



Report 2379

DESIGN AND INTEGRATION OF AN ELECTRIC TRANSMISSION

IN A 300-hp MARINE CORPS AMPHIBIOUS VEHICLE

by
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and
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| A design for a d.c. electric drive for components is proposed. The proposed electric trive for components were made to make this estimated nents such as field supply, cooling system, by and a miscellaneous category adds another 0 (con | the M113A2 based ctric drive has a speci weight as realistic as braking resistor, and o | fic weight of about 9 lb/hp. s possible; auxiliary compo- |

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SUMMARY

A design for an electric drive for the M113A2 based on available state-of-the-art components is proposed. The proposed electric drive has a specific weight of about 9 lb/hp. Efforts were made to make this estimated weight as realistic as possible; auxiliary components such as field supply, cooling system, braking resistor, and controls account for 1 lb/hp and miscellaneous items add another 0.44 lb/hp.

As proposed, the vehicle design for the M113A2 meets the standard military requirements and is capable of 40 mi/h and a maximum sprocket torque of 17,000 ft·lb. It has no separate water propulsion system; however, a water propulsion system powered by the alternator can be added without disturbing the land propulsion system.

The drive train consists of a Detroit Diesel 6V-53T engine, a Westinghouse 500-kVA alternator, an air-cooled rectifier, and, on each side, a GE 90-hp d.c. drive motor driving the track through a Funk two-speed gearhox which is coupled to the existing final drive. The field excitation for the drive motors is supplied by a Bendix 48-V brushless d.c. generator driven by the vehicle engine.

The layout of the major components is similar to the standard M113. The engine remains in the same place and drives the 500-kVA alternator with a belt. The alternator is mounted in place of the existing transmission. The two drive motors and gearboxes will replace the existing differential.

The operator controls appear to be conventional to the operator. They are accelerator, brake, shift, and steering wheel. However, control is accomplished by the use of a micro-computer. Operator inputs, as well as other inputs from the vehicle, are fed into the computer which then sets the proper engine speed, generator voltage, motor field, etc. The vehicle is capable of regenerative steering and has both electric resistive braking and hydraulic disc brakes,

Specific weight reduction opportunities are identified that could reduce the weight of the proposed system by 1.1 lb/hp. Additional areas of technological development that would be likely to yield further specific weight reduction are discussed.

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PREFACE

The authors appreciate valuable guidance by the following personnel of the Electrical Equipment Division, Electrical Power Laboratory:

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Mr. Anthony J. Smith.

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DESIGN AND INTEGRATION OF AN ELECTRIC TRANSMISSION IN A 300-HORSEPOWER MARINE CORPS AMPHIBIOUS VEHICLE

1. INTRODUCTION

- 1. Background. This report summarizes a MERADCOM preliminary design of an electric-drive demonstrator using an M113A2 as a surrogate for a new Marine Corps Amphibian. The work was funded by the Marine Corps Programs Office at the David W. Taylor Naval Ship Research and Development Center as a part of their exploration of alternative drive trains for future amphibious vehicles.
- 2. Scope. It is worthwhile to discuss the scope of this effort and its relation to an earlier competitive solicitation for the development of an electric-drive train. Our effort was relatively compressed in time and limited in the seale of the investigations. Considerable emphasis has been placed on experience, engineering judgment, and even intuition in arriving quickly at a design we believe will meet both the Marine Corps near-term goal for demonstrating the performance of an electric drive and offer significant opportunity for performance growth. At the outset this investigation was limited to a.e. generators and d.c. drive motors. Furthermore, the water propulsion aspects of the competitive statement of work has been eliminated from eonsideration, although such a requirement is fully compatible with the approaches considered.

The work was done during the fall of 1982. Our thrust was to locate state-of-the-art components and to combine them into an electric-drive design that would meet the Marine Corps goals for performance, light weight, and low space claim and that could be built and tested in the immediate future at a moderate cost. The effort was structured this way to emphasize development of electric-drive-train technology as a whole. The initial demonstration would establish the capability of satisfying the Marine Corps near-term goals with an electric drive. It would also provide information needed to guide the electric-drive technology development needed to realize potential improvement in performance.

II. INVESTIGATION

3. Requirements. The initial requirements for the M113 vehicle were as follows:

Gross Vehicle Weight: 28,000 lb.

Tractive Effort to Weight Ratio: 0.89 (25,000-lb tractive effort).

Engine: 6V-53T, 300 blip @ 2800 r/miu.

Rolling Resistance: Assume 1200 lb constant.

Gradahility: 60% longitudinal: 40% transverse.

Maximum Speed: 45 mi/h on land (788 r/min on a 9.6-in, rolling radius).

10 mi/h in water (4500 H) thrust).

Sprocket Torque: 10,000 ft-lb per side.

Steering: Fully variable, fully regenerative.

Braking: 16 ft/s1 dynamic, static for 60% grade.

Acceleration: 0-20 mi/h in 5 s. 0-45 mi/h in 45 s.

Life Cycle: 2400 h at specified duty cycle.

Weight: 3000 th or less.

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Efficiency: 200+ sprocket horsepower available over 90% of the speed torque range.

Environmental: -25° to +124° F: 10% to 100% humidity.

Based on observations made at the GE, Dalton, Massachusetts, Test Track, instructions from the Marine Corps were to decrease sprocket torque and maximum speed to 8500 ft-lb per side and 40 mi/h for purposes of this investigation.

In addition, the water propulsion requirement was eliminated for this investigation.

Four of the most severe operating conditions were added to the requirements as specific cases. These are:

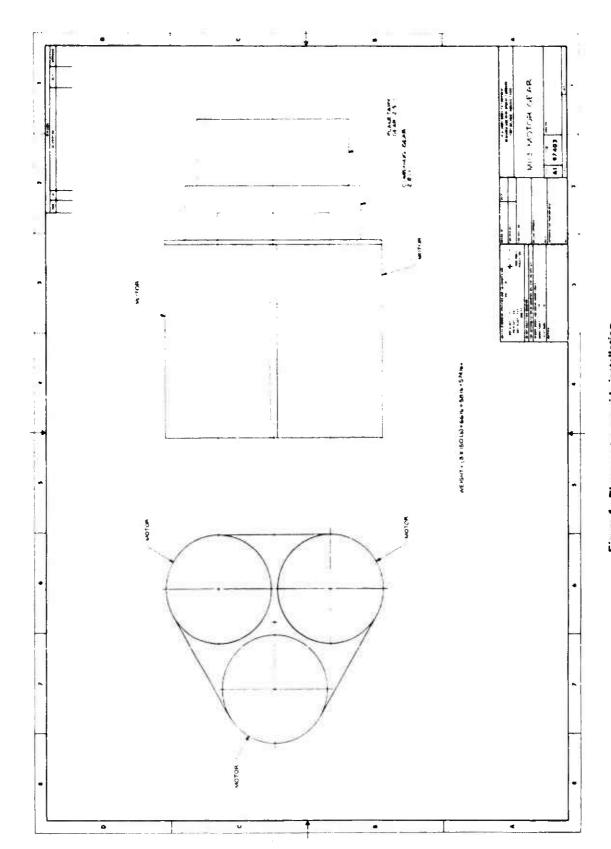
a. Low Speed, Straight Ahead, 60% Grade.

b. High Speed, Straight Ahead, 0% Grade.

c. Low Speed, Clockwise Pivot Turn in Soft Soil, 0% Grade.

d. High Speed, Clockwise Turn, 0% Grade.

- 4. Drives Considered. Two systems will be discussed, one using three motors per side driving through a combining gear and the other using one motor per side with the two motors mounted one above the other in the front center of the vehicle in place of the differential steering unit. The two systems are shown in Figures 1, 2, and 3.
- 5. Description of System. All major components of the electric-drive system and their interconnections are shown in Figure 4. The system consists of a diesel engine driving, through a speed increaser, one alternator. The output of the alternator is rectified in a three-phase full-wave rectifier, and the d.c. output of the rectifier is fed to the motors via a two-position switch such that the motors can be connected to the hraking grid. The broken lines from components to the control box denote control lines for the most important control functions. These functions are engine speed, alternator field current, motor field currents, gear shift, and dynamic hraking. All control power is supplied by the battery and battery charger, and motor field power is supplied by a small generator which is belt-driven from the engine.



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Figure 1. Three-motor-per-side installation.

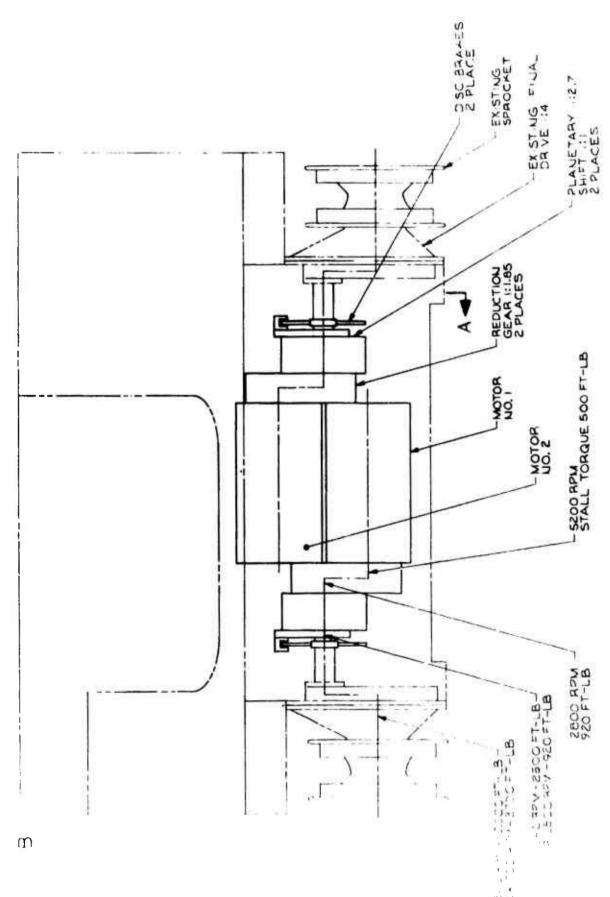
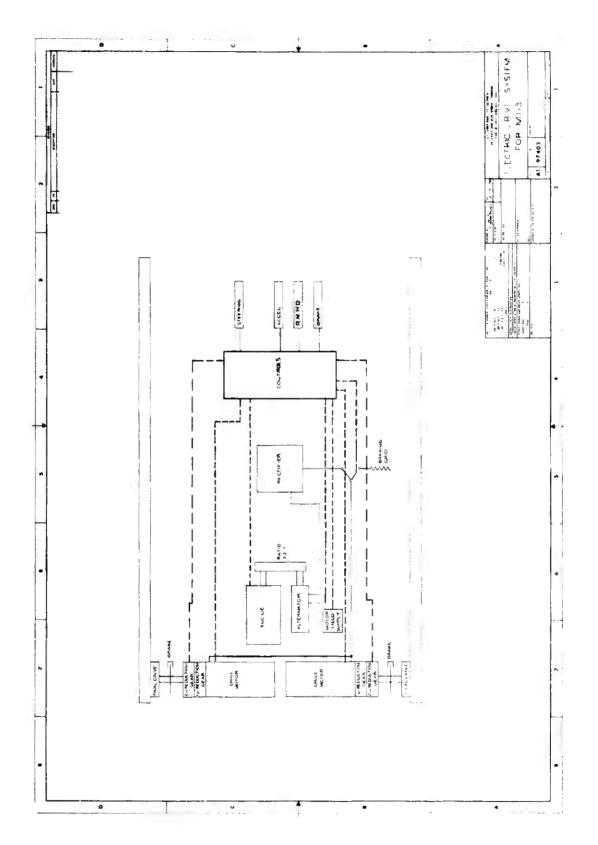


Figure 2. Two-motor electric-drive system.

Figure 3. Two-motor installation in an M113A2 APC.



6. Description of Components.

- a. Engine. The engine is a Detroit Diesel. 6V-53T, capable of delivering 300 bhp at 2800 r/min.
- b. Alternator. In order to demonstrate electric drive for a tracked vehicle at reasonable cost, great emphasis has been placed on selecting components on hand or in regular production. For the safety of personnel it is desirable to keep the system voltage at a level as low as possible. However, the lewer the voltage, the higher the current will be. In both designs to be discussed, maximum motor current will be 1000 A or a total of 2000 A in order to get 17,000-ft-lb total sprocket torque. For three motors per side maximum voltage will be 300 V, and for one motor per side it will be 120 V.

