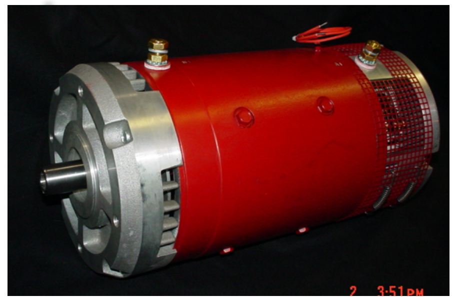
Application Notes and Service and Support Manual for DC Powered

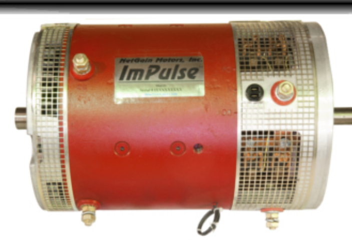
AmP™ Motors



WarP™ Motors

TransWarP Motors™

ImPulse™ Motors



Version 2.2: This version contains formatting changes, numerous consistency modifications, enhanced information and updated materials – GFH 6/8/2016

Version 2.3: This version contains updates, formatting changes, numerous consistency modifications, enhanced information and updated materials – GFH 1/1/2017

Version 2.4: This version contains updates required for the addition of the AmP™ motors, formatting changes, numerous consistency modifications, enhanced information and updated materials – GFH 4/14/2017

Application Notes and Service and Support Manual

To get the best results from the motor, please read this document carefully.

Before carrying out any maintenance or repair, read the SAFETY section of this publication. Motors can cause serious injury or damage if operated, dismantled or reassembled incorrectly.

Contents

Table of Contents

List of Illustrations

Illustration Index

Credits

Special thanks to:

Helwig Carbon Products, Inc.
8900 W. Tower Ave.
Milwaukee, WI 53224-2849

And especially: Jay Koenitzer, Nitin Kulkarni, Tom Brunka, and the rest of the folks at Helwig Carbon Products, Inc. Technical expertise and professionalism at a personal level!

NetGain Motors, Inc.
800 South State Street
Lockport, Illinois 60441

Especially: Hannah Etzkorn, Hollie A. Rossi, and G. Hunter Hamstra for proofing this document and for their patience and aid in helping me produce it. Without them filling in the void I could not have completed this document.

And to, Dr. Rich Carroll whose careful proofing and recommendations improved the overall quality, readability and correctness of the document.

And Jack Rickard of evtv.me. Jack provided generic EV information on one of his early Porsche conversion documents that was modified and incorporated within this document.

(And, lest I forget, very special thanks to any others I may have plagiarized and forgot to give credit to... it happens, and probably wasn't intentional!)

Enjoy!
George F. Hamstra
NetGain Motors, Inc.

Safety Information

This is not an all inclusive list. Use common sense and act responsibly, electric motors are extremely powerful and could cause death, dismemberment or other serious injury if misused or not safely handled!

Use caution when operating any motor. If you're not sure what you're doing, find a knowledgeable person to advise you!

Remove all metal jewelry and metal objects from hands, wrist, fingers, etc. before working on any electric motor.

If working on an electric vehicle, make certain the vehicle is positioned securely with the drive wheels safely clear of the floor and blocked up so that the drive wheels cannot make contact with the floor under any circumstances. Block the non-drive wheels if they remain in contact with the floor so that the vehicle cannot roll in either direction.

Before troubleshooting or working on any electric vehicle, disconnect the battery and discharge all capacitors. Reconnect the battery only as needed for specific checks or tests.

Motors must only be connected to a power source by knowledgeable and experienced personnel.

Motors should NEVER be run at more than 12 Volts without a load. Running a motor without a load could result in harm to people or the motor. Absence of a load is considered misuse and could prove dangerous to anyone in the vicinity and void the motor warranty.

Portions of the motor may become **hot** and proper precautions must be taken.

Motors are heavy and are likely to become damaged if dropped, or cause damage to anything they fall upon (including people and body parts). Use extreme caution when working with motors!

Make certain the motor is disconnected from any power source before servicing.

Motors contain moving parts that could cause severe injury if the proper precautions are not taken. Never touch an operating motor.

Motors should never be operated beyond the limits established by the manufacturer.

Motors must not be modified in any manner; doing so will void the motor warranty and could prove extremely dangerous.

Wear protective or safety equipment such as safety shoes, safety glasses and gloves when working with motors.

Make sure you know where the closest functioning eye wash station is before working on or testing batteries.

Do not defeat any safety circuits or safety devices.

Under no circumstances should you push in any contactor of an electric vehicle while the drive wheels are in contact with the floor. Pushing in a contactor when the drive wheels are in contact with the floor can cause serious property damage, personal injury or death.

New WarP™ Motor Warranty

WARFIELD ELECTRIC COMPANY, INC. (Company), warrants that new motors sold by it are merchantable and free of defects in material and workmanship at the time that they are shipped from the company's factories.

The company makes no warranty with respect to the re-manufactured motors other than the warranty stated above. All implied warranties of merchantability and all express and implied warranties of any other kind are hereby excluded.

The company will repair or, at its option, replace any part of any re-manufactured motor sold by it that fails to conform to the warranty stated above, provided Warfield Electric Company, Inc. (factory) is contacted for a Repair Authorization Number (RA#) and such part is returned to the company's factory or to a factory authorized service station, transportation charges prepaid, within the warranty period specified below:

NEW MOTOR WARRANTY extends for a period of six months or 2000 hours of equipment operation, whichever first occurs, following the date of delivery of such equipment into which the motor has been installed, but warranty coverage will not exceed a period of two years from the date the motor was shipped from the company's factory. Proof of equipment installation date and equipment hour-meter reading must be provided on request.

