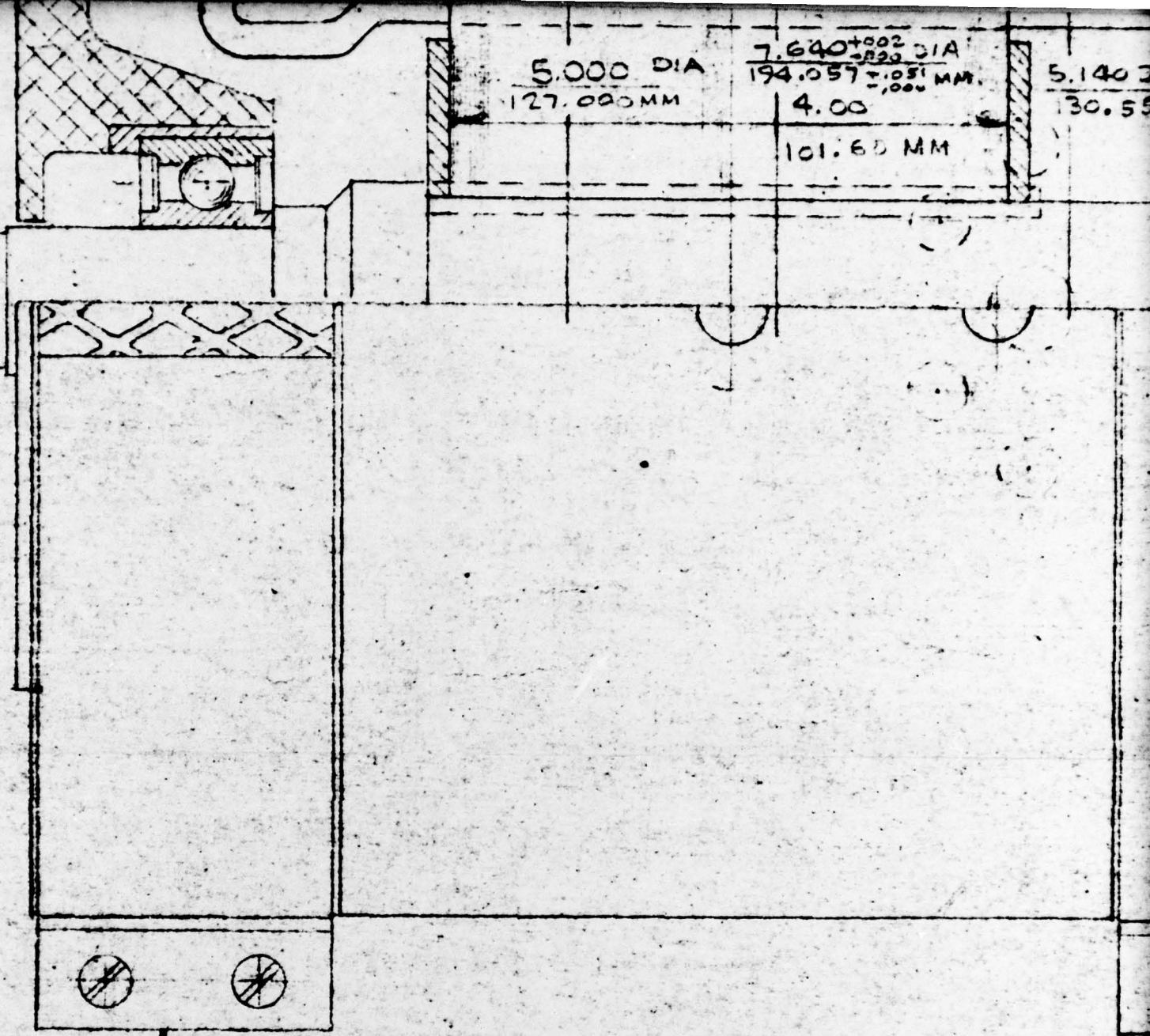
1.000 ± 0.001
25.400 ± 0.025 MM



KEYWAY
1.75
44.45 MM
FLAT LGTH

9

MM
L6TH



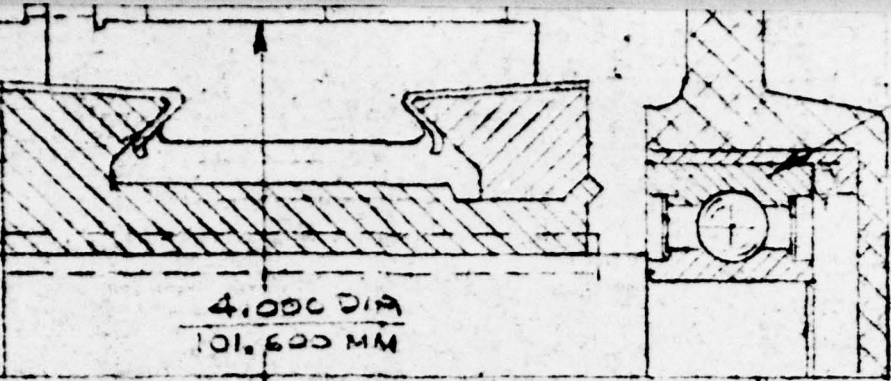
10

THIS END COVER
WITH AIR OUTLET
CAN BE ROTATED
TO ANY POSITION.