The alternator selected for the demonstrator is a 500-kVA Westinghouse alternator of the same type as that used in the M113 demonstrator made by the FMC Corporation. This alternator is on hand at MERADCOM, and recent tests at MERADCOM show that it is eapable of delivering 2000 A at 4000 r/min, which corresponds to 1250 r/min engine speed, The alternator will be belt-driven as in the FMC demonstrator (SAE Paper No. 690442, May 1969). The weight of this alternator is 430 lb.

For future electric-drive systems, a weight saving of 280 lb can be realized by using two Bendix type 28B329-1 brushless alternators. This alternator is an oil-cooled 150-kVA machine (see Appendix A for description). For this application the machine could be wound for half the usual voltage, which will double its usual current capability. The two alternators would be driven through a speed-increasing combining gear box and mechanically arranged so that their phase voltages will add arithmetically. The system could still be used as a 400-Hz mobile electric power plant with the standard output of 120/208 V, when the phases in the two machines are series-connected.

- c. Rectifier. The rectifier is a three-phase full-wave bridge and there are three choices of units:
- (1) Forced-air-cooled. The Westinghouse PDA7B7SO16 in a three-phase full-wave bridge arrangement can supply in excess of 2000 A if 60° C or less inlet air is delivered over the heat sink at 500 lin ft/min, A straightforward arrangement of these assemblies would be about 18 in, wide by 15 in, high by 7 in, deep and would weigh 50 lb. Required airflow would be about 400 ft³/min. Air ducts and cooling fans will be required in addition.
- (2) Natural Convection Cooling. The Westinghouse PDA9R9G022 is a typical natural convection air-cooled assembly. These assemblies are rated at 2000 A in ambient air at 55° C. An arrangement of these assemblies would occupy a space 32 in, wide by 18 in, high by 7 in, deep and would weigh about 110 lb.

(3) Water-cooled. Westinghouse PDW7R720 assemblies are sufficient to deliver in excess of 3000 A with a cooling water flow of 1 gal/min per assembly (3 gal/min total) at 40° C inlet temperature. The basic assembly would occupy a space 18 in, wide by 12 in, high by 6 in, deep and would weigh about 25 lb.

A modified structure could be reduced to 18 in, by 9 in, by 6 in. A coolant distribution manifold, pump, heat exchanger, and fan (or flowing air) are also required. These, with the coolant, would add an additional 30 fb to the rectifier system weight.

A natural convection unit is recommended for the demonstrator for simplicity.

d. Drive Motors. The first approach was to use three GE model 5BY101A5 motors per side, mainly due to MERADCOW's experience with this motor and because five were on hand. The motor is rated 40 hp, 8000 r/min, 96 V, 345 A continuous duty. A series of tests performed in 1969 at the GE plant, Eric, Pennsylvania, established short time ratings, Results of the GE tests show that the motor is capalde of 100-ft-lb shaft torque for 1 minute (Appendix B). To get 8500-ft-lb sprocket torque from a three-motor drive assembly, a total gear ratio of 28:1 is required. It was decided to obtain this ratio with a 2.8:1 combining gear for the three motors, a 2.5:1 planetary gear which can be shifted to a 1:1 ratio, and the present 4:1 final drive. Estimates of size, weight, and volume for the gear calculated by David P. Guimand are in Appendix C, GEAR DESIGN CALCULATIONS, Estimated size and weight of one unit consisting of three motor; and the gears will then be 26.4 in, long, maximum width 18,6 in., and total weight 574 lb (see Figure 1). When we contacted GE, we learned that the BY 401 motor is no longer in regular production but could still be manufactured at substantial cost. However, a new line of d.c. motors for electric cars and forklift trucks is now being manufactured. One of these motors, the BT2378, was selected for a final design. This motor is a 90-hp. 5200-r/min, 120-V, 611-A machine capable of 500-ft-lb shaft torque for 10 min and 120-hp for 30 min from a cold start. Computer runs were performed at GE for eight different shunt field voltages giving shaft torque, revolutions per minute, horsepower, and efficiency as a function of armature current (Appendix D). Using these data, the vehicle performance can be estimated.

Several distinct advantages are obtained by using this motor compared to the BY401 motor; efficiency is higher, 91,6 percent compared to 86.2 percent; maximum voltage is 120 V, where 300 V would be required for three BY401s in series; mounting is more easily accomplished; and there will be more room for the brakes. Figures 2 and 3 show the mounting of the two motors and associated gears. An additional advantage when the arrangement shown is used is that the end bells of the two motors and the housing of the first reduction gear can be made one casting and thus contribute to a very solid unit.

The total gear ratio wilf in this case be 20:1 in low and 7.f:f in high gear. Total weight per side for motor and gears wilf be 675 lb. based on 180 fb for gears estimated by Funk Manufacturing Company, GE was contacted for an estimate of cost and defivery time and both are very reasonable, Bendix was also contacted but only for the small motor similar to the GE BY f01: they quoted a substantial cost for development and delivery of six motors (see Appendix A).

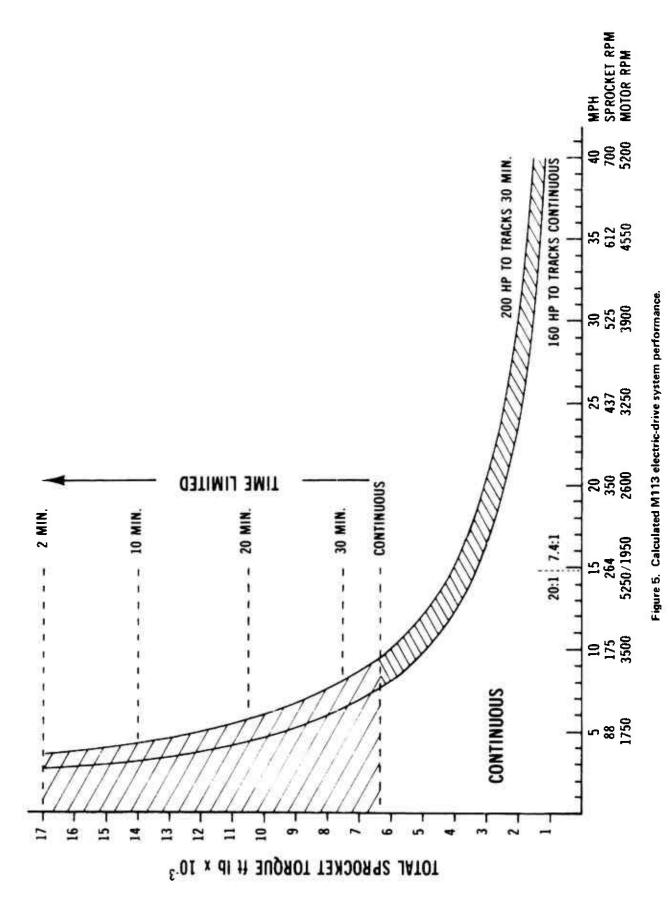
Excitation power for the motors wift he delivered from a brushfess d.e. generator. This generator is a type 30B119-9 machine presently being manufactured by Bendix; this generator must be modified to produce an output of 48 V and 200 A when driven at 4000 to 10,000 r/min. The weight of the generator is 15 lb (see Appendix F for descriptions).

IR. DISCUSSION

7. Vehicle Performance and Contol. Calculated vehicle performance is shown in Figure 5 and is derived from the computer runs for the motor and short time ratings for the alternator. With 270 hp available from the engine and 30 estimated efficiency of 69 percent to 75 percent (the low efficiency is at low speed only). 200 hp can be defivered to the tracks from approximately 7 mi/h to 40 mi/h, but time will be limited to 30 minutes, Assuming 88 percent efficiency of the gears. 160 hp can be delivered continuously above 8 mi/h.

Control of vehicle speed is accomplished by control of engine speed, alternator field current, motor field current, and gear box ratio. When the vehicle is started from a dead stop, three things must happen simultaneously to obtain sufficient motor torque to get it rolling. These are; increase of motor field current, increase of engine speed, and increase of alternator field current to generate enough voltage to produce a motor armature current which, in combination with the motor field, will create the required motor torque.

As an example, if maximum sprocket torque of 17,000 ft-lb is required, the motor field voftage must be increased to 48 V resulting in a field current of approximately 100 A, engine speed must be increased to 1250 r/min which will increase the alternator speed to 4000 r/min and in combination with increasing the alternator field current to 5,2 A, will result in 1000 A of armature current in each of the two motors. The above-mentioned numbers are the result of actual testing performed at MERADCOM with the 500-kVA alternator using a fixed resistor to simulate initial motor load (see Appendix F). Referring to the GE computer run (Appendix D) for 48 V on the motor field and 1000 A armature current, the motor torque will be 433 ft-lb and the total result in low gear will then be 433 ft-lb x 20 ratio x 2 tracks = 17,400 ft-fb, After this initial startup, increase in speed is accomplished by decreasing motor field voftage and increasing alternator voltage output: this wiff necessitate an increase of the engine speed.



Again referring to the GE computer runs, full motor speed will be reached when motor field voltage is decreased to approximately 12.5 V. In low gear maximum motor speed results in 15-mi/h vehicle speed; to further increase speed the gear must be shifted to high, Maximum motor speed will then result in $5200/7.4 = 700 \, \text{r/min}$ sprocket speed or $40 \, \text{mi/h}$ vehicle speed.

If high starting torque is not required, the vehicle can be run through the speed range in high gear, total starting torque would then be 2×7 , $4\times433=6400$ ft-lb, or total tractive effort of 8000 fb. Referring to Figure 5, any power curve can be followed through the speed range according to the operator's wish. Maximum performance is 200 hp to the tracks, but is theoretically time fimited, as noted in Figure 5. In practice, this limitation might be disregarded since it is unfikely that a condition will be encountered where full power will be required for 30 uninterrupted minutes. Below the 160-hp curve and above 8 mi/h, vehicle operation is continuous. Low speed, straight ahead on 60 percent grade requires a total of 12.400 ft-lb sprocket torque. This requirement is well within the drive system's short term capability, but time-limited operation will apply. The requirement for high speed, straight ahead is 120 hp per side with a sprocket speed of 750 r/min. Since maximum sprocket speed for this investigation is 700 r/min, the borsepower requirement will be 112 hp per side. However, with 270 hp available for traction, an efficiency of 83 percent would be required to transmit a total of 224 hp to the tracks. With a maximum estimated efficiency of 75 percent this requirement cannot be met,

Vehicle steering is accomplished by control of the motor fields, and steering control will be continuously variable with regenerative transfer of energy from one side to the other. When, as an example, a sharp right turn is required, the field on the right motor must be increased to force the motor to slow down. At the same time, the field on the left motor is decreased and the feft motor wiff try to increase in speed. The right motor then gets into the generating mode supplying power to the left motor and, in doing so, holding back on the right track while the left motor will speed up the left track and thus force the vehicle into a right turn.

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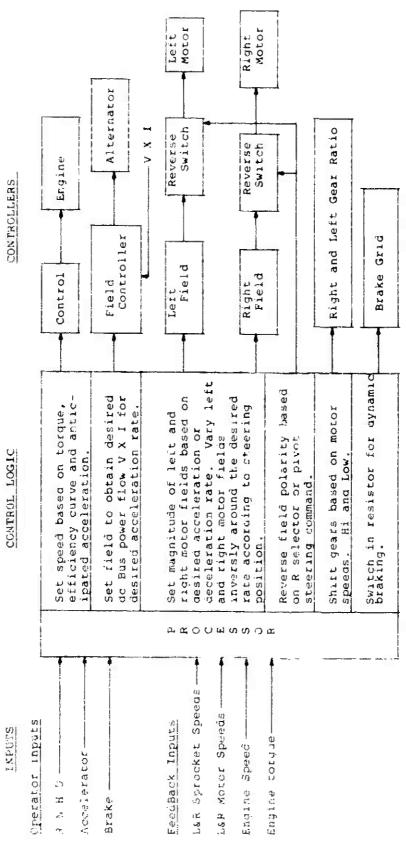
'flie field current to the two motors is supplied from the Bendix d.e. generator through two high-current switching transistor power supplies, which are controlled by the micro-computer with inputs from the operator's controls.

High-speed turns require power defivery to the outer motor greater than the engine can deliver. However, with the regenerative transfer capability the inner motor operating in the generator mode will supply the difference. One of the original requirements is a high-speed, clockwise turn, requiring 293 hp to the left sprocket at 770 r/\min sprocket speed and f f3 hp generated by the right sprocket motor at 740 r/\min sprocket speed. Since top sprocket speed is 700 r/\min , the required power will be 293 \times 700/770 = 266 hp and 103 hp generated. According to the GE computer run, this is within the capability of the motor.

Pivot steering is accomplished by reversing the field on one of the motors. The requirement for a pivot turn is ±90000 ft-llc to one sprocket and -90000 ft-llc to the other, this is more than the 85000 ft-llc per side agreed upon but will be within the capability of the system.