LIMITATION OF LIABILITY

The company's liability, whether in contract or in tort or under any other legal theory, arising out of warranties, representations, instruction or warnings (or any lack or inadequacy thereof), deficiencies, failures or defects of any kind or from any cause shall be limited exclusively to repairing or replacing parts (during normal business hours) under the provisions stated above. All liability for damages, including, but not limited to, those expenses, or injury to business credit, reputation or financial standing is hereby excluded.

The warranties contained therein shall not apply to or include any of the following and the company shall have no liability with respect to:

1. Repair or replacement required as a result of: (A) accident; (B) misuse or neglect; (C) lack of reasonable and proper maintenance; (D) operation in excess of recommended capacities; (E) repairs improperly performed or replacements improperly installed; (F) use of replacement parts or accessories not conforming to Warfield Electric Company, Inc. specifications which adversely affect performance or durability; (G) alterations or modifications not recommended or approved in writing by Warfield Electric Co., Inc. and (H) wear and deterioration of motor appearance due to normal use or exposure.

2. Normal replacement of consumable service items, such as brushes and brush springs.

3. Motors in equipment whose ownership has been transferred from the first purchaser for use to another.

No agent of Warfield Electric Company, Inc. is permitted or authorized to change, modify, or amend any term of this warranty.

New AmP™ Motor Warranty

ADVANCED MOTORS & DRIVES 6268 E. Molloy Rd – E. Syracuse, NY ▪ Tel: (315) 434-9303 ▪ Fax: (315) 432-9290

ADVANCED MOTORS & DRIVES, INC.
WARRANTY POLICY

1. Scope
The following document states the warranty policy of Advanced Motors & Drives, Inc. Kinetek division. Unless otherwise specified, the term "Advanced Motors & Drives" shall include the Unites States Kinetek division, its affiliates of other Kinetek divisions, and their representatives, officers and employees. The warranty policy describes Advanced Motors & Drives, Inc. warranty obligations to its customers, the limitations of this policy, and summarizes the procedures regarding submission of warranty return claims, return of product, rejection and receipt of reworked or replacement material.

2. Limited Warranty
Advanced Motors & Drives, Inc. warrants to the original buyer (purchaser) of its motors that each of its products will be free from defects in workmanship and material, during the Warranty Period and subject to Limitations and Exclusions as delineated in this document.

3. Warranty Period
The Warranty Period begins on the manufacturing date of products shipped to the user.

The basic standard Warranty Period is of 1 (one) year or for the first 2000 (two thousand) hours of use, whichever occurs first.

A Warranty Period longer than 1 (one) year may be awarded under contractual agreements for specific Advanced Motors & Drives, Inc. products, subject to following Limitations and Exclusions.

If a warranty claim results in Advanced Motors & Drives, Inc. replacing the product, then the Warranty Period for the replacement will be the remaining unexpired portion of the original Warranty Period for the motor that was replaced.

4. Warranty Claim Procedure
4.1 Customer must submit the warranty claim within 30 (thirty) days of the occurrence of the alleged non-compliance or defect
4.2 Promptly upon customer's communication, Advanced Motors & Drives, Inc. will provide Customer with a Returned Goods Authorization Number (RGA #)

R.A. Issued November 24, 2009
Rev A. April 20, 2010

ADVANCED MOTORS & DRIVES 6268 E. Molloy Rd – E. Syracuse, NY ▫ Tel: (315) 434-9303 ▫ Fax: (315) 432-9290

4.3 Customer must complete the Returned Goods Authorization Form. Customer must await receipt of RGA # before returning the motor to Advanced Motors & Drives, Inc. Customer must properly identify the returned motor. Customer will pay for the shipment of the returned motor.

4.4 Advanced Motors & Drives, Inc. will await the receipt of the motor before processing the warranty claim. If Advanced Motors & Drives, Inc. determines that the returned motor is covered under the Limited Warranty (item 2), Advanced Motors & Drives, Inc. will reimburse Customer for the actual cost of shipment of the returned motor.

5. Determination of Warranty Coverage

5.1 As soon as practical, Advanced Motors & Drives, Inc. will inspect the returned motor to determine if the motor is covered under Limited Warranty provisions.

5.2 Approval: If Advanced Motors & Drives, Inc. approves the warranty claim, the Customer will be reimbursed as delineated in Item 6, Remedy.

5.3 Denial: If Advanced Motors & Drives, Inc. denies the warranty claim, AMD will promptly communicate the reasons of denial of the claim

5.4 If Customer disagrees with the determination, Advanced Motors & Drives, Inc. and Customer will discuss the determination in good faith and solve the warranty claim amicably. If the determination cannot be resolved amicably, then Item 9 of the Warranty Policy shall apply.

6. Remedy

6.1 Approved warranty claims: Advanced Motors & Drives, Inc. will credit the customer with an amount agreed with the Customer and not higher then the original purchase price, or replace the motor free of charge, within 60 days of the warranty claim determination.

6.2 All credits issued under this Policy will be issued to the Customer's account. The Customer will not debit Advanced Motors & Drives, Inc. without specific written approval from Advanced Motors & Drives, Inc. or Kinetek's Controller or Finance Officer.

6.3 The remedy as stated under Item 6 provides for complete responsibility of Advanced Motors & Drives, Inc. for all warranty claims for non-compliance, or defects.

7. Limitations and Exclusions

7.1 The Limited Warranty applies exclusively to motors that have received normal use and service, and their application was approved by Advanced Motors & Drives, Inc. before purchase.