TWO BUNA SE
S 3506. 22

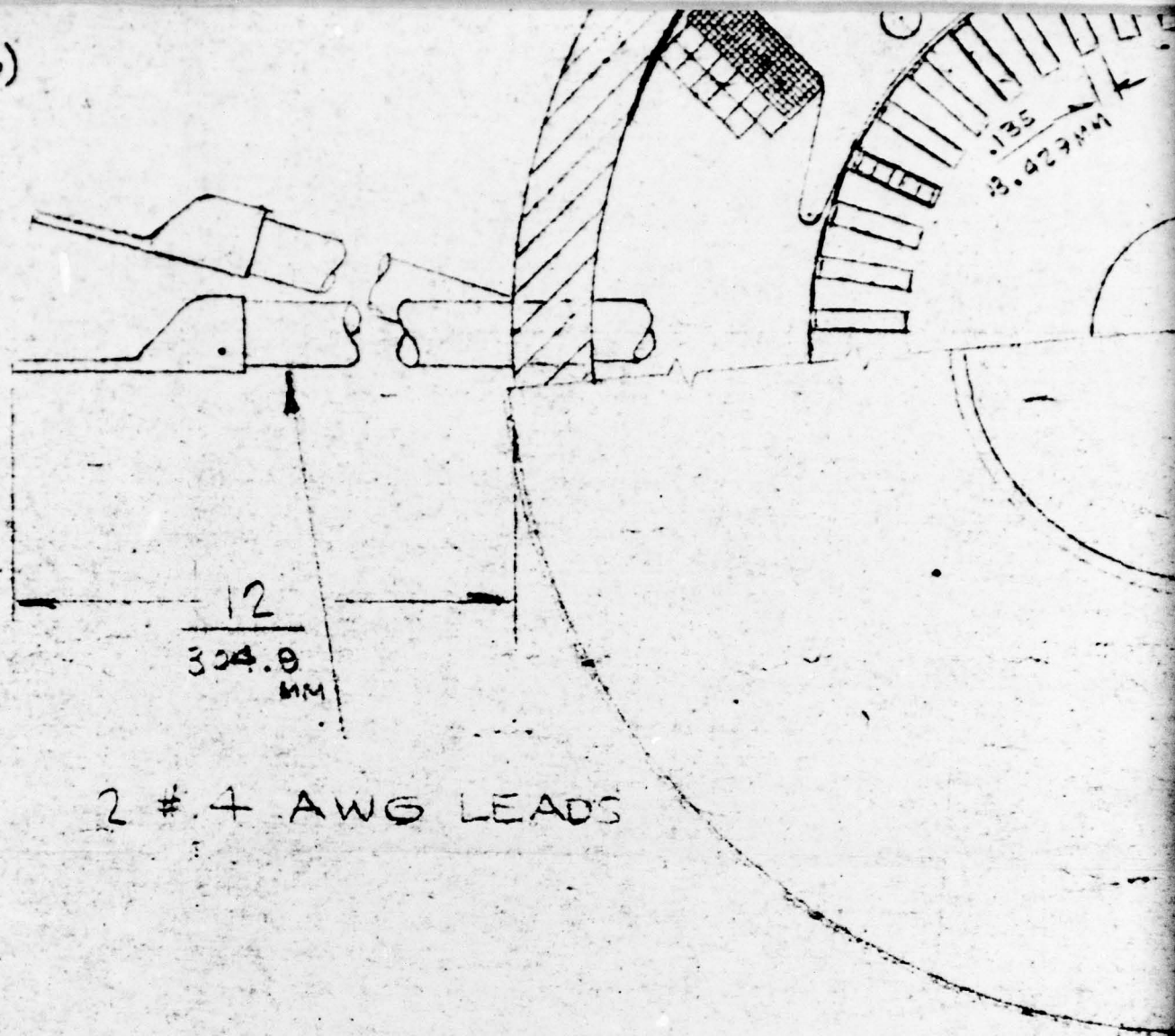
0 DIA
557 MM

4.000 DIA
101.600 MM



//

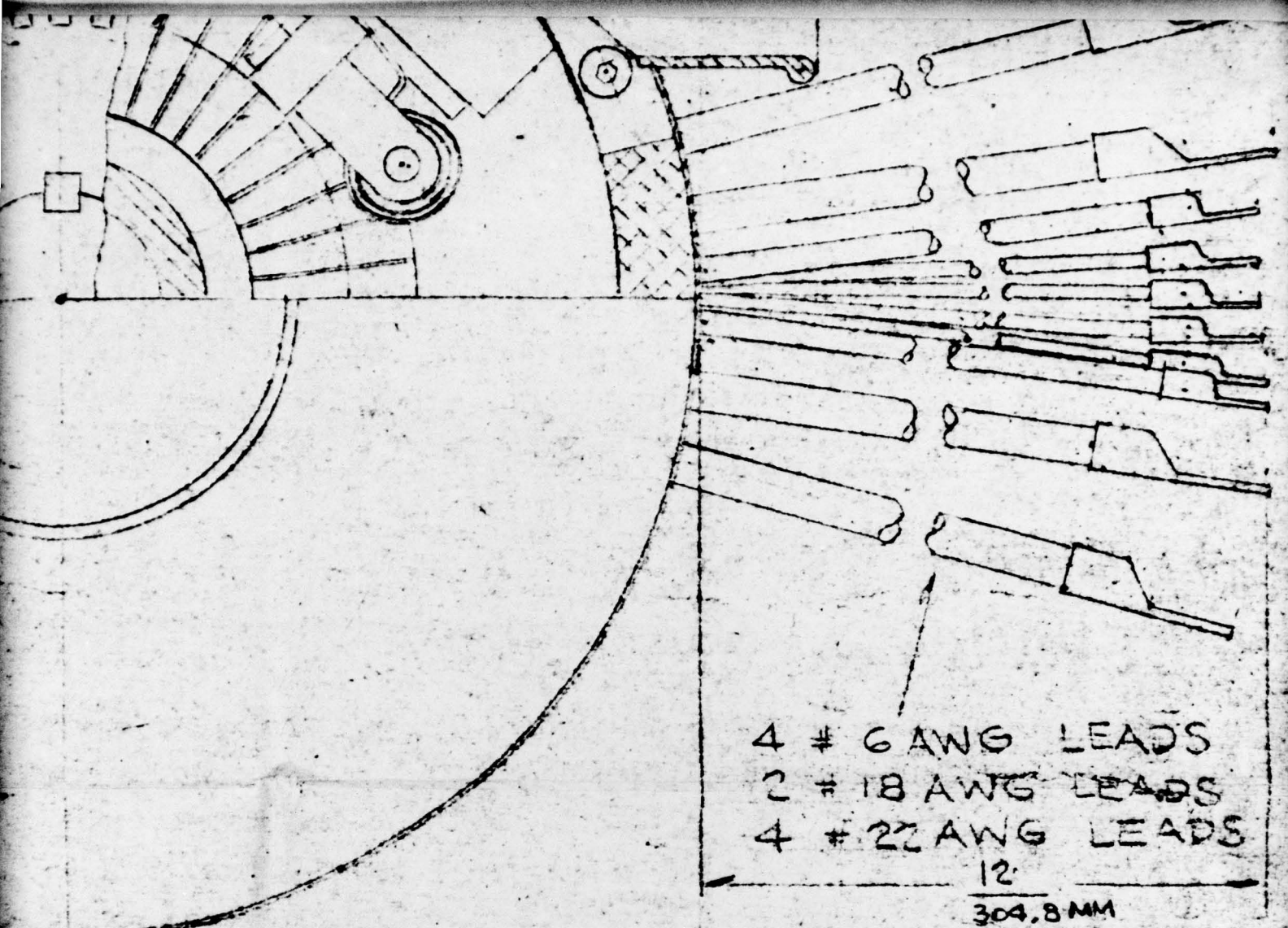
INA SEALS
6.2RS(FAG)



2 #.4 AWG LEADS

12

ALL DIMENSIONS ABOVE LINE
ARE IN INCHES & BELOW LINE
IN MILLIMETERS.