Dynamic braking is accomplished by connecting the motors to a braking grid and applying excitation. The motors will then generate power which will be dissipated in the braking grid. Since the motor excitation is individually controlled, steering will function normally.

- 8. Operator Controls and Functions. The control system will consist of operator input controls, a digital processor, analog output controllers, and vehicle parameter feedbacks. A block diagram of the basic control functions is shown in Figure 6. The processor itself, operator control hardware, engine controller, and software routines in common with the hydrostatic effort will be purchased from Southwest Research. Inc. The analog controllers additional programming and hardware, assembly, and debugging will be done by MERADCOM. Functions of the operator controls are discussed below:
- a. Accelerator. Sets desired vehicle speed. Signal will be compared to actual vehicle speed and accelerated at a rate proportional to the difference. Initiation of acceleration consists of increasing engine speed, alternator field current, and motor field currents, followed by a decrease of motor field to increase speed.
- b. Brake. Overrides accelerator, First part of brake travel will activate proportional dynamic braking, further travel will pickup the hydraulic disc brakes via a master cylinder.
- e. Steering. Sets a desired track speed differential, which is accomplished by inversely adjusting the motor field currents. Steering response should be slow on center and faster toward end stops. Pivot steering becomes available toward the end stops.
- d. Selector Functions—R N H D. Reverse—allows operation in low gear only in reverse direction; will be inhibited if vehicle has forward velocity. Neutral—engine speed controlled by accelerator position; alternator field disabled; steering and foraking functions normal; manually apply hydraulic brake to park. High—allows operation in high gear ordy; will be inhibited if vehicle has reverse velocity. Drive—allows operation in low gear under 15 mi/h; automatic shifting at 15 mi/h.



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Figure 6. Control functions for M113 electric-drive system.

9. Weight Estimates. Estimated weights are in the following table:

Weight Estimates

| Component | Weight (lb) | Number Required | Total Weight (lb) |
|---|-------------------|--------------------|-------------------------|
| Alternator | 430 | i | 430 |
| Belt Drive | 95 | 1 | 95 |
| Rectifier | 110 | 1 | 119 |
| Drive Motors | 495 | 2 | 990 |
| Motor Field Supply | 45 | 1 | 45 |
| Controls | 90 | 1 | 90 |
| Gears | 180 | 2 | 360 |
| Final Drive | 220 | 2 | 440 |
| Braking Grid | 75 | 1 | 75 |
| | | | 2635 |
| Mise, Cables, Blowers | etc. 5 percent | | 132 |
| Total Proposed | | | 2767 |
| Lightweight option: Oil-cooled Alterna | tor and Rectifier | | 2430 |

- 10. Potential Weight Savings. The specific weight of the system as proposed is 9.2 lb/hp. There are several ways in which this specific weight might be reduced:
- a. Replacement of the proposed alternator with the two high-speed oil-cooled machines discussed earlier and selection of the lightweight fluid-cooled rectifier option will save 335 Hz or 1.1 lb/hp.
- lc. Component technology can be improved. One could develop higher speed motors with a likely saving of 75 lb and a single high-speed alternator saving, perhaps another 25 lb. Combined, these developments would yield another 1/3-lb/hp saving. One of the heaviest components where weight savings may be possible is the gearing. The proposed system weight includes 800 lb of gears, It seems worthwhile from a system point of view to integrate the motors and gears and to develop lightweight gear technology. We have not estimated the weight savings from such efforts.
- c. One can develop better overall electric-drive technology by identifying opportunities for weight and volume savings during developmental testing of the demonstrator. The demonstrator, as proposed, will yield important data on the performance of the electric drive under computer control in the variety of operating conditions which the amphibian will encounter. It is likely that these data will advance electric-drive technology by providing improved specifications and requirements for system engineering.

APPENDIX A

BENDIX BRUSHLESS GENERATOR, TYPE 28B329-1 IDG

DESCRIPTION.

A single-hearing generator, the 28B329-1 is designed to share a hearing with a constant speed drive and to utilize the drive's oil for cooling. The generator bolts directly to the drive, and integration involves the mating of the drive spline and oil-in, oil-out ports,

A complete AC machine, the 28B329-1 is extremely lightweight, It weighs only 75 lb, yet it carries an output rating of 150 kVA, and has full overload capabilities.

Similar to other Bendix IDG generators, the 28B329-1 ntilizes both conduction and oil-mist spray cooling techniques to provide optimum heat transfer characteristics.

Cooling. Cooling oil from the drive enters the generator at the mating flunge interface where it goes through a short connecting channel and then into a series of grooves in the housing.

The grooves surround the generator stator core which is shrunk into the machined bore of the housing to form a channel through which the cooling oil flows.

Oil flow through the channel is turbulent and it contacts all surfaces of the channel including the stator core to provide optimum heat transfer.

The oil then leaves the stator cooling passages, and flows through a cast-in channel to the anti-drive end of the generator. Here, a small amount of oil is metered through a clearance to first hibricate the hearing and then to spray the permanent-magnet generator,

Most of the oil enters the rotor through a hollow generator shaft where it proceeds towards the drive end. Metering orifices in the shaft provide a means of distributing the cooling oil in the proper quantity and in the right places to do an effective cooling job.

The first orifice discharges a jet of oil into the rotating diode heat sink area to remove heat from the diodes and then to spray and cool the exciter armature.

The oil in the shaft next is metered through orifices at the main generator rotor where it is first distributed over the rotor windings and then sprayed over the stator end turns. A unique design feature directs the oil to flow between the rotor poles to carry away heat from these areas. The same oil is then used again to spray and cool the stator winding end turns. This cooling technique is extremely efficient and operating temperatures of the generator stabilize very rapidly.

Insulation. Insulation used throughout the 28B3294 is DuPont's "Nomex" and our own RB-160 insulating material. The combination of these two materials provides optimum heat transfer characteristics.

RB-160, used to impregnate the wound assemblies of the generator, also has great mechanical strength to provide excellent bonding within the windings. These are important characteristics since movement within the windings due to vibrational stresses is prevented.

Tables I and II show insulation life and thermal conductivity of the installation used in the 28B329-1.

Specifications

* Rating: 150 KV \(\), continuous output \(\@ \), 75 PF,

120/208 voits, 3 phase, 4-wire, 400 Hz at 12,000 RPM

Cooling Oil: Oil-in @ 250°F and

flow at 7.5 gpm @ 230-240 psi

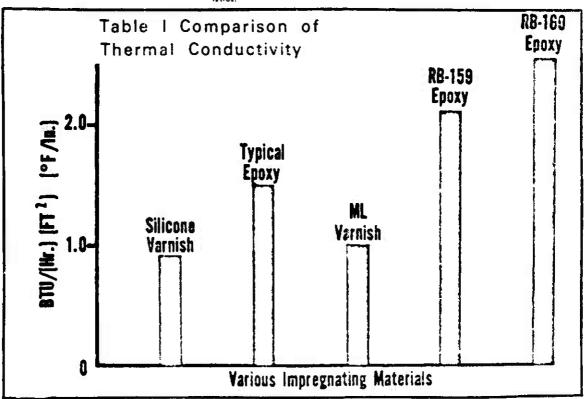
* Weight: 74 lbs.

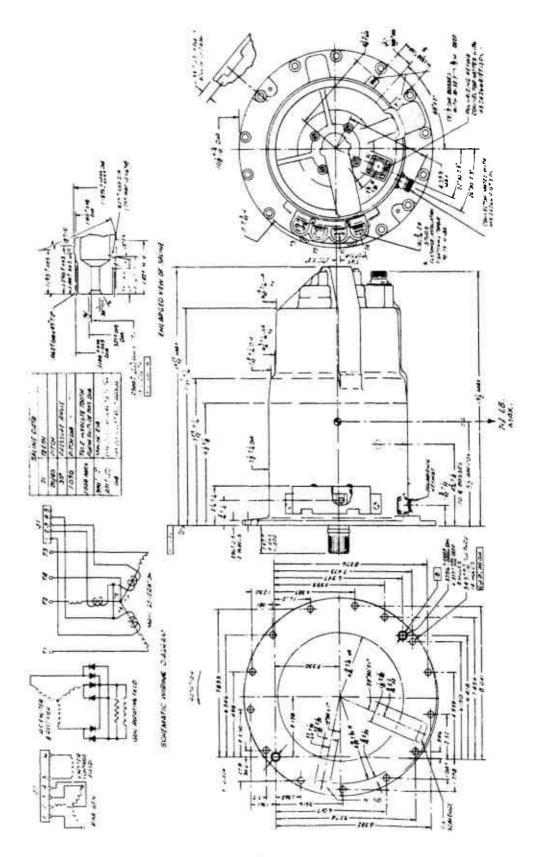
PMG Output: 42 = volts

Design Features

- * Oil-cooled by conduction and oil-mist
- Integrates with drive to provide compact compact drive generator package.
- Lightweight unit has weight-to-output ratio of only 5 lb./KVA.
- PMG excitation source with solid-state control unit eliminates need for external excitation and produces excellent generator output characteristics.

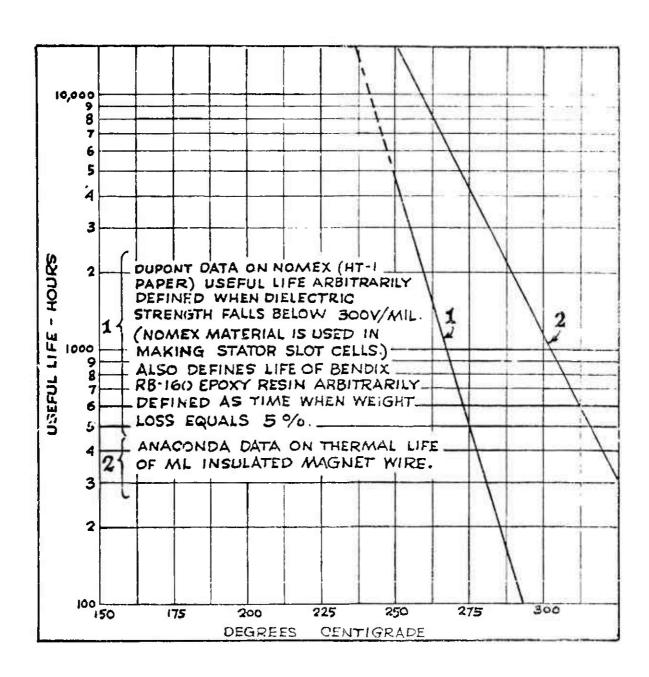
- Cooling techniques provide extremm, effective cooling system with conservative generator operation
- Insulation system is completely compatible with, and unaffected by MIL-L-7808, MIL-L-23699 hydraulic fluids.
- Integration with drive makes up lightweight overall package.
- Brushless design provides long service life and low overhaul/maintenance costs.