7.2 The Limited Warranty does not apply to: a). any motor that was dismantled, repaired or altered without prior consent from Advanced Motors & Drives,

R.A. Issued November 24, 2009
Rev A. April 20, 2010

New AmP™ Motor Warranty

6268 E. Molloy Rd – E. Syracuse, NY ▪ Tel: (315) 434-9303 ▪ Fax: (315) 432-9290

Inc. ; b) failure of the motor was the result of improper installation, vehicle accident or misuse.

7.3 The Limited Warranty does not apply to component parts that are subject to wear, for example bearings, brushes or seals.

7.4 This Limited Warranty does not cover any damage to the vehicle, compensation for loss of time or inconvenience, and does not provide for any liability for incidental or consequential damage arising from the use of the motor by its buyer, its assignees, Customers, agents or employees.

8. Disclaimer

Except for the Limited Warranty set forth above, Advanced Motors & Drives, Inc. makes no other representation or warranty, expressed or implied, arising by operation of law or otherwise, with respect to any product including, without limitations, the warranties of merchantability and fitness for a particular purpose whether or not the use or purpose has been disclosed in specifications, drawings or otherwise, and whether or not any product if specifically designed and/or manufactured by Advanced Motors & Drives, Inc. for the Customer' s use or purpose. The warranty set forth above is given in satisfaction of any and all obligations or liabilities of Advanced Motors & Drives, Inc. to any Customer, or any third party, with respect to the product, whether such liabilities or obligations arise out of contract, negligence, strict liability, tort or otherwise. Advanced Motors & Drives, Inc. shall not be liable for any property damage or personal injury to any Customer or third party, with respect to the product. Advanced Motors & Drives, Inc. shall not be liable to any Customer or any Customer's owners, officers, agents, employees, or subcontractors, or otherwise for any indirect, consequential, incidental, special, punitive or exemplary damages including without limitation damage or loss of profits or revenues, even if Advanced Motors & Drives, Inc. has been advised of the possibility of such damages.

9. Dispute Resolution

The interpretation, performance and completion of all transactions under the Limited Warranty Policy shall be governed by the Laws of the State of New York, without regard to or application of its principles, procedures or laws regarding conflicts of laws.

R.A. Issued November 24, 2009
Rev A. April 20, 2010

General Information

NetGain Motors, Inc's. ***AmP***™ and ***WarP***™ motors are contract manufactured in the USA. We utilize NetGain's engineering and racing expertise to help design motors that will perform under the unusual operational dynamics of electric vehicles.

All aspects of an electric motor have been considered - from the components to the methodology of assembly - to make a motor that would offer excellent performance in an electric vehicle.

Electric motor components are a critical aspect of an electric vehicle. The bearings, shaft sizing and material, commutator, brush rigging and brush composition, field and armature windings, armature laminations, and insulation quality are all critical aspects of an electric motor. Assembly steps critical to performance are clearances, brush "break-in", the insulation, and overall quality of workmanship.

Many DC motors are made to meet class F temperature rating (155º C.), our ***AmP***™ and ***WarP***™ motors all utilize class H insulation materials rated at 180ºC. Our ***AmP***™ and ***WarP***™ motors have been stress tested to 205ºC. Whether using your DC motor for drag racing or for an everyday EV, temperatures should normally never approach 180ºC. ***AmP***™ and ***WarP***™ motors have internal fans and a temperature snap switch (normally open) as a standard item. Depending upon the motor model, this switch will close at 120ºC or 150ºC. in order to allow protection of the motor and all its components (assuming the proper circuitry has been implemented by the user). High volume fans not only help dissipate motor heat, but also help clear carbon dust from the motor, thus preventing a possible flash-over and would-be damage.

It is important that you periodically use compressed air to blow out any carbon dust that may have accumulated within the motor. As very fine carbon and graphite dust will be exhausted **it is important to wear a mask that covers your nose and mouth, as well as goggles (not glasses) for your eyes.** Those in close proximity to the motor should also observe these precautions.

Compressed air should be directed at the brushes and armature and should exhaust through the fan end of the motor. If proper caution is taken, this can be accomplished with the motor spinning in order to help exhaust the carbon dust. Once the commutator end of the motor has been blown, it is also advisable to blow the drive end of the motor in a similar manner, and to then repeat the process.

Motor ratings are given for the normal range of the motor's operation under various voltages and loads. Ratings with forced cooling have not been done since there are many variables that cannot be controlled to allow the data to be useful. Motors will perform closest to their initial HP output the cooler they are kept within normal operating temperatures!

Some larger DC motors have interpoles. Due to the compactness of most motors 9" or less in diameter, in these horsepower ratings, interpoles are difficult to fit inside. Our ***WarP 11HV***™ motor does have interpoles and is thus able to withstand higher voltages. By default all of our other motors are advance timed at the factory in order to handle voltages as high as 170 Volts to the armature. Though many users have exceeded this voltage, we do not condone it. If there is a need to run at a higher voltage, there are motor modifications that may help that are not in our normal product line. Contact us if you have a specific need not addressed by our stock motors.