2 THERMAL SWITCHES ON INTERPOLES TO
 CLOSE AT $\frac{200^{\circ}\text{F}}{93.3^{\circ}\text{C}}$ AND $\frac{350^{\circ}\text{F}}{192.2^{\circ}\text{C}}$

13 RATING

10 HP 6000 RPM 48VDC CONTINUOUS
 20 HP 3000 RPM 48VDC INTERMITTENT

WEIGHT CALCULATED = 90 LBS
 40.823 KG

DESIGNED BY	7896	
CHECKED BY	BY	DATE
	5/1	7/4/70
DATE		

BOGUE ELECTRIC MFG. CO.
 PATERSON, NEW JERSEY, U.S.A.

LAYOUT

4 # 6 AWG LEADS
 2 # 18 AWG LEADS
 4 # 22 AWG LEADS

12
 304.8 MM

2 THERMAL SWITCHES ON INTERPOLES TO
 CLOSE AT $\frac{200^{\circ}\text{F}}{93.3^{\circ}\text{C}}$ AND $\frac{350^{\circ}\text{F}}{192.2^{\circ}\text{C}}$

13 RATING

10 HP 6000 RPM 48VDC CONTINUOUS
 20 HP 3000 RPM 48VDC INTERMITTENT

WEIGHT CALCULATED = 90 LBS
 40.823 KG

FIRST USED ON 7896		BOGUE ELECTRIC MFG. CO. PATERSON, NEW JERSEY, U.S.A.		
BY	DATE	LAYOUT D.C. MOTOR		
DESIGN	1/4/79			
DRAWN				
CHECKED				
ENGINEER	1/4/79			
APPROVED		SIZE	CODE IDENT NO.	DRAWING NO.
		07860		