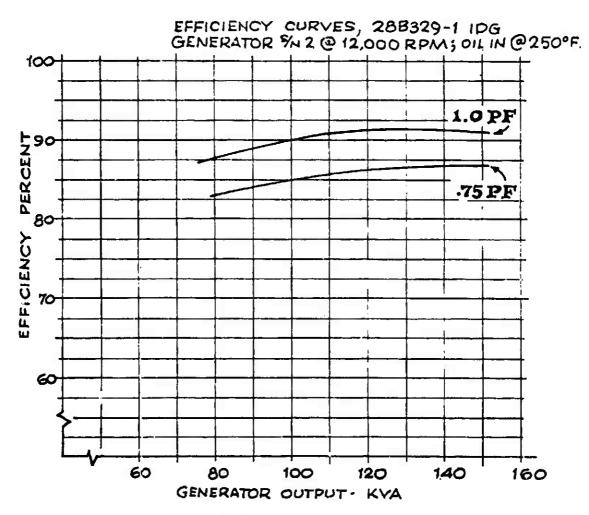




THE STANDARD CONTRACT SECTIONS OF THE STANDARD SECTIONS OF THE STANDARD CONTRACTORS OF

Table II Insulation Life





OVERLOADS

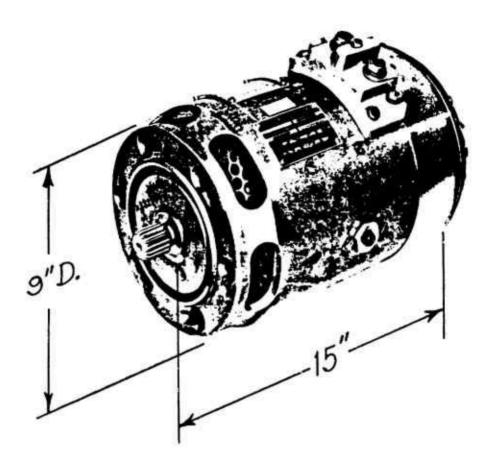
| | | | GEN. | YOLTA | GES | 4 | OAD | | FIELD | مهر عد | TIME | |
|-------|----------|-----|-------|-----------|----------|-------------|-------------|--------------|--------------|--------|------|------|
| RPM | KVA | PE | | 72.79 | | | KW2 | KW3 | EFIF | OUT | MIN | REZO |
| 12000 | 150 | .75 | 119.8 | 119.7 | 119.5 | 37.5 | 37.5 416 | 37.5° 416 | 17.2 | 118 | 0 | |
| 12000 | 150 | .75 | 119.8 | 119.7 | | | 37.5 | 37.5 | 17.2 | 120 | 5 | |
| 12000 | 150 | .75 | 119.9 | 1198 | 119.8 | 37.5 | 37.5 | 37.5 | 17.5 | 120 | 10 | |
| 12000 | 150 | .75 | 208 | 120 257.5 | 119.9 | 375 | 37.5 | 37.5 | 2.90 | 131 | 20 | |
| 12000 | 225 | .75 | 119.8 | 119.2 | 207 | 634 | 624 | 624 | | 120 | 0 | 208V |
| 12000 | 225 | .75 | 119.9 | 119 | 118.9 | 5625 624 | 56.25 | 56.25 | 28.0 | 120 | 5 | 2% |
| 12000 | 225 | .75 | 119.5 | | 207 | | 56.25 | 56.25 624 | 28.0 4.45 | 121 | 10 | 1 |
| 12000 | 300 | .75 | 1185 | - | _ | 75 832 | 75 832 | 75 852 | 40.0 6.54 | - | SEC. | 208V |
| | <u> </u> | | 200.5 | | <u> </u> | | | | | | | 35% |

WAVEFORM

| | 3/17S | | NO COND | 1.US 1040 | 240 E. | E 75 | B.F. | KVA | KVA 1000 | E. 1.0 PF | JOE |
|-------|------------|------|-----------------|-----------|--|--|------------|------|-----------------------|--|-------------|
| KPM | אטי בחי | 71.7 | 7-7 | 11.7 | 7-7 | K-N | 7-7 | N-7 | | N-7 | 7-7 |
| 00021 | 1 | 100 | 001 | 001 | 100 | 100 | 001 | 001 | 001 | 001 | 100 |
| 12000 | w | 1 | I | ı | 1 | ı | 1 | ı | ı | I | 1 |
| 12000 | 5 | 1.37 | 1.34 | 9. | 9 | .62 | 79. | 1.5 | 1.45 | 2.9 | 28 |
| 12000 | ٧ | 1.59 | 1.54 | 1.7 | 1.7 | 1.7 | 1.7 | 1.55 | 1.45 | 1.97 | 3.0 |
| 12000 | o) | ١ | 1 | į. | 1 | 1 | 1 | ı | ! | 1 | : |
| 12000 | 11 | .52 | .53 | .56 | .56 | .41 | .42 | 14. | .37 | .46 | .45 |
| 12000 | 13 | .36 | 30 | 1 | ı | <.7 | K.7 | V.7 | V.7 | .25 | 37. |
| 12000 | 15 | ×., | \(\frac{1}{2}\) | <.7 | <.7 | \.\ \.\ | 4.7 | ×.7 | \.\\\ | \.\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ | 4.7 |
| 12000 | | V. V | <.7 <.7 | V.7 | V.V | <.7 | K.7 | K.7 | V.7 | .23 | .22 |
| 12000 | 6/ | 177 | .77 | <.7 | <.1 | 13 | <.1 | ×.× | V:7 | .28 | .27 |
| 13000 | 27 | < | 1.7 | < | \.\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ | \.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\.\. | <> | ×.× | 1.7 | V. Y | <. Y |
| 12000 | 23 | .27 | .27 | .20 | .22 | V. V | 4.1 | 4.7 | <.7 | .23 | .23 |
| 12000 | 25 | ×. × | V | 111 | .76 | 4.7 | 4.7 | .15 | 1.14 | 11. | 81. |
| 12000 | 27 | V. X | × | 4.7 | 4.7 | ×.7 | V.7 | V. Y | V.7 | √. √ | ×.7 |
| 12000 | 29 | <.7 | <.7 | 4.7 | <.1 | 7.7 | 7.7 | V | \ \ \ \ \ | V.V | \ \ \ |

NOTE: ALL HARMONICS ABOVE 29TH ARELESS THAN 0.1%

PROPOSED BENDIX TRACTION MOTOR



40 IP DC MOTOR 8000 RPM 100 VOLTS, DC 140 LB

APPENDIX B

GENERAL ELECTRIC TEST RESULTS



COMPANY

777 FOURTEENTH STREET, N. W., WASHINGTON, D. C. 20005 . . . TELEPHONE EXecutive 3-3600

DEFENSE PROGRAMS
DIVISION

EQUIPMENT AND COMPONENT FIELD OFERATION

January 13, 1969

Department of the Army MERDC Fort Belvoir, Virginia 22060

Attention: Mr. C. Heise

Gentlemen:

The attached information hopefully provides sufficient data for your present planning. J. Nadzam will check the engineers to determine if additional tests are planned so that you may have a complete speed torque curve family. At one time, this action was contemplated but the availability of test equipment was delayed.

Very truly yours,

C.J. White

Manager - Ground Power Programs

CJW/ra

Encl.

GENERAL ELECTRIC

Dial Comm: 8*342-2981 Date: November 26, 1968 Copies: GF Bond, 64-3

WG Brighton,

17-2

Dept: Direct Current Motor & Generator Dept.

Address: 3001 East Lake Road, Erie, Pa. 16501

Subject: Type BY401 Motors for ERDL

RECEIVED OFF HIGHWAY VEHICLE EQUIPMENT PROJECT NOV 27 1968 TEPMO TRANSPORTATION SYSTEMS DIVISION

Mr. J. P. Nadzam Bldg 42-3

A little over one year ago we shipped 5 motors to ERDL for powering an experimental vehicle. Questions from the customer on overload capability of the motor prompted us to suggest that they return one motor to us for testing with a dynamometer facility that was not available at the time the motors were initially shipped. This facility has permitted us to test the motors at speeds up to 8000 r/min and at outputs of 100 hp or more. We have now completed these tests with the results as shown on the attached two curve sheets.

The attached curve sheet "Duty Cycles and Short Time Ratings" is particularly interesting because it is a complete statement of the thermal capability of the motor on any type of repetitive load.

You will observe that the maximum duration for an overload condition is somewhat shorter than we had previously indicated that it would be. The following observations are appropriate.

(1) The maximum capability of the motor is 102 lb-ft for one minute. This is simultaneously a thermal and a commutation limitation. At this torque, and at 6000 r/min, 116 hp will be delivered by the motor.

(2) The rated maximum speed of the motor is 8000 r/min. Any speed greater than this value should be considered an overspeed. The maximum safe speed is 10,000 r/min.

Our tests disclosed that when operation at high currents and high speeds will be frequently repeated, two changes will improve commutation, brush life, and commutator life, These are:

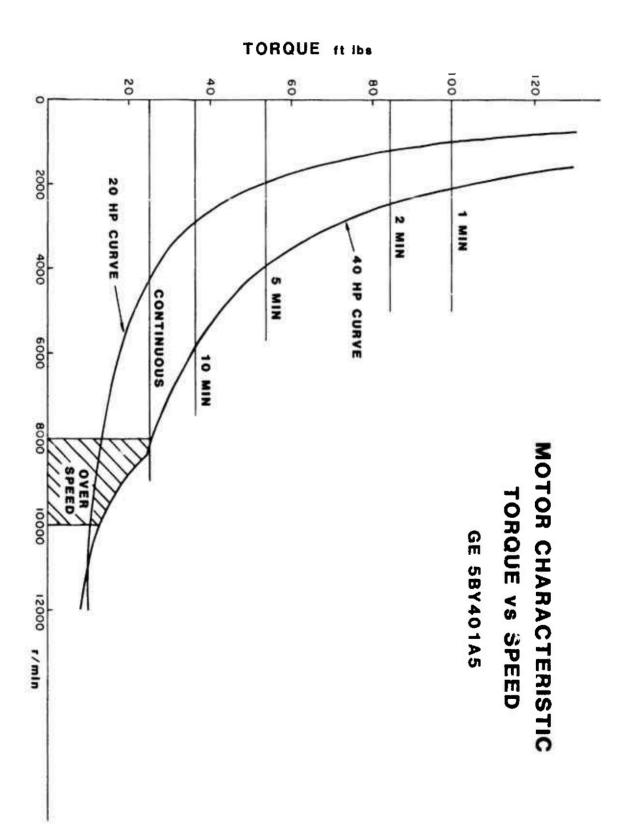
- (a) Change brush grade to L-206.
- (b) Increase spring pressure 50 percent.

I am attaching a copy of Mr. Bond's test report, from which you can see the importance of these changes. We understand that the enstoner is interested in converting from shunt to series windings. At the time the machines are returned to us for conversion we would plan to install the new brushes and springs. He should, at the same time, return the two motors to us which have already been converted to series windings in order that we can make the brush and spring changes as well as recheek the machines thoroughly to see that they are in top condition.

18/

C. M. Wheeler, Supervisor Special Product Engineering Specialty Motor Product Engineering Subsection Bhlg. 64B-3, Ext. 2981

Attachments



Brush Tests on Model 5BY401A5

The motor is a series wound machine, separately ventilated and is rated 40 hp, 8000 r/min, 96 V, 345 A continuous duty-100 hp, 6000 r/min, 96 V, 920 A, 20 s short time duty.

The customer, Mobility Equipment R&D Laboratories anticipated the motor's capabilities as shown in Figure 1 and requested our comments on the "time-on" values for the various lnad conditions.

Tests have been taken and the important results are included in this report.

Conclusions.

- (1) The commutator was designed for operation at 8000 r/min and tests confirm commutator stability at this speed. No load overspeed is 10,000 r/min.
 - (2) Brushes should be changed to grade L206.
 - (3) Brush springs should be changed to give 50 percent additional pressure.
- (4) For load currents exceeding rated, the operating time is limited by brush temperatures rather than winding temperatures.

Tests.

- (A) Black band tests were taken to confirm compensation and to compare different brush grades. Tests were at half rated volts. Vibration required the use of double-pressure springs,
- (1) Grade 537. This is one of the original brushes, preferred for good wear properties. Black band is narrow and closes at less than peak current.
- (2) Grade 456. Favored brush for low contact drop, but rejected for poor wear. Has open band to peak corrent.
 - (3) Grade L206. Recommended by Carbon Products. This split brush has very wide band.
 - (4) Grade L206 solid. Poor band.
- (B) Tests were taken to find "time-on" values at points on or below the characteristic curve. Brush temperature by thermocouple and winding temperature by volt drop were observed. The motor was run to selected speed and load current as quickly as possible.

Results (CW rotation only)

| | | | | ° C | | |
|------|------|-------|---------|------------|----------|---|
| LV | LA | r/min | Comm | Brush Temp | Time On | Remarks |
| 67.5 | 1000 | 4000 | 1-1 1/2 | 250 | 1.3 min | L206 split brush |
| 93 | 1000 | 6000 | 1-2 | 250 | 1.25 | heavy springs |
| 94 | 800 | 6500 | 2 | 250 | 2.5 | |
| 92 | 650 | 6800 | 2 | 250 | 4.75 | high friction |
| 58 | 350 | 6000 | 1 | 150 | Cont | |
| 66 | 1000 | 4000 | 1 14-3 | 230 | l min | L206 split brush |
| 95 | 800 | 6500 | 2-3 | 200 | 1.2 | light spring |
| 94 | 650 | 6800 | 2-3 | 200 | 2.5 | |
| 88 | 450 | 7500 | 2.3 | 175 | 3.25 | worse sparking accounts |
| 61 | 350 | 6000 | 1 | 130 | Cont | for short times |
| 62 | 1000 | 4000 | 1.2 | 200 | 2.25 min | 456 heavy spring |
| | 1000 | 6000 | 2 | 150 | 1 | shut down due to |
| 87 | 800 | 6000 | 3 | 175 | 1.5 | brush dusting |
| | 1000 | 4000 | - | - | _ | 456 light spring severe sparking streamer |
| _ | 1000 | 4000 | - | - | _ | SA45 light spring vicious sparking |
| | | | | | | |

The L206 split brush is clearly the most successful. A spring of 6 lb/in.² would be a compromise between high brush friction (with double spring at 8 lb/in.²) and poorer commutation with the normal spring. Brush temperatures indicate a strict time limit on overloads, and it may be concluded that an increase in brush area and commutator size is needed to achieve more reasonable short time ratings where an application of this motor demands such ratings.