Lastly, please remember that ***AmP***™ and ***WarP***™ motors offer distinctive standard features on every motor that we feel make it the best choice for an electric vehicle motor in the industry. Some of these features may include:

Motor Features

- ✔ Specifically designed for street and racing EV's
- ✔ Top quality, sealed, steel bearings with high temperature grease
- ✔ Motor temperature snap switch
- ✔ Motor temperature thermistor / diode (most models, effective 2010)
- ✔ Brush Wear Indicators (some models, effective 4/2007)
- ✔ High efficiency fan
- ✔ Fully counter-sunk field pole bolts for a clean/smooth appearance and to provide reduced clearance requirements.
- ✔ Optimized brush timing
- ✔ Oversize brushes
- ✔ High quality brushes- not "quick-seat"
- ✔ Fully 90% plus brush wear-in[1]
- ✔ Heavy duty, vibration resistant, brush springs
- ✔ Predrilled, advanced timing holes for higher performance
- ✔ Class "H" insulation temperature rating throughout the motor
- ✔ Best in class patented varnishing process, includes "flooding the cases to ensure no insulation gaps!
- ✔ Voltage ranges starting at 48 Volts
- ✔ Interlocking commutator construction
- ✔ High peak motor efficiency
- ✔ Dynamically balanced armatures
- ✔ Hand made in the U.S.A. by experts

1 The brush wear-in process is completed before the brushes are placed into the enclosure so that no carbon dust is allowed into the motor.

To ensure that we are on the same page when talking about the motors, we provide some lingo, or "motor speak" terminology.

Motor Lingo

Motor Frame or Case

This is the rolled iron field ring that holds the motor field pole shoes. The holes around the field ring represent the field pole shoe bolt holes. There may be 4 sets of 3 holes each on the (**WarP 9** ™ and **WarP 11** ™), 4 sets of 2 holes (**ImPulse 9** ™, **AmP 8** ™) or 8 sets of 2 holes (**WarP 11HV** ™). Additionally, there may be lift-eye holes around the field ring – usually between the field pole bolt holes. The field rings are lathe bored and the end surfaces are machined to provide mounting for the end brackets.

Illustration 1: Field Rings, Motor Frame or "Case"

Complete Motor Armature

These are completed armatures. The double bands around the armature stack allow these motors to handle higher RPMs more gracefully. The complete armature also includes the commutator.

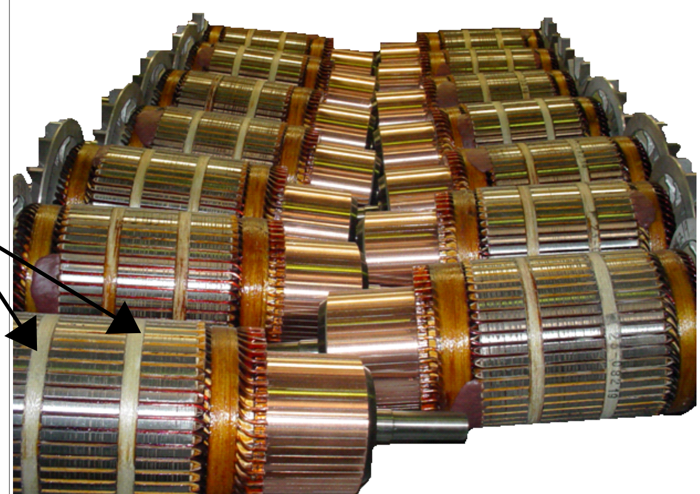


Illustration 2: Complete armatures

Brush Ring

This is the "ring" that the brush holder is attached to. The ring is then bolted to the aluminum commutator end bell

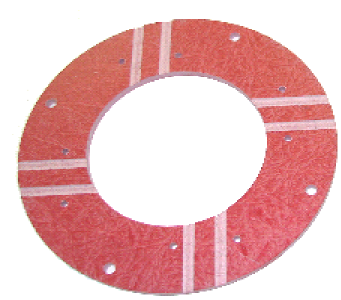


Illustration 3: Brush Rings

Motor Lingo

Motor Armature Shaft

These are armature shafts. They are machined to exacting tolerances to accommodate the application. Bearings will eventually be pressed onto both ends.

Illustration 4: Armature Shafts

Terminal Studs

These are the terminal studs, 3/8” on the left and the new style 1/2” size on the right.

Illustration 5: Terminal Studs

Armature Stack

The armature stack consists of laminated discs made of a magnetic steel alloy pressed onto a keyed shaft. Every motor requires a specific number of discs that have been calculated to provide the desired performance curve. Discs are weighed to determine the proper amount and even a single disc discrepancy will be detected by the balancing process.

Illustration 6: Armature Stack - laminations

Motor Lingo

Armature Wire

The armature wires used in our ***WarP 9*** ™ motors are 0.091 inches by 0.365 inches. They start out as a long flat wire and then go through a process to bend them to the exact shapes needed for an armature. The ends have the insulation removed so they are suitable for welding.

Illustration 7: Armature Wire

Commutator End (CE) Bell

These aluminum housings are the commutator end bells. The new style with Helwig-Carbon brushes is on the top, while the lower one is representative of the earlier models. Notice the 1/2" terminal studs, 4-wires per brush pair, dual wafer, and red-top brushes. These brackets encase the armature bearings in precision machined cavities to support the armature in the magnetic field structure of the frame. The commutator end bell supports and precisely locates the brush rigging assembly and the armature shaft. The armature shaft may be used for RPM sensors, alternators, air conditioning, power steering or other appliances.

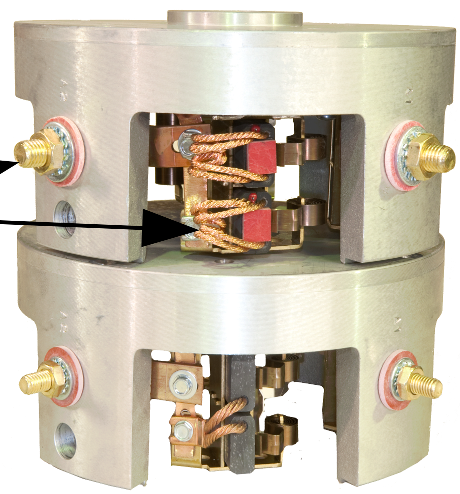


Illustration 8: Commutator End Bells (CE)

Drive End (DE) Bell (or Bracket)

Our brackets are made of aluminum to provide a lower overall weight essential in electric vehicles.