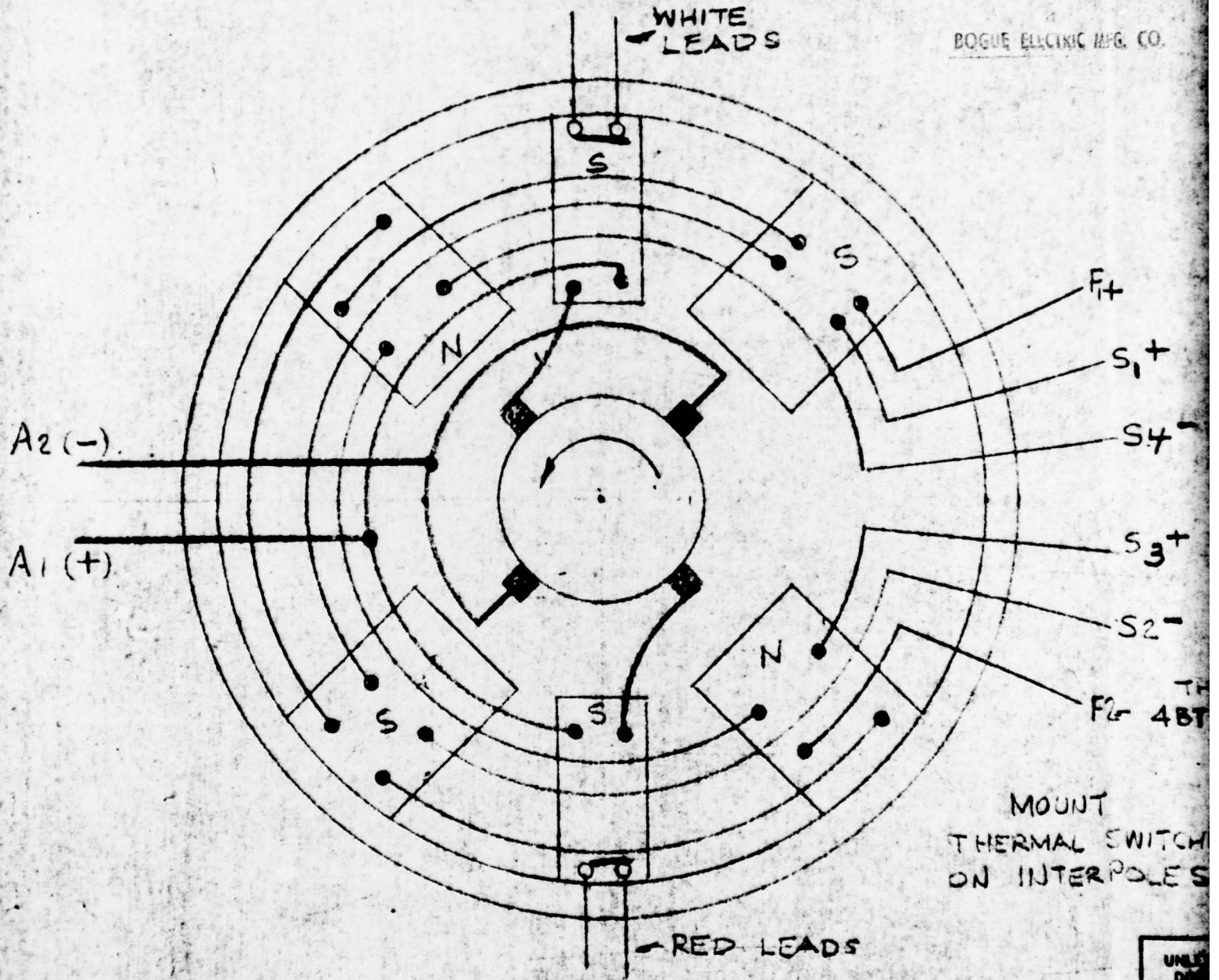
14

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DATE OF ISSUE

SEP 28 1979

BOGUE ELECTRIC MFG. CO.



ROTATION VIEWED FROM COMMUTATOR END

UNLESS OTHERWISE SPECIFIED
 TOLERANCES ARE AS SHOWN
 2 PLACE
 3 PLACE
 4 TO 6
 MATERIALS
 FINISH

2

8 43079

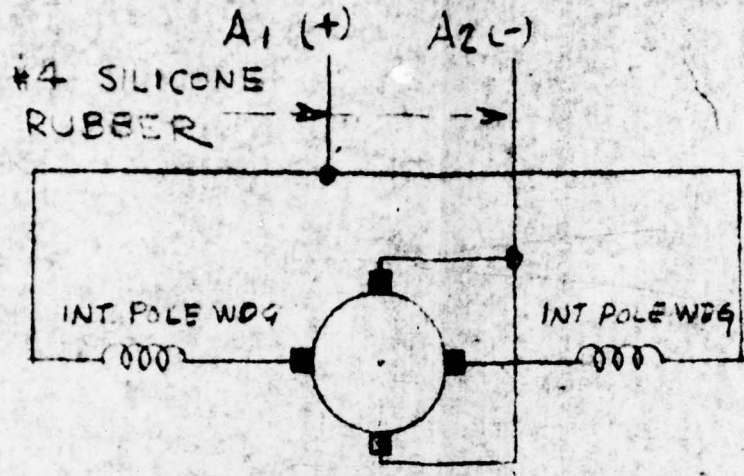
1

REVISIONS							
D.C.N.	ZONE	LTR	DESCRIPTION	DRFT	DATE	ENG	APPRVD
39658		A	ADDED THERMAL SWITCH TO DIAGRAM INT. POLE WDG. NAG COMM FIELD	Fw	7/20/79	SG	[Signature]
39720		B	WHITE LEADS WERE YELLOW LEADS: A2A59 A1 T44) & A2 T1(-)	Fw	8/4/79	SG	[Signature]

OF ISSUE

28 1979

BOGUE MFG. CO.