APPENDIX C

GEAR DESIGN CALCULATIONS

MEMORANDUM

From: Code 2723 (D. Guimond)
To: MERADCOM (C. Heise)

Via: Code 2723

Subj: Final drive gearbox; preliminary design for

Ref: (a) Meeting on 10 Sep 82 btwn G. Anderson (DTNSRDC, Code 2723) and

MERADCOM personnel at DTNSRDC, Carderock

Encl: (1) Design Calculations

- 1. In support of your work with Mark Rice, of the Marine Corps Project Office, for the design of final drive for tracked vehicles and based on the requirements discussed in reference (a), preliminary designs were worked out for two gearboxes to obtain estimates of size, volume, weight and cost.
- 2. The first gearbox consists of three input pinions (each being driven by an electric motor) meshing with a central output gear giving a reduction ratio of 2.8:1. Each pinion has a pitch diameter of 2.857". The gear has a pitch diameter of 8.000". The gearbox would be approximately 14.00" in diameter and 4.50" wide. The weight would be $66\ lbs$.
- 3. The second gearbox is a planetary arrangement taking as it's input the output of gearbox No. 1. It consists of an input sun gear, five planet gears and a ring gear held stationary by a clutch or brake. The output is taken from the planet gear carrier, with the overall reduction being 2.5:1. The unit can be by passed by releasing the clutch holding the ring gear and energizing a second clutch which connects the input sun gear to the ring gear, locking the planet gears, to achieve a 1:1 ratio. The unit would have overall dimensions of 13.00" diameter by 5.50" wide and weighs 58 lbs.
- 4. Funk Manufacturing Company has been asked to supply cost and lead time estimates for 2 of each unit.
- 5. The gearboxes should have a life of at least 600 hours. Rough design calculations are included in enclosure (1).

David P. Guimond

David P. Lluimonel

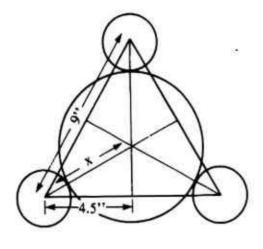
Ext. 2362

Copy to: Code 2723

Code 1120 (Mark Rice)

Code 2723S

2.8:1 Simple Mesh



$$\cos 30^{\circ} = \frac{4.5}{x}$$

$$x = \frac{4.5}{\cos 30^{\circ}} = 5.20$$

center distance = 5.20"

$$\frac{dG \div dp}{2} = 5.20 \qquad 2.8 = \frac{dG}{dp}$$

$$2.8 = \frac{dG}{dp}$$

$$\frac{2.8 \text{ dp} + \text{dp}}{2} = 5.20 \qquad \frac{3.8 \text{ dp}}{2} = 5.20$$

$$dG = 2.8 dp$$

dp = 2.737" smallest dG = 7.664" possible

$$N_p = 40$$

$$N_G = 112$$

$$N_p = 40$$
 $N_G = 112$ $\frac{112}{40} = 2.8$

$$P = 14$$

$$P = 14$$
 $d = \frac{N}{P}$ $dp = \frac{40}{14} = 2.857$ " $dg = \frac{112}{14} = 8.00$ "

$$dg = \frac{112}{14} = 8.00$$
"

$$dp = 2.857$$
" $dg = 8.00$ " $F = 1.50$ " $N_p = 40$ $N_g = 112$ $J = .495$

$$N_n = 40$$

$$N_{\sigma} = 112$$

$$J = .495$$

Bonding Stress

$$S = \frac{4.8 \text{ TN}}{\text{Fd}^2 \text{JB}} = \frac{4.8 (120) (12) (40)}{(1.50) (2.851)^2 (.495)}$$

$$S_{\rm b} = 45,619$$
 PSI

$$K = \frac{W}{Ed R} \frac{Mg + 1}{Mc}$$

$$K = \frac{W}{Fd_0B} \frac{Mg+1}{Mg}$$
 $W = \frac{2T}{d} = \frac{2(120)(12)}{2.857} = 1008 \text{ lb.}$

$$K = \frac{1008}{1.5 (2857)} \left(\frac{2.8+1}{2.8} \right)$$

$$K = 319$$

Size & Weight

2.5:1 Planetary

Input Torque 120 (12)(3)(2.8) = 12,096 lb. in. Speed
$$\frac{8000}{2.5}$$
 = 285 RPM

2.5 ratio
$$\frac{Nr}{Ns} = 1.5$$
 Ns = 80 Nr = 120

$$Np = \frac{Nr - Ng}{2} = \frac{120 - 80}{2} = 20$$
 $\frac{Nr + Ng}{\text{# planets}} = \text{integer}$ $\frac{120 + 80}{5} = 40$

$$p = 14$$
 $d = \frac{N}{p}$ $ds = 5.714$ $dp = 1.429$ $dr = 8.571$ $F = 1.375$

$$ds = 5.714$$
"
 $Ng = 80$
 5 planets

 $dp = 1.429$ "
 $Np = 20$
 $p = 14$
 $dr = 8.57$ "
 $Nr = 120$
 $F = 1.375$ "

$$V = .2518 \frac{\text{ndr}}{\text{Mg}} = \frac{.2618 (2857)(8.571)}{2.5}$$
 $V = 2564.31 \text{ Ft./Min.}$

$$W = \frac{33000 \text{ Hp}}{V} \left(\frac{dr}{dr + ds} \right) \qquad \text{Hp} = \frac{Tn}{63000} = \frac{12096 (2857)}{63000} = 550$$

$$W = \frac{33000 (550)}{2564 31} \left(\frac{8.571}{8.571 + 5.714} \right)$$
 $W = 4246.76 \text{ lb.}$

$$K_{sun}_{pinion} = \frac{W}{BF} \left(\frac{ds + dp}{dsdp} \right) = \frac{4246.76}{5(1.375)} \left[\frac{5.714 + 1.429}{(5.714)(1.429)} \right]$$
 $K_{sun}_{pinion} = 540$

$$K_{\text{ring}} = \frac{W}{BF} \left(\frac{dr - dp}{drdp} \right) = \frac{4246.76}{5(1.375)} \left[\frac{8.571 - 1.429}{(8.571)(1.429)} \right]$$
 $K_{\text{ring}} = 360$

Bending Stress

$$S = \frac{4.8 \text{ TN}}{\text{Fd}^2 \text{ JB}} \qquad S_{\text{sur}} = \frac{4.8 (12096) (80)}{(1.375)(5.714)^2 (.505)(5)} \qquad \underline{S_{\text{sun}} = 40,976 \text{ PS1}}$$

$$T_{planet} = T_{sun} \frac{dp}{ds} = 12096 \left(\frac{1.429}{5.714} \right) = 3025 \text{ lb.-in.}$$

$$S_{planet} = \frac{4.8 (3025) (20)}{1.375 (1.429)^2 (.405)5}$$

$$S_{planet} = 51,075 PSI$$

Weight & Size

Weight
$$\simeq 9500 \frac{Q}{K}$$

$$Q = \frac{P}{N_S} \left[\frac{(Mg+1)^3}{Mg} \right]$$

$$Q = \frac{550}{2857} \left[\frac{(2.5+1)^3}{2.5} \right] = 3.30 \quad \cdot \quad 9500 \frac{(3.30)}{540} = 57.9$$

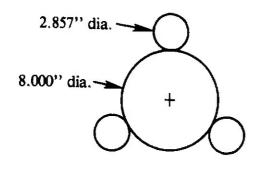
Weight \simeq 58 lb.

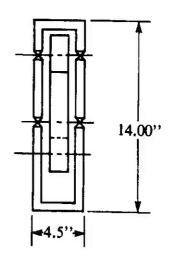
$$d = 1.5 dr$$
 $d = 1.5 (8.57) = 12.855$

$$L = 3F$$
 $L = 3 (1.375) = 4.125 + room for clutches$

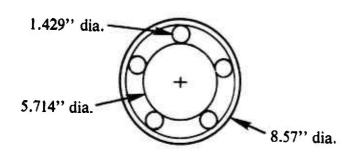
13" dia. × 5.5" wide

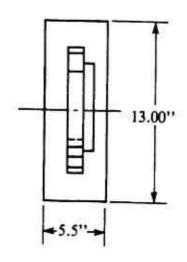
2.8:1 Ratio





2.5:1 Ratio





APPENDIX D

MOTOR PERFORMANCE

USAMERADCOM

cc: Charles Faulkerson 13-2

Oct 27, 1982

Mr. Mike Mando

Enclosed find computer runs for our BT2378 motor rated:

90 hp, 5200 r/min, 120 V, 611 Amps, BV (150 CFM)

Short time ratings are shown on an attached sheet,

Runs were made with 48 V, 36 V, 24 V, 20 V, 16 V, 14 V, 13 V, and 12 V excitation.

Also included are runs for our BT2346 motor with 48 V and 36 V excitation.

181

TO SECURITY OF SECURITY SECURI

E. D. Elwonger

General Electric Company

USAMERADCOM

BT2378-3311

FLD = 65 T .1285''

Thermal Ratings

| Time | I | ī |
|-------|------|-----|
| (min) | ARM | FLD |
| 1 | 2574 | 250 |
| 2 | 1920 | 187 |
| 5 | 1480 | 119 |
| 10 | 1227 | 144 |
| 25 | 1040 | 101 |
| 30 | 763 | 50 |
| Cont | 611 | 40 |

BT2378-3311 .115 M785 USMERADCOM ELWONGER WED, UCT 27, 1982, 9:26 AM

ELECTRIC VEHICLE PERFORMANCE-REV 7/14/81

CIRCUIT PARAMETERS

```
MAX STALL BAT AMPS (SCR) = 400.0
                                      ARM. IND. L = .11995E+00
PEAK MTR STALL AMPS (SCR) = 8918.1
                                     UNSAT SER L =
                                                     .00000E+00
                                     SAT. SER. L =
TOT. MTR. L =
                                                     .00000E+00
MAX STALL MTR AMPS (SCR) = 1000.0
RB= .0000
                  NL BV =
                           120.0
                                                     .95336E-01
RL# .0070
                                     UNSAT SH, L =
                  DI/DT = 1258.7
                                                     .21540E+02
RA= .0057
                  SCRTYP=
                             8.0
                                     SAT. SH. L = .37341E+02
```

FIELD DATA (SPD# 2)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.2000E+02 SHUNT TURNS = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750 BRUSH DROP=1.40+ .00064*IA

FOR IA (= 468.750: BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

| 11421011 | CHILINATE I | FV 10 1 1 | 2 27 (1) [1] | | | | |
|----------|-------------|-----------|--------------|-------|--------|---------|--------------|
| IB | IA | VM | TORQ | RPM | HP | LOSSES | EFF |
| 8918. | 8918. | 57.6 | 3755.7 | 0. | .00 | 590931. | . 0 |
| 4459. | 4459. | 88.8 | 1860.4 | 958. | 339.31 | 148153. | 63.1 |
| 3656. | 3656. | 94.4 | 1552.3 | 1139. | 336.65 | 99417. | 71.6 |
| 2998. | 2998. | 99.0 | 1279.8 | 1280. | 312.05 | 69440. | 77.0 |
| 2459. | 2459. | | 1061.0 | 1380. | 278.90 | 50016. | 80.6 |
| 2016, | | 105.9 | | 1456. | 244.03 | 36773. | 83.2 |
| 1653. | 1653. | | 722.0 | | 210.28 | 27720. | 85.0 |
| 1356. | 1356. | 110.5 | | 1593. | 179.12 | 21511. | 86.1 |
| 1112. | 1112. | 112.2 | 482.4 | 1646. | 151.24 | 17235. | 86 . 7 |
| 911. | 911. | 113.6 | 394.1 | 1689. | 126.81 | 14278. | 86.9 |
| 747, | ,747. | 114.8 | 321.9 | 1725. | 105.72 | 12223. | 86,6 |
| 613. | 61.3. | 115.7 | 262.6 | 1753. | 87.72 | 10785. | 85. 9 |
| 503. | 503. | 116.5 | 214.1 | 1777. | | 9773. | 84.7 |
| 412. | | 117.1 | 174.3 | 1799. | 59.75 | 8990. | 83.2 |
| 338. | 338. | 117.6 | 141.7 | 1819. | 49,10 | 8420. | 81.3 |
| 277. | 277. | 118.1 | 115.0 | 1835. | 40.19 | 8028. | 78.9 |
| 227. | 227. | 118.4 | 93.1 | 1848. | 32.76 | 7756. | 75.9 |
| 186. | 186. | 118.7 | 75.1 | 1859. | 26.59 | 7568. | 72.4 |
| 153. | 153. | 118.9 | | 1867. | 21,48 | 7436. | 68.3 |
| 125. | 125. | 119.1 | | 1874. | 17.25 | 7343. | 63.7 |
| 103. | 103. | 119.3 | 38.4 | 1880. | 13.76 | 7278. | 58.5 |
| 84, | 84, | 119,4 | 30.3 | 1885. | 10.88 | 7231. | 52.9 |
| 69. | 69. | 119.5 | 23.6 | 1889. | 8.51 | 7197. | 46 . 9 |
| 57. | 57. | 119.6 | 18.2 | 1892. | 6.55 | 7172. | 40.5 |
| 46. | 46. | 119.7 | 13.7 | 1895. | 4.95 | 7154, | 34.0 |
| 38. | 38. | 119.7 | 10.0 | 1897. | 3.63 | 7141. | 27.5 |
| 31. | 31. | 119.8 | 7.0 | 1899. | 2.54 | 7131. | 21.0 |
| 26. | 26. | 119.8 | 4.6 | 1901. | 1.65 | 7123. | 14.7 |
| 21. | 21. | 119.9 | 2.5 | 1902. | .92 | 7117, | 8.8 |
| 17. | 17. | 119.9 | . 9 | 1903, | .32 | 7113. | 3.2 |
| | 1000 | 113 | 433 | 1665 | /37 | | |