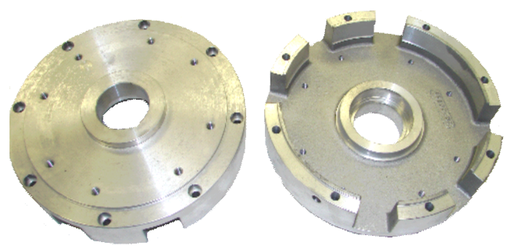


Illustration 9: Drive End Bells (DE)

Motor Lingo

Shunt Wires

These are the wires that come out of the brushes.

Brushes

The new style brushes from Helwig-Carbon with 4-wires per brush pair, dual wafer, and red-tops are on the left, while a more conventional brush is shown at right. Also notice the difference in color between the brushes which indicates a different formulation that is used in these high performance brushes.

Illustration 10: Shunt Wires and Brushes

Thermal Switch, Temperature Snap Switch/Nuisance Switch

This is a snap switch (Normally Open "NO) and may be terminated to a plastic plug identical to the BWI (newer design), or may be 2 wires extending from the motor case (older design)

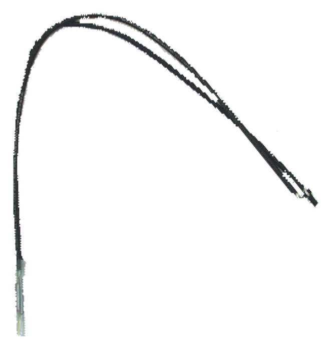


Illustration 11: Temperature Snap Switch

Connectors for Instrumentation

This is the connector that is used for connection to a BWI (Brush Wear Indicator**)** if the motor is so equipped. They accept 1/4" female spade connectors. If a motor is equipped with BWI this connector will be located in the aluminum end-bell. These same connectors are also used for connection of the temperature snap switch, and for the thermistor. These two connections will be in the motor frame, and the thermistor will have a "+" and "-" symbol stamped in the case to designate which is which.

Illustration 12: BWI and Temperature Snap Switch Connections

Motor Lingo

Brush Rigging

Electrical "switching" of the motor takes place between the commutator and the brushes. The brush ring may be made of a phenolic plastic ring that locates and supports steel studs or holes that support and precisely locate the brush holders at the proper angle in relation to the commutator. Brush springs

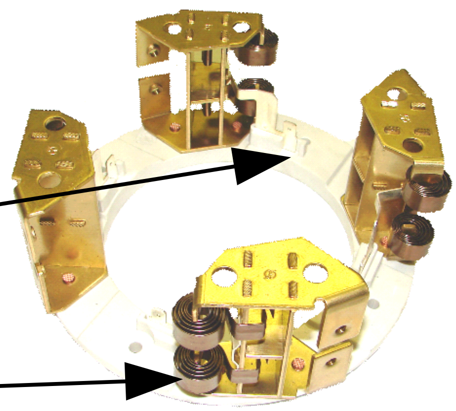


Illustration 13: Brush Rigging Assembly

Brush Holder

Brush holders are generally made of bronze and are machined to allow the precision made brushes to slide easily up and down. A spring is used to apply pressure to the brush that holds it in contact with the commutator. In this photo a brush wear indicator connection is also shown.

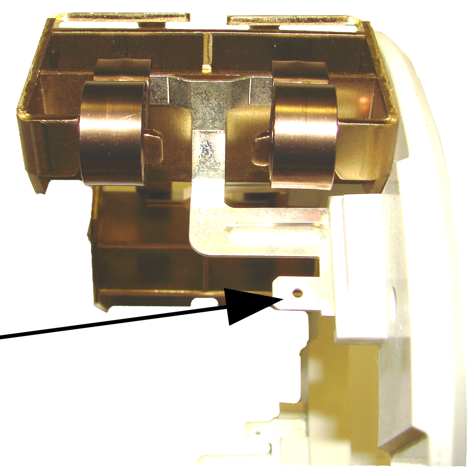


Illustration 14: Brush Holder

Interpoles

Most of our motors do not use interpoles. If so equipped, the interpoles are constructed similar to these, and they will be placed between the field coils.

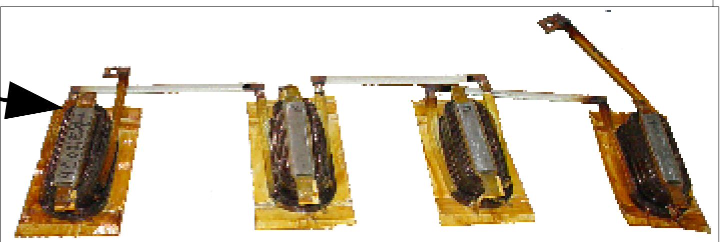


Illustration 15: Interpoles

Motor Lingo

Commutator

The commutator (collector) contains a number of copper bars that the brushes will contact. The number of bars must match the number of "slots" in the armature laminations. Varying the number of bars and slots allows motor performance to be modified.