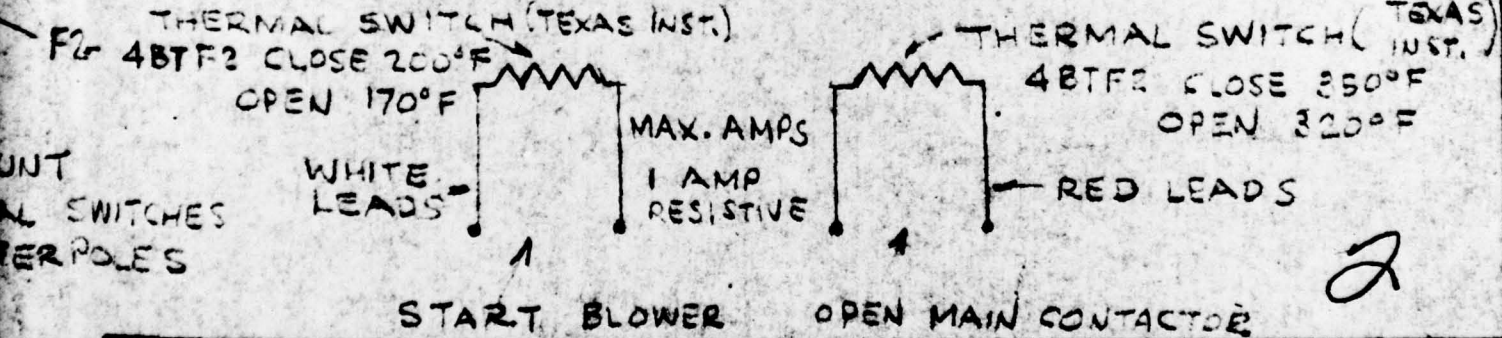
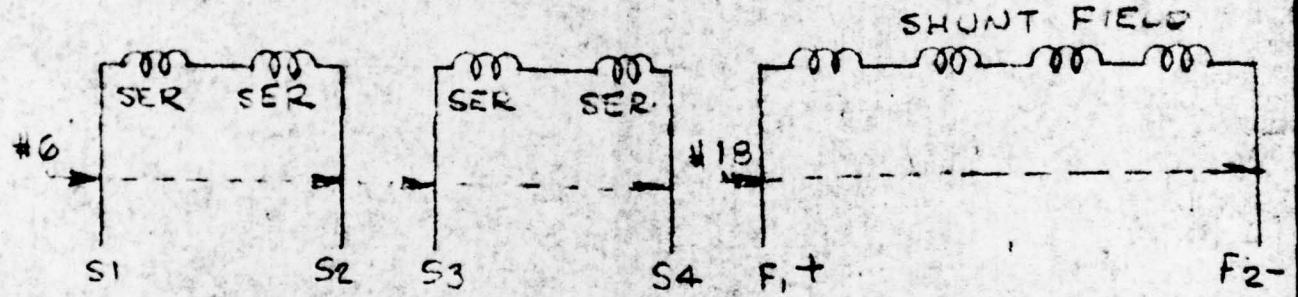
F1+

S1+

S4-

S3+

S2-



UNT

NAL SWITCHES

TER POLES

START BLOWER OPEN MAIN CONTACTOR

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONS ± ANGLES ± 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± 6 TO 6 HOLES ± MATERIAL FINISH	FIRST USED ON 7896		BOGUE ELECTRIC MFG. CO. PATERSON, NEW JERSEY, U.S.A.		
	DRAWN CHECKED ENGINEER APPROVED	BY Fw	DATE 7/20/79	CONNECTION DIAGRAM	
	ENGINEER S.G.	DATE 7/7/79			
	SIZE B	CODE IDENT NO. 07880	DRAWING NO. B 43079	REV B	
SCALE	WT.	SHEET			

2

1

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D

$.250 \times .141$ KEYWAY
 6.350×3.572 MM

$.135$
 3.429 MM

$.216$
 5.486 MM

45 SLOTS EQUALLY SPACED ($8^{\circ}-00'$)

C

$.130$
 3.302 MM
 1.900 R
 48.260 MM

$5.021 \pm .001$ DIA
 $127.53 \pm .025$ MM

B

$1.502 \pm .003$ DIA
 $38.151 \pm .076$ MM

A

UNE
 DR
 TOL
 ANGL
 2 PL
 3 PL
 C TO
 MATE

FIN

REVISIONS						
D.C.N.	ZONE	LTR	DESCRIPTION	DRFT	DATE	ENG APPRVD
		A	45 SLOTS @ 8°.00' WAS 49 SLOTS @ 7°.20' 49.8' - 1.9002 WAS 1.9902 .135 WAS .125 - .210 WAS .197 .130 WAS .131 - SLOT DIE WAS A 5020	FW	9/12/79	STR. JCS
39702		B	ADDED METRIC DIMENSIONS	JW	9/2/79	JCS

8° EQUALLY
(8°-00')

BLANKING DIE - A 2849 (206)
SLOT DIE A 50655 (T-7692)