FIELD DATA(SPD# 3)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.3600E+02 SHUNT TURNS = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750 FOR IA (= 468.750: BRUSH DROP=1.40+ .00064*IA BRUSH DROP= .00363*IA INCREASED BRUSH DROP DUE TO FIELD WEAKENING = BD*2.50

MOTOR CHARACTERISTIC DATA TR IA VM TORO RPM HP **EFF** LOSSES 8918. 8918. 57.6 2889.2 0. . 0 .00 588643. 339,28 4459. 4459. 88.8 1395.8 1276. 63.4 145863. 1520. 3656. 3656. 94.4 1163.0 336.60 97140. 72.1 2998. 2998. 99.0 1677. 311.99 976.5 67170. 77.6 2459. 2459. 102.8 812.1 1803. 278.83 47751. 01.3 105.9 675.3 2016. 2016. 1897. 243.96 34513. 84.1 1653. 1653. 108.4 561.6 1965. 210.20 25462. 86.0 1356. 1356. 110.5 464.9 2022. 179.05 19254. 87.4 2075. 151.17 1112. 1112. 112.2 382.4 88.3 14980. 911. 911. 113.6 312.5 2129. 12024. 126.74 88.7 747. 747. 114.8 255.2 2174. 105.64 9969. 88.8 208.2 87.64 88.5 613. 613. 115.7 2210. 8533. 503. 2239. 72.40 503. 169.7 116.5 7521 . 87.8 412. 412. 117.1 138.2 2267. 59.67 6739. 86.9 338. 338. 117.6 112.3 2291. 49.02 6170. 85.4 277. 277. 91.1 118.1 2311. 40,11 5778. 83.8 118.4 227. 227. 73.7 2327. 32,68 5507 81.6 186. 186. 118.7 59.5 78.8 2341. 26.51 5319. 153. 153. 118.9 47.8 2352. 75.5 21.40 5188. 125. 125. 119.1 38.2 2361. 17.17 5095. 71.5 119.3 103. 103. 30,3 2368. 13.67 5030. 67.0 84. 84. 119,4 23.9 2374. 10.79 4983. 61.8 69. 69. 119.5 18.6 2379. 4949. 55.9 8.42 57. 57. 119.6 14.2 2383. 6.47 4925. 49.5 119.7 10.7 4907 46. 46 . 2386. 4.86 42.5 38. 38. 119.7 7.8 2389. 3.54 4893. 35.0 31. 31. 119.8 5.4 2.45 27.3 2391. 4883. 26. 119.8 26. 3.4 2393. 1.56 4876. 19.3 . 83 21. 21. 119.9 1.8 2395. 4870. 11.3 17. 17. 119.9 .5 2396. 4866. .23 3.4

BT2378-3311 .115 M785 USMERADCOM ELWONGER TUE, OCT 26, 1982, 5:22 PM

ELECTRIC VEHICLE PERFORMANCE-REV 7/14/81

CIRCUIT PARAMETERS

```
ARM, IND, L =
MAX STALL BAT AMPS (SCR)= 400.0
                                                   .11995E+00
PEAK MTR STALL AMPS(SCR) = 8918.1
                                    UNSAT BER L =
                                                   .00000E+00
MAX STALL MTR AMPS (SCR) = 1000.0
                                    SAT. BER. L =
                                                   .00000E+00
RR# .0000
                  NL RV = 120.0
                                    TOT. MTR. L =
                                                   .95336E-01
                  DI/DT = 1258.7
RL# .0070
                                    UNBAT SH. L =
                                                    .21540E+02
RA= .0057
                  SCRTYP=
                             8.0
                                    SAT. SH. L =
                                                    .30180E+02
```

FIELD DATA(SPD# 2)

THE PARTY OF THE PROPERTY OF THE PARTY OF TH

RSH=.4360E+00 RSHD=.0000E+00 SEV=.2400E+02 BHUNT TURNB = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA > 468.750 FOR IA <= 468.750; BRUSH DROP=1.40+ .00064*IA BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

| IB | IA | UM | TORQ | RPM | HP | LOBBES | EFF |
|---------------|---------------|-------|--------|-------|--------|---------------|--------|
| 8918. | 8918. | 57.6 | 2022.6 | 0. | . 00 | 587008. | . 0 |
| 4459. | 4459. | 88.8 | 920.9 | 1935. | 339.45 | 144082. | 63.7 |
| 3656. | 3656. | 94.4 | 763.4 | 2316. | 336.73 | 95389. | 72.5 |
| 2998. | 2998. | 99.0 | 641.0 | 2556. | 312.10 | 65437, | 78.1 |
| 2459. | 2459. | 102.8 | 542.8 | 2698. | 278.94 | 46024. | 81.9 |
| 2016. | 2016. | 105.9 | 459.5 | 2788. | 244.05 | 32795. | 84.7 |
| 1653. | 1653. | 108.4 | 387.2 | 2851. | 210.28 | 23754. | 86.8 |
| 1356. | 1356. | 110.5 | 327.4 | 2872. | 179.11 | 17558. | 88 . 4 |
| 1112. | 1112. | 112.2 | 272.2 | 2916. | 151.22 | 13289. | 89.5 |
| 911. | 911. | 113.6 | 225.5 | 2952. | 126,78 | 10338. | 90.1 |
| 747. | 747. | 114.8 | 186.1 | 2982. | 105.69 | 8286. | 90.5 |
| 613. | 613. | 115.7 | 153.0 | 3009. | 87.68 | 6852. | 90.5 |
| 503. | 503. | 116.5 | 125.3 | 3034. | 72.44 | 5842. | 90.2 |
| 412. | 412. | 117.1 | 102.2 | 3066. | 59.70 | 5060, | 89.8 |
| 3 38 . | 338. | 117.6 | 83.1 | 3098. | 49.05 | 4491. | 89.1 |
| 277. | 27 7 . | 118.1 | 67.5 | 3123. | 40.14 | 4099. | 88.0 |
| 227. | 227. | 118.4 | 54.6 | 3145. | 32.72 | 3829. | 86.4 |
| 186. | 186. | 118.7 | 44.1 | 3162. | 26,55 | 3641. | 84.5 |
| 153. | 153. | 118.9 | 35.4 | 3177. | 21.43 | 3509. | 82.0 |
| 125. | 125. | 119.1 | 28.3 | 3186. | 17.20 | 3417. | 79.0 |
| 103. | 103. | 119.3 | 22.5 | 3198. | 13.71 | 3351. | 75.3 |
| 84. | 84. | 119.4 | 17.7 | 3206. | 10.83 | 3305. | 71.0 |
| 69. | 69. | 119.5 | 13.8 | 3212. | 8.46 | 3271. | 65.9 |
| 57. | 57. | 119.6 | 10.6 | 3217. | 6.50 | 3247. | 59.9 |
| 46. | 46. | 119.7 | 8.0 | 3222. | 4.90 | 3229. | 53.1 |
| 38. | 38. | 119.7 | 5.8 | 3225. | 3.58 | 3215. | 45.3 |
| 31. | 31. | 119.8 | 4.0 | 3228. | 2.49 | 3205. | 36.7 |
| 26. | 26. | 119.8 | 2.6 | 3231. | 1.60 | 3198. | 27.2 |
| 21. | 21. | 119.9 | 1.4 | 3233. | .87 | 3192. | 16.8 |
| 17. | 17. | 119.9 | . 4 | 3234. | . 27 | 3188, | 5.8 |

FIELD DATA(SPD# 4)

STATE AND ADDRESS OF THE PARTY OF THE PARTY

RSH=.4360E+00 RSHD=.0000E+00 SEV=.2000E+02 SHUNT TURNS = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA > 468.750 BRUSH DROP=1.40+ .00064*IA FOR IA (= 468.750: BRUSH DROP= .00363*IA

| MOTOR | CHARACT | ERISTIC | DATA | | | | |
|-------|---------|---------|--------|-------|--------|---------|--------|
| IB | IA | VM | TORQ | RPM | HP | LOSSES | EFF |
| 8918. | 8918. | 57.6 | 1733.8 | 0. | . 00 | 586608. | . 0 |
| 4459. | 4459. | 88.8 | 756.1 | 2357. | 339.52 | 143629. | 63.8 |
| 3656. | 3656. | 94.4 | 624.6 | 2831. | 336.77 | 94955. | 72.6 |
| 2998. | 2998. | 99.0 | 524.9 | 3122. | 312.15 | 65000. | 78.2 |
| 2459. | 2459. | 102.8 | 445.3 | 3289. | 279.01 | 45562. | 82.0 |
| 2016. | 2016. | 105.9 | 380.9 | 3365. | 244.16 | 32311. | 84.9 |
| 1653. | 1653. | 108.4 | 323.4 | 3415. | 210.41 | 23256. | 87.1 |
| 1356. | 1356. | 110.5 | 275.0 | 3422. | 179.24 | 17058. | 88.7 |
| 1112. | 1112. | 112.2 | 234.3 | 3390. | 151.32 | 12809. | 89.8 |
| 911. | 911. | 113.6 | 194.8 | | | 9862. | 90.6 |
| 747. | 747. | 114.8 | | 3444. | 105.78 | | 91.0 |
| 613. | 613. | 115.7 | 133.0 | 3465. | | | 91.1 |
| 503. | 503. | 116.5 | 109.3 | | | | 91.0 |
| 412. | 412. | 117.1 | 99.6 | 3504. | 59.79 | 4596. | |
| 338. | 338. | | 73.2 | | | 4029. | 90.1 |
| 277. | 277. | 118.1 | 59.5 | | | | 89.2 |
| 227. | 227. | 118.4 | 48.3 | 3565. | 32.79 | 3368. | 87.9 |
| 186. | 186. | 118.7 | | 3582. | | 3180. | 86.2 |
| 153. | 153. | 118.9 | 31.4 | 3598. | | 3049. | 84.0 |
| 125. | 125. | 119.1 | 25.1 | 3611. | | | 81.3 |
| 103. | 103. | 119.3 | | | | | 78.1 |
| 84. | 84. | 119.4 | | 3630. | | | 74.1 |
| 69. | 69. | 119.5 | 12.3 | 3637. | | 2811. | 69.4 |
| 57. | 57. | 119.6 | 9,5 | 3643. | 6.58 | 2786. | 63.8 |
| 46. | 46. | 119.7 | | 3648. | 4.97 | 2768. | 57.3 |
| 38. | 38. | 119.7 | 5.2 | 3651. | 3.65 | 2755. | 49.7 |
| 31. | 31. | 119.8 | 3.7 | 3655. | 2.57 | | 41 . 1 |
| 26. | 26. | | 2.4 | | 1.67 | | 31.3 |
| 21. | 21. | | 1.4 | | | | 20.5 |
| 17. | 17. | 119.9 | . 5 | 3661. | .34 | 2727. | 8.5 |

FIELD DATA(SPD# 5)