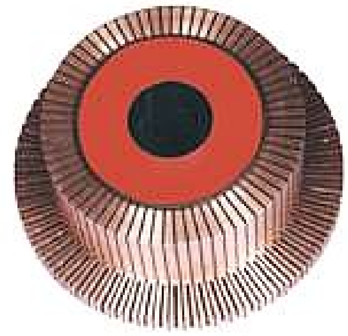


Illustration 16: Commutator

Bearings

Our motors use very high quality sealed bearings that are rated to 14,000 RPMs.

Illustration 17: Bearings

Brush Springs

The brush springs provide pressure on the top of the brushes to ensure the brushes maintain proper contact pressure with the commutator.

Illustration 18: Brush Springs

Motor Lingo

Field Pole Shoes

The field pole shoe consists of laminations which are riveted together to form a single structure. Laminations are critical because they allow magnetic flux to pass along the length of the lamination, but do not allow electrical eddy currents to pass from one lamination to another.

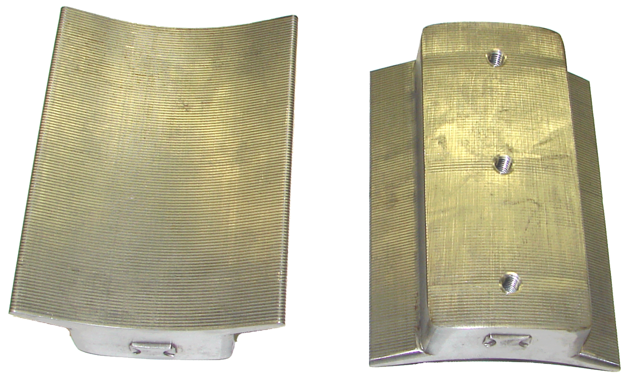


Illustration 19: Field Pole Shoes

Field Coils

The field coils consist of an exact length of carefully wound flat copper ribbon insulated with NOMEX® between turns and then covered in insulating varnish. Each coil is shaped to the contour of the inside dimension of the frame assembly. After insertion into the frame, the entire frame will be flooded with insulation varnish and baked.

Illustration 20: Field Coil Assembly

Cover-band

This may also be referred to as the "brush guard". It is designed to keep debris from entering the motor. There are numerous variations and styles such as the forced-air (shown) or ventilated (shown)