MATERIAL

PART 1 - #29 SA M-19-05 STEEL ^{.014} .250MM

DATE OF ISSUE
SEP 28 1979
BOGUE ELECTRIC MFG. CO

INCHES
MILLIMETERS

2

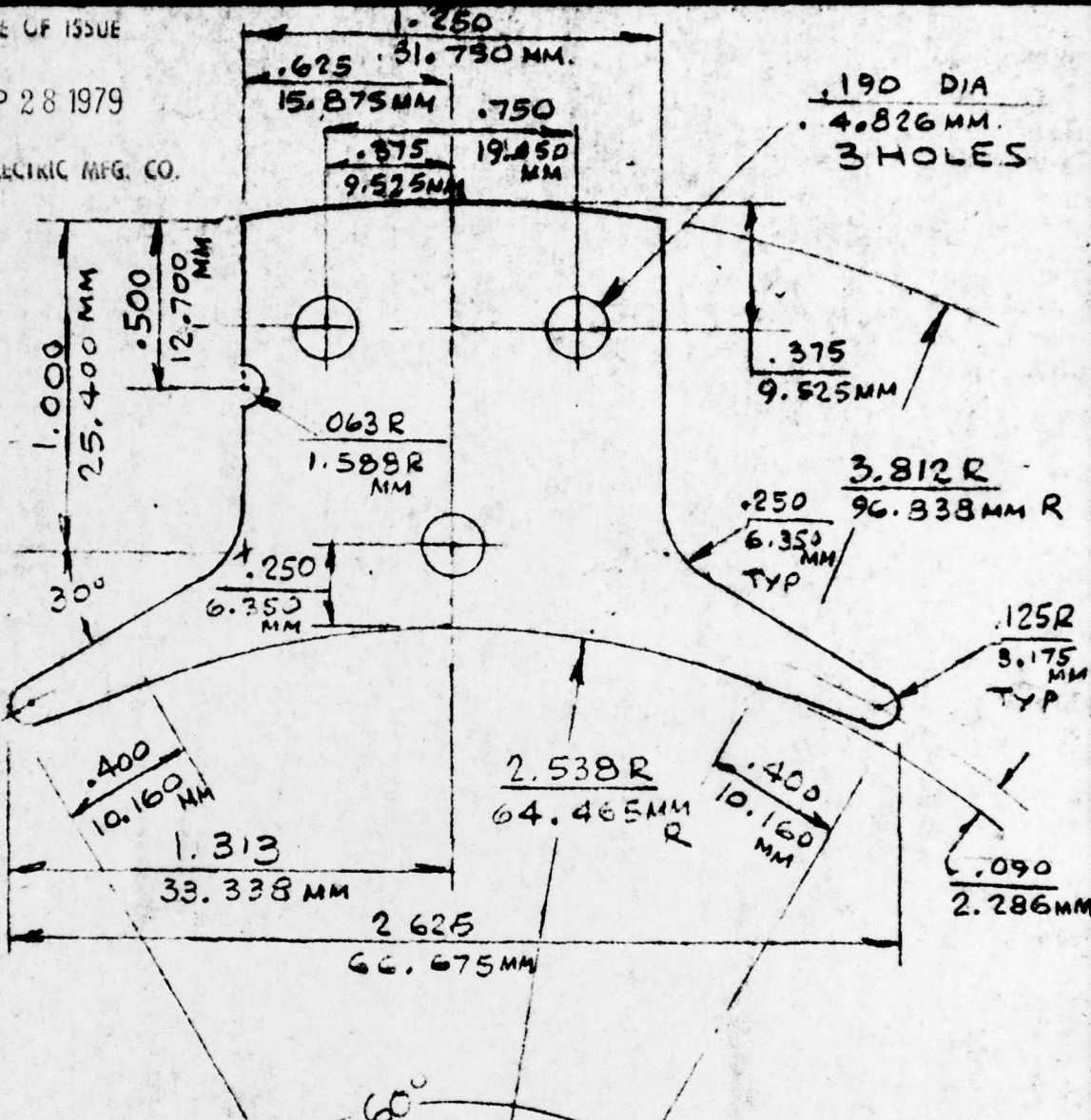
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONS ± ANGLES ± 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± TO HOLES ± MATERIAL FINISH	FIRST USED ON 7896		BOGUE ELECTRIC MFG. CO. PATERSON, NEW JERSEY, U.S.A.	
	DRAWN	BY JW	DATE	7/27/78
	CHECKED			
	ENGINEER	JCS	DATE	11/27/78
	APPROVED			
	SIZE	CODE IDENT NO.	DRAWING NO.	REV.
	B	07860	B 43080	B
	SCALE	WT.	SHEET	

REV. A	REVISION
A-2300	DATE
CHANGE NOTICE	NO.
	NO.
	DATE
	BY
	DATE

DATE OF ISSUE

SEP 28 1979

BOGUE ELECTRIC MFG. CO.



. MATERIAL
 PT.1 #26 GA C.R.S .018 / .457 MM
 PT.2 #29 GA M19 .014 / .356 MM

DIE NO. 154

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MILLIMETERS

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BOGUE ELECTRIC MANUFACTURING CO.
 PATERSON, N.J.