THE STATE OF THE PROPERTY OF T

RSH=.4360E+00 RSHD=.0000E+00 8EV=.1600E+02 SHUNT TURNS = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750 FOR IA (= 468.750: BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA IB IA VM TORQ RPM HP LOSSES 0. .00 8918. 8918. 57.6 1445.0 586281. . 0 4459. 4459. 88.8 580.7 3068. 339.41 143381. 63.8 3656. 3656. 94.4 477.5 3701. 336.58 94768. 72.6 401.8 2998. 2998. 99.0 4075, 311,92 78.2 64842. 2459. 102.8 2459. 343.3 4263. 278.79 45400. 82.1 2016. 2016. 105.9 295.7 4332. 243.97 32126. 85.0 1653. 1653. 108.4 255.4 4322. 210.27 23029. 87.2 1356. 219.0 4295. 179.16 1356. 110.5 16783. 88.8 1,88.6 4214. 151.34 1112. 1112. 112.2 12468. 90.1 162.5 4100. 126.94 911. 911. 113.6 9488. 90.9 747. 747. 135.4 4105. 105.86 114.8 7424. 91,4 613. 613. 115.7 112.1 4115. 87.86 5984. 91.6 503. 503. 116.5 92.5 4123. 72.62 4972. 91.6 4137. 59.89 412. 412. 117.1 76.0 4188. 91.4 338. 338. 117.6 62.3 4152. 49.24 91.0 3618. 50.8 277. 277. 118.1 4165. 40.33 3226. 90.3 227. 227. 118.4 41.4 4176. 32.90 2954. 89.3 2766. 186. 186. 118.7 33.5 4185. 26.73 87.8 153. 153. 118.9 27.1 4193. 21.62 2634. 86.0 2541. 125. 125. 119.1 21.7 4200. 17.39 83.6 119.3 103. 103. 17.3 4207. 13.90 2475. 80.7 84. 119.4 13.7 4212. 77.2 84. 11.02 2428. 69. 69. 119.5 10.8 4216. 8.65 2394. 72.9 57. 57. 119.6 8.3 4221 . 6.69 2379. 67.B

**SCREEN CONTENTS @: WED, OCT 27, 1982, 9:28 AM

FIELD DATA(SPD# 3)

RSH=.4360E+00 RSHD=.0000E+00 BEV=.1400E+02 BHUNT TURNS = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 BERIES TURNS= .00

FOR IA > 468.750:

BRUSH DROP=1.40+ .00064*IA

INCREASED BRUSH DROP DUE TO FIELD WEAKENING = BD*2.50

| MOTOR | CHARACT | ERISTIC | DATA | | | | |
|-------|--------------|---------|--------|-------|--------|----------------|--------------|
| IB | IA | UM | TORQ | RPM | HP | T088E8 | EFF |
| 8918. | 8918. | 57.6 | 1300.6 | 0. | . 00 | 586145. | . 0 |
| 4459. | 4457. | 88.8 | 485.8 | 3666. | 339.23 | 143375. | 63.8 |
| 3656. | 3656. | 94.4 | 397.1 | 4446. | 336.29 | 94846. | 72.6 |
| 2998. | 2998. | 99.0 | 335.3 | 4879. | 311.56 | 64768. | 78.2 |
| 2459. | 2459. | 102.8 | 288.7 | 5063. | | 45532. | 82.0 |
| 2016. | 2016. | 105.9 | 250.8 | 5100. | | 32235. | 84.9 |
| 1653. | 1653. | 108.4 | 218.7 | 5040. | 209.98 | 23107. | 87.1 |
| 1356. | 1356. | 110.5 | 189.4 | 4960. | 178.92 | 16827. | 88 . 8 |
| 1112. | 1112. | 112.2 | 163.9 | 4840. | | | 90.0 |
| 911. | 911. | 113.6 | 142.0 | 4687. | 126.79 | 9461. | 90.9 |
| 747. | 747. | 114.8 | 119.4 | 4650. | 105.74 | 7378. | 91.4 |
| 613. | 613. | 115.7 | 99.2 | 4644. | 87.75 | 5924. | 91.7 |
| 503. | 503. | 116.5 | 82.1 | 4641. | 72.53 | | 91.7 |
| 412. | ,412. | 117.1 | 67.6 | 4646. | 59.82 | | 91.6 |
| 338. | 3 30. | 117.6 | 55.5 | 4655. | 49.17 | 3532. | 91.2 |
| 277. | 277. | 118.1 | 45.3 | 4663. | 40.26 | 3137. | 90.5 |
| 227. | 227. | 118.4 | 36.9 | 4669. | | | 89.5 |
| 186. | 186. | 118.7 | 30.0 | 4674. | 26.67 | 2673 . | 88.2 |
| 153. | 153. | 118.9 | 24.2 | 4679. | 21.56 | 2540. | 86.4 |
| 125. | 125. | 119.1 | 19.4 | 4686. | 17.33 | 2447. | 84 . 1 |
| 103. | 103. | 119.3 | 15.5 | 4693. | 13.84 | | 81.3 |
| 84. | 84. | 119.4 | 12.2 | 4699. | 10.96 | 2 333 . | 77.8 |
| 69. | 69. | 119.5 | 9.6 | 4704. | 8.59 | 2 299 . | 73.6 |
| 57. | 57. | 119.6 | 7.4 | 4708. | 6.64 | 2274. | 48.5 |
| 46. | 46. | 119.7 | 5.6 | 4711. | 5.03 | 2256. | 62.5 |
| 38. | 3 8. | 119.7 | 4.1 | 4715. | 3.71 | 2243. | 55. 2 |
| 31. | 31. | 119.8 | 2.9 | 4718. | 2.63 | 2233. | 46.7 |
| 26. | 26. | 119.8 | 1.9 | 4721. | 1.73 | | 36.8 |
| 21. | 21. | 119.9 | 1.1 | 4723. | 1.00 | 2220. | 25.2 |
| 17. | 17. | 119.9 | . 4 | 4725. | . 40 | 2215. | 11.9 |

FIELD DATA(SPD# 4)

CONTROL OF SPINS INSTRUMENT OF SPINS OF

R8H=.4360E+00 RSHD=.0000E+00 SEV=.1300E+02 SHUNT TURNS = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA > 468.750 BRUSH DROP=1.40+ .00064*IA FOR IA (= 468.750: BRUSH DROP= .00363*IA

| MOTOR | CHARACT | ERISTIC | DATA | | | | |
|-------|---------|---------|--------|-------|--------|-----------|--------|
| 13 | IA | W | TORQ | RPM | HP | LOS8E8 | EFF |
| 8918. | 8918. | 57.6 | 1228.3 | 0. | , 0 0 | 586 084 . | . 0 |
| 4459. | 4459. | 88.8 | 432.5 | 4116. | 339.07 | 143432. | 63.8 |
| 3656. | 3656. | 94.4 | 351.7 | 5016. | 336.02 | 94986. | 72.5 |
| 2998. | 2998. | 99.0 | 299.1 | 5463. | 311.24 | 65145. | 78.1 |
| 2459. | 2459. | 102.8 | 259.5 | 5626. | 278.10 | 45715. | 81.9 |
| 2016. | 2016. | 105.9 | 226.8 | 5633. | | 32406. | 84.9 |
| 1653. | 1653. | 108.4 | 199.3 | 5525. | 209.72 | 23242. | 87.1 |
| 1356. | 1356. | 110.5 | 173.9 | 5396. | 178.70 | 16931. | 88.7 |
| 1112. | 1112. | 112.2 | 151.2 | 5243. | 150.95 | 12555. | 90.0 |
| 911. | 911. | 113.6 | 131.4 | 5060. | 126.64 | 9511. | 90.9 |
| 747. | 747. | 114.8 | 110.7 | 5010. | 105.60 | 7418. | 91.4 |
| 613. | 613. | 115.7 | 92.1 | 4996. | 87.63 | 5958. | 91.6 |
| 503. | 503. | 116.5 | 76.3 | 4983. | 72.41 | 4930. | 91.6 |
| 412. | 412. | 117.1 | 62.9 | 4981. | 59.69 | 4135. | 91.5 |
| 338. | 338. | 117.6 | 51.7 | 4984. | 49.06 | 3556. | 91 . 1 |
| 277. | 277. | 118.1 | 42.3 | 4987. | 40.15 | 3157. | 90.5 |
| 227. | 227. | 118.4 | 34.4 | 4990. | 32.74 | 2880. | 89.5 |
| 186. | 186. | 118.7 | 27.9 | 4995. | 26.57 | 2687. | 88.1 |
| 153. | 153. | 118.9 | 22.5 | 5004. | 21.46 | 2553. | 86.2 |
| 125. | 125. | 119.1 | 18.1 | 5011. | 17.24 | 2459. | 83.9 |
| 103. | 103. | 119.3 | 14.4 | 5017. | 13.74 | 2392. | 81.1 |
| 84. | 84. | 119.4 | 11.4 | 5024. | 10.87 | 2344. | 77.6 |
| 69. | 69. | 119.5 | 8.9 | 5030. | 8.49 | 2310. | 73.3 |
| 57. | 57. | 119.6 | 6.8 | 5035. | 6.54 | 2285. | 68.1 |
| 46. | 46. | 119.7 | 5.1 | 5039. | 4.93 | 2267. | 61.9 |
| 38. | 38. | 119.7 | 3.8 | 5043. | 3.61 | 2253. | 54.5 |
| 31. | 31. | 119.8 | 2.6 | 5046. | 2.53 | 2243. | 45.7 |
| 26. | 26. | 119.8 | 1.7 | 5048. | 1.64 | 2236. | 35.3 |
| 21. | 21. | 119.9 | . 9 | 5050. | . 90 | 2230. | 23.2 |

FIELD DATA(SPD# 5)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.1200E+02 SHUNT TURNS = 65.00 RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA > 468.750 BRUSH DROP=1.40+ .00064*IA FOR IA (= 468.750: BRUSH DROP= .00363*IA

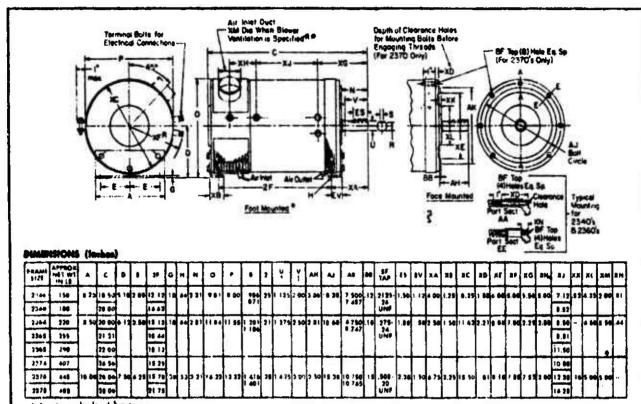
| MOTOR | CHARACT | ERISTIC | DATA | | | | |
|-------|---------|---------|-------|--------|--------|---------|--------|
| IR | | VM | | RPM | HP | LOSSES | EFF |
| 8918. | | 57.6 | | 0. | | | . 0 |
| 4459. | | 88.8 | | | 338.78 | 143595. | 63.B |
| 3656. | | 94.4 | | 5846. | 335.51 | 95309. | 72.4 |
| 2998. | | 99.0 | | 6298. | 310.67 | 65515. | 78.0 - |
| 2459. | | 102.8 | | 6396. | 277.57 | | 81.8 |
| 2016. | 2016. | 105.9 | 201.1 | 6340 . | 242.B3 | 32713. | 84.7 |
| 1653. | | 108.4 | 178.8 | 6145. | | | 86.9 |
| 1356. | | 110.5 | 157.7 | 5937. | 178.36 | | 88.6 |
| 1112. | | 112.2 | 137.9 | | 150.67 | | |
| 911. | 911. | 113.6 | 120.5 | 5510. | | | 90.7 |
| 747. | 747. | 114.B | 101.8 | | | | 91.3 |
| 613. | 613. | 115.7 | 84.7 | | | 6047. | |
| 503. | 503. | 116.5 | 70.3 | | 72.22 | | 91.5 |
| 412. | 412. | 117.1 | 58.1 | 5381. | 59.52 | | 91.3 |
| 338. | 338. | 117.6 | 47.7 | 5377. | | | 91.0 |
| 277. | 277. | 118.1 | 39.1 | | | | 90.2 |
| 227. | 227. | 118.4 | 31.8 | 5379. | | | 89.2 |
| 186. | 186. | 118.7 | 25.7 | 5384. | 26.40 | 2755. | 87 . 7 |
| 153. | 153. | 118.9 | 20.7 | 5394. | 21,29 | | 85.B |
| 125. | 125. | 119.1 | 16.6 | 5403. | 17.07 | | B3.4 |
| 103. | 103. | 119.3 | 13.2 | 5411. | 13.58 | | 80.5 |
| 84. | 34. | 119.4 | 10.4 | | | | 76.8 |
| 69. | 69. | 119.5 | B . 1 | 5424. | 8.32 | | 72.3 |
| 57. | 57. | 119.6 | 6.2 | 5429. | 6.37 | 2354. | 66.9 |
| | 1000 | | | | | | |

**SCREEN CONTENTS @:TUE, OCT 26, 1982, 5:24 PM

APPEDNIX E

GENERAL ELECTRIC MOTOR DIMENSIONS

DtMENSIONS: Open or Separately Ventilated Motors



- Feet are holted on type
 Machine can be furnished with or without feet. When feet are specified, they can be turned inward or outward.
- ****** For blower ventilation bottom half cover is solid for open fan-cooled ventilation screen covers top and bottom half will be turnished
 - † Shatt diameters 1.375 inches and smaller shall come within the limits of ±0 0000. -0 0005 Diameter 1.625 inches =0.000, -0.005
 - Mininting face will be square and rabbet diameter concentric with shaft within 0.004 inch indicator reading. Shaft runout will not exceed 0.002 inch indicator reading.
 - 1"V represents length or straight part of shaft.