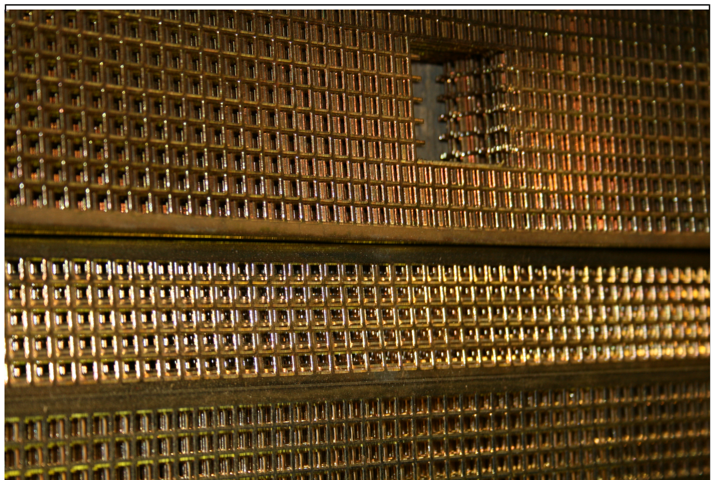


Illustration 21: Ventilated brush guard

Illustration 22: Forced air cover-band

Motor Characteristics

Timing Marks

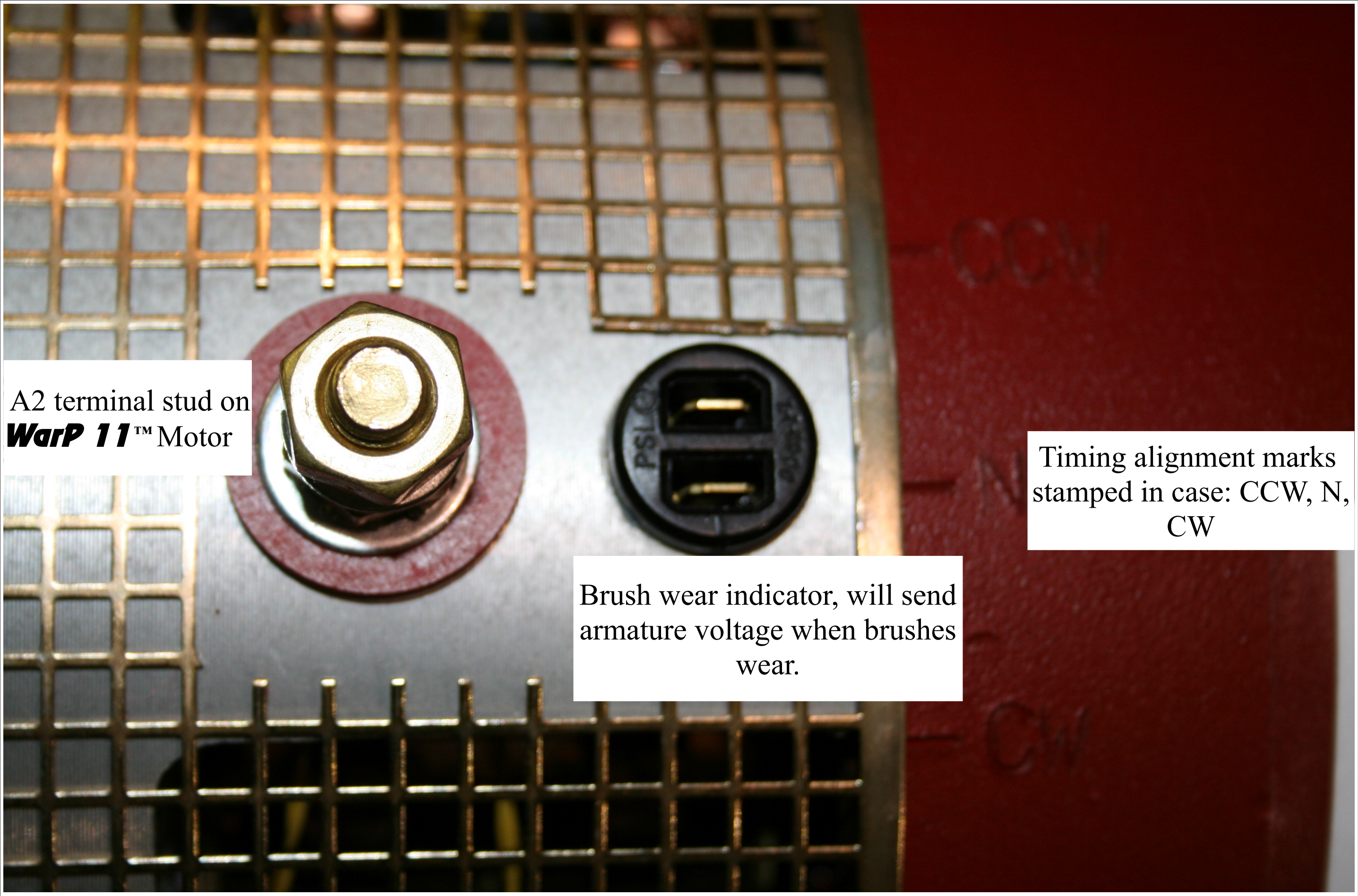


Illustration 23: Motor Timing Marks

The timing marks will align with a bolt in the CE end-bell. There are twelve holes pre-drilled and tapped into the case that allow the end-bell to be rotated to a Neutral position (**N**), a Clock-Wise (**CW**) when viewed from the Drive End of the motor, or Counter-Clock-Wise (**CCW**). The A2 terminal stud happens to align with the "**N**" Neutral timing mark when the motor is actually advanced **CCWDE**. It is not the terminal location that determines the timing, but rather the BOLT that holds the end bell to the steel case.

In the neutral timing position the motor will perform the same regardless of rotation and will provide equal power in both rotations (**CW** and **CCW**). If the motor is to be rotated primarily in a single rotational direction, performance of the motor in that rotational direction may be increased (higher RPMs per volt, less arcing, lower amp draw at higher torque level, higher voltage) by having the timing set for the normal rotational direction. Performance will be decreased when the motor is then rotated in the opposite direction of the favored timing. Full power should be avoided when the motor is operated in the rotational direction opposite the favored timing, or damage to the motor may occur.