POLE LAMINATION

DR. BY: 9/27/79
 APPROVED: S.G. [Signature]
 SCALE: 2X [Signature] A-2300 A

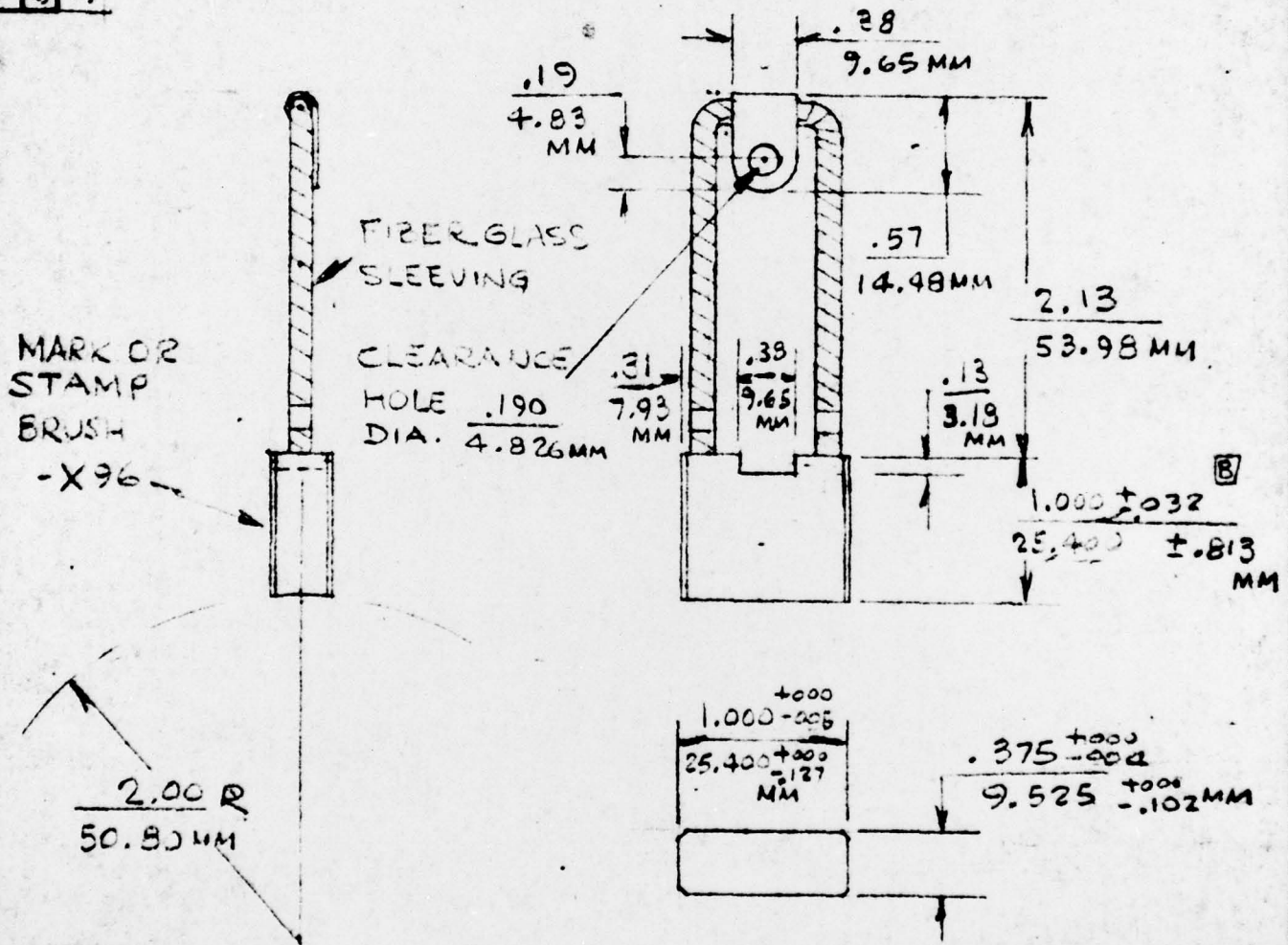
TOLERANCES:
 Unless Otherwise Specified
 Fractions: Decimals:

NO.	NO.	DATE	REVISION
39762	A	9/1/79	NUMBER METAL D. 4.83
39889	B	9/26/79	1.000 WAS .875 S.G.

MATERIAL
A53200-X96

DATE OF ISSUE
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BOGUE ELECTRIC MFG.



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INCHES
MILLIMETERS

BOGUE ELECTRIC MANUFACTURING CO.

PATERSON, N.J.

BRUSH

DR. BY: *JW 9/27/79*

APPROVED: *S.G. 9/27/79*

SCALE: *1/4" = 1"*

A-54305

RB
B

TOLERANCES:
Unless Otherwise Specified
Fractions \pm Decimals \pm

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