APPENDIX F

BENDIX BRUSHLESS GENERATOR, TYPE 30B119-9

Description

Utilizing design features which provide maximum operating reliability with minimum maintenance, the 30B119-9 will produce 300 amps of 30-volt DC electric power when driven at 4000 to 10,000 rpm.

A brushless generator, the 30B119-9 is designed for extended operating service. It is equipped with a fan which supplies cooling air for ground operations and it will accept an air spout for blast air. The generator will provide the outputs shown here:

| Altitude Feet | 30 Volt DC Output | Air Required |
|------------------------|----------------------|---|
| Sea Level | 300 amps | Self-Cooled |
| 30,000 to 57,500 | 400 amps | Blast Air at II in., H ₂ 0 |

Brushless Design

THE RESIDENCE TO A STATE OF THE PARTY OF THE

The 30B119-9 has 6 poles with two 3-phase windings connected in wye, and separated by 30 electrical degrees to produce 12-phase commutation of twelve output diodes. The diodes are connected in two full-wave bridges to produce the DC output. No interphase transformer is used in the circuit.

Build-up excitation is provided to the generator exciter field through "residual magnetism" inherent in the generator. When the generator begins to produce its rated output, a portion of this output is used to supply the exciter field.

A small current transformer winding brought out through a rectifier bridge to the (E-) and (D) terminals provides an equalizing voltage for parallel generator operation.

Curvle Drive Spline

The generator is equipped with a curvic drive spline which will accommodate a polyimide spline sleeve with a low coefficient of friction. The sleeve eliminates the metal to metal contact between drive members and smooths driving operations.

Electronic Components 100 Percent Tested

All of the diodes and rectifiers used in the generator undergo audit procedures and 100 percent testing, including soak/bake cycles at hot and cold temperatures.

These components are mounted on an extruded aluminum heat sink which provides efficient transfer of dissipated heat to the cooling air stream.

Solid Epoxy Insulating Material

The generator windings are assembled and held together with welded stainless steel bands. The windings are insulated with 100 percent solid epoxy material which not only provides resistance to hydraulic fluids, fuels, and other solvents found in aircraft environments, but also provides the best possible heat transfer from the inner portion of the assembly.

Generator Control Unit

Bendix 25B12-3 Generator Control Unit is recommended for use with the 30B119-9. This GCU provides voltage regulation and over-voltage, and flywheel diode protection; it will annunciate faults and detects failed diodes in the generator. The 25B12-3 is described in Specification Sheet 79-180.

Design Features

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- Brushless design provides long life and high MTBF-practically climinates maintenance and overhaul.
- Unit delivers full output at sea level and high altitudes—efficient fan supplies cooling air for ground operations and does not impair flow of blast air at higher altitudes.
- Auxiliary bearing system takes over rotor load when main bearings show signs of malfunctioning.
- Curvic drive spline with polyimide spline sleeve eliminates metal-to-metal contact.

Specifications

Nominal Output-30 Volts, 300 Amperes

Speed Range-4,000 to 10,000 RPM

Mounting Flange-Conforms with AND 10262, Type X11A

Spline & Adapter-Per MS 14169, Basic Size 34-inch

Weight-See Outline Drawing

Auxiliary Bearing System

A unique "bearing-failure sensing and auxiliary bearing system" is designed into the generator. The system detects main bearing failure and provides a means to prevent generator damage in the event of a bearing failure.

The bearing failure sensing device and auxiliary bearing system consists of a small auxiliary bearing mounted on the generator shaft directly adjacent to the bearings at each end of the generator, together with insulated sensing circuits installed in the outer race support housing. Radial clearance of approximately .0025 inches is provided between the outer race of the auxiliary bearing and its support surface so that in operation, the auxiliary bearing, as a unit, turns with the shaft and does not contact the stationary support. When the main bearings begin to wear or fail in any manner such that the shaft becomes displaced from its normal rotational center by .0025 inches, the outer race of the auxiliary bearing will contact its stationary support surface. In doing so, the outer race of the bearing bridges the gap between the insulated detector ring and the adjacent steel surface of the support. This grounds the detector circuit thus closing an indicator light circuit and alerting the pilot to the fact that a main generator bearing is in process of failing. The sketch shows the arrangement of installing the detector circuit in the stationary outer race support.

The sensing circuit consists of a low-carbon steel punched ring installed in the outer race bearing support and insulated with Melamine glass washers and rings. A steel ring is shrunk into the main stationary ring and pressed firmly against the insulated detector ring assembly with appropriate staking at the outer edge to assure positive retention of the assembled parts.

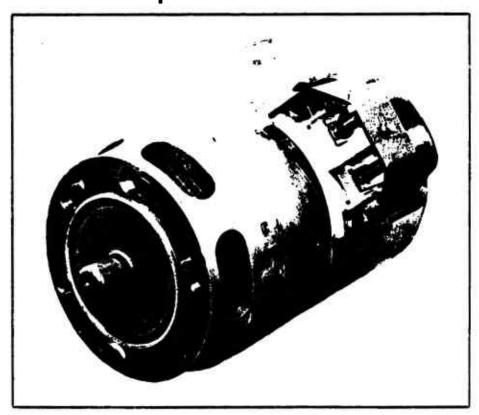
The auxiliary bearing is an extremely lightweight assembly with a 25-millimeter bore, an OD of 1.653 inches and a width of .354 inches. It is temperature stabilized, equipped with Viton seals and greased with DuPont Krytox AC high temperature grease. The combined weight of the auxiliary bearing' outer race support, indicator circuit and connecting leads does not exceed .25 lb per generator.

Advantages of the System

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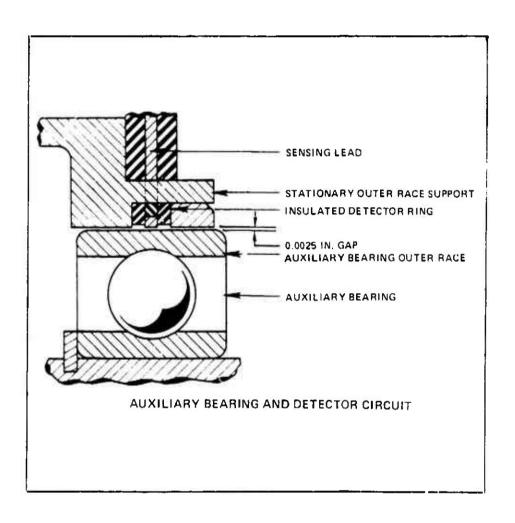
- a. Detection of a main bearing failure is indicated at an early stage.
- b. The system prevents disintegration of the main bearing and supports the rotor, thus, preventing the rotor rubbing the stator with resultant major damage.
- c. The system permits sufficient time for the pilot to take corrective action, de-energizing the generator and permits continued operation of the aircraft engine and/or the constant speed drive.
- d. The system permits re-energizing the generator in the event of emergency and continued use of the generator on the auxiliary bearing.
- e. The system provides a means whereby the generators can be operated "on condition" rather than on a scheduled overhaul basis.
- f. An analysis of the cost per operating hour indicates that a reduction in cost to one-third (two-thirds reduction) can be obtained by the use of the Bearing Failure Sensing and Auxiliary Bearing, primarily in the reduction of scheduled overhauls and in the reduction in damage when generator bearings fail.

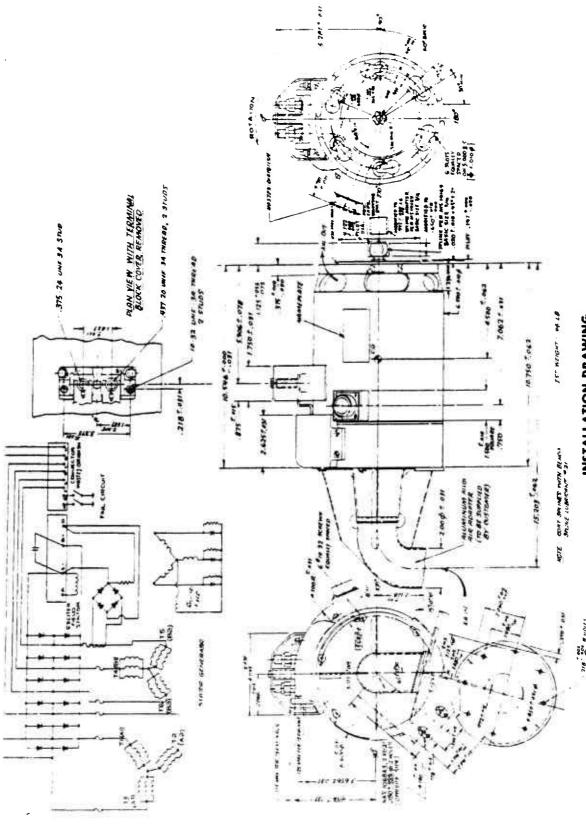
30B119-9 Brushless DC Generator, 300 Amps.





The generator is equipped with a curvic drive spline which will accomadate a polyimide spline sleeve eliminates the metal to inetal contact Letween drive members and smooths driving aperations.



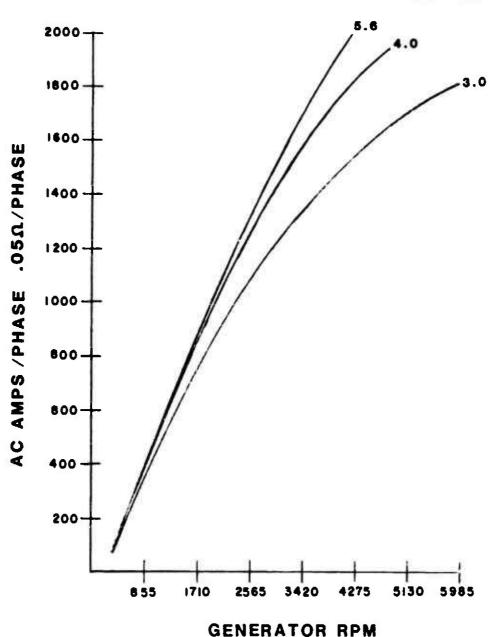


APPENDIX G

LOW-SPEED, HIGH-CURRENT TEST OF WESTINGHOUSE ALTERNATOR

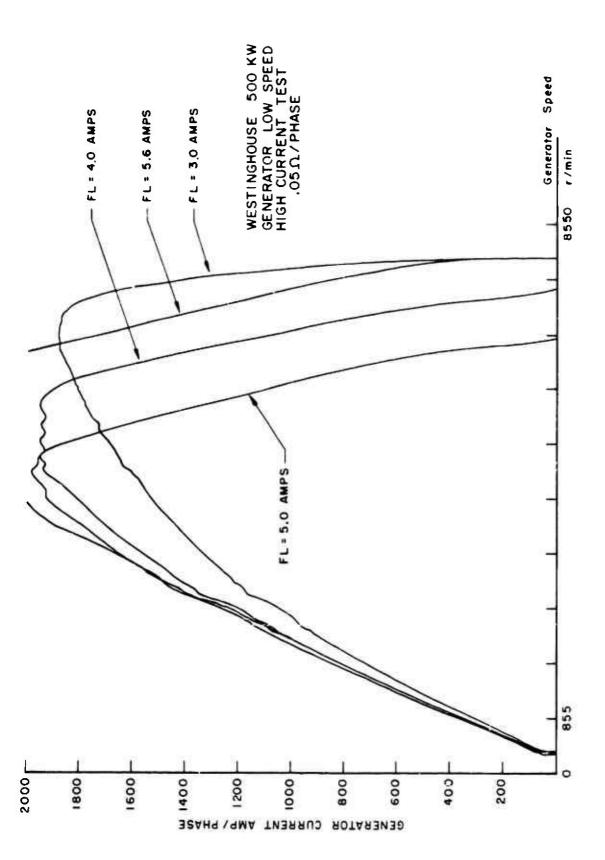
LOW SPEED HIGH CURRENT TEST WESTINGHOUSE 500KVA 400HZ ALTERNATOR

FIELDCURRENT AMPS



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