Motor Characteristics

Motor Rotation

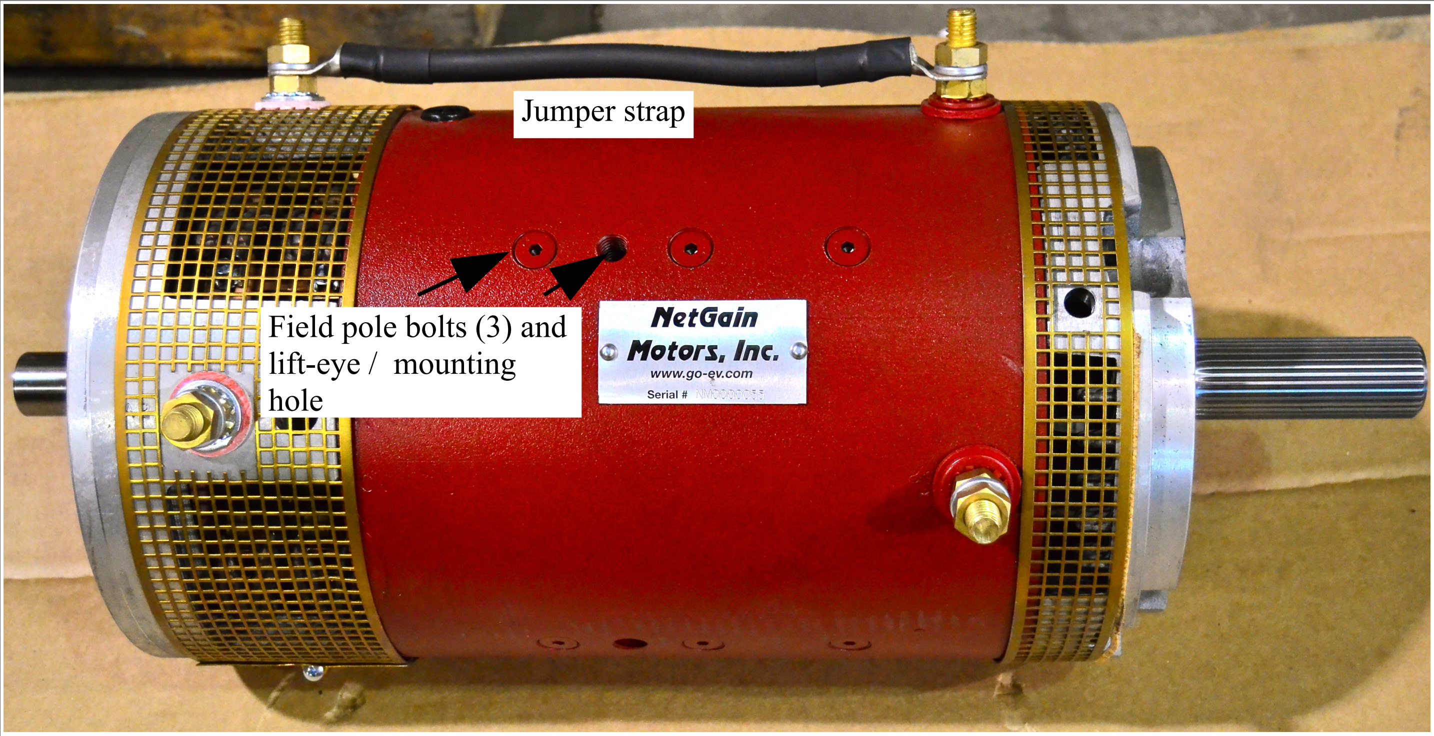


Illustration 24: Motor Rotation

The direction of series wound DC motor rotation is not affected by the polarity of the input power source. The direction of rotation is determined by the sequence in which fields are energized. The cable jumper strap shown above may be positioned either between the A1 (Armature) terminal, and the S1 (Stator) terminal, or the A2 and S2 terminals in order to effect a counter-clockwise rotation when viewed from the Drive End (DE) of the motor.

If the jumper strap is placed between A1 and S2, or A2 and S1 the rotation of the motor will be in the Clock-Wise (**CW**) rotation when viewed from the DE of the motor – regardless of input polarity from the power source.

Though it does not matter to the motor whether it is wired (A1-S1, A2-S2, A1-S2, A2-S1) some controllers do require a specific connection arrangement. Precedence should always be given to the controller manufacturers recommendation or possible damage to the controller may result. In Europe it is common to wire the motors to reverse the armature (A1, A2), while in the USA we normally reverse the field (S1, S2).

Total allowable indicator run out on shafts is .002". Shafts are continually checked to ensure tolerance compliance through the entire manufacturing process. The raw stock used on 9" diameter motors is 1 5/8", while the raw stock for 11" motors is 2.25".

NetGain Motors, Inc. strongly encourages the use of single wafer brushes in ***WarP*** ™ motors that will spin CWDE! CWDE will also require a change in the timing of the motor, both of these options may be requested from the factory at extra charge. This is not necessary for ***AmP*** ™ motors.

Motor Mounting

The bearing can accept axial loads (thrust) (See attached Special Update), so if the motor is coupled directly to the propeller shaft of a boat (or aircraft) it is not necessary to use a separate thrust bearing. In such an installation the shafts should be connected by a universal joint or the motor should be on flexible mounts symmetrically positioned around it. The motor can withstand occasional splashes of fresh water when it is running, but it should be protected against falling rain, sea water, oil (and other liquids that are corrosive or that do not evaporate without leaving a deposit) or direct impingement of water thrown off the wheels of a vehicle. It should not be in a small unventilated space, except in low current or intermittent applications. Note that when the motor is used with an electronic controller the current in the motor can be several times the current being taken from the battery when the motor is running slowly. The motor should not be mounted where a flammable or explosive atmosphere could be present. The motor should be connected using cables suitable for the current at which the motor will be run.

When attaching driven components to the shaft, lock the shaft against rotation by holding the driven component with a suitable tool. Do not try to lock the motor by pushing anything through the ventilation holes or into the motor to jam the armature as this could cause serious damage. Components which are a tight fit on the shaft should be pressed using suitable distance pieces, and removed using a puller whose pressure screw presses on the end of the shaft. The use of a hammer or lever is likely to damage bearings, making them noisy and shortening their life. Taper locks may be used to fit components to the shaft; they avoid the need for force fits and also prevent fretting. Care must be exercised that the correct key-stock is used on shafts. Using a key-way with a taper-lock adapter can cause some minor distortions or even cracking of the armature shaft if tightened too hard.

Total allowable indicator run out on shafts is .002”. Shafts are continually checked to ensure tolerance compliance through the entire manufacturing process. The raw stock used on 9” diameter motors is 1 5/8”, while the raw stock for 11” motors is 2.25”. Normal key stock is economical 1018 grade, not rated for hardness, 416 stainless may also be used.

The motor should be protected from road debris, liquids, dust, etc. as much as possible. We highly encourage the use of an air filter and blower motor, such as the one pictured below.

Illustration 25: Forced Air Cover-band and Blower example

Motor Timing

Most motors are assembled at the factory with the brush timing set in the 'advanced' **CCW** (Counter Clock-Wise) position when viewed from the **DE** (Drive End) of the motor. This provides maximum efficiency for most vehicular applications with the exception of some Honda vehicles. Most Honda vehicles will require a **CW** advancement of the brushes. You should ALWAYS know the desired rotation for the particular application of a motor. Incorrect timing may cause significant performance degradation, motor damage, and safety issues. Advanced timing may also be referred to as "favored timing".

If the motor will be run in only one direction, or in one direction most of the time, but with occasional reversing at low power, then the efficiency at high power can be increased by 'advancing' the brushes. All ***AmP*** ™ and ***WarP*** ™ motors ship in an advanced CCWDE rotation unless otherwise specified.

To change the brush advance, remove the four bolts that hold the Commutator End (CE) bell in position (see photo) and turn the CE end bell until the CE end bell bolt holes align with the stamped marking in the case for the desired timing. For an application in which the current will always be high (150A or more) or where the voltage will exceed 72 Volts, advance timing should be considered.

The A2 terminal stud **SHOULD NOT** be used to set motor timing. Notice that in this example the timing is set to advanced CCWDE, while the A2 terminal stud aligns with the "N" Neutral timing mark! This motor is correctly timed advanced CCWDE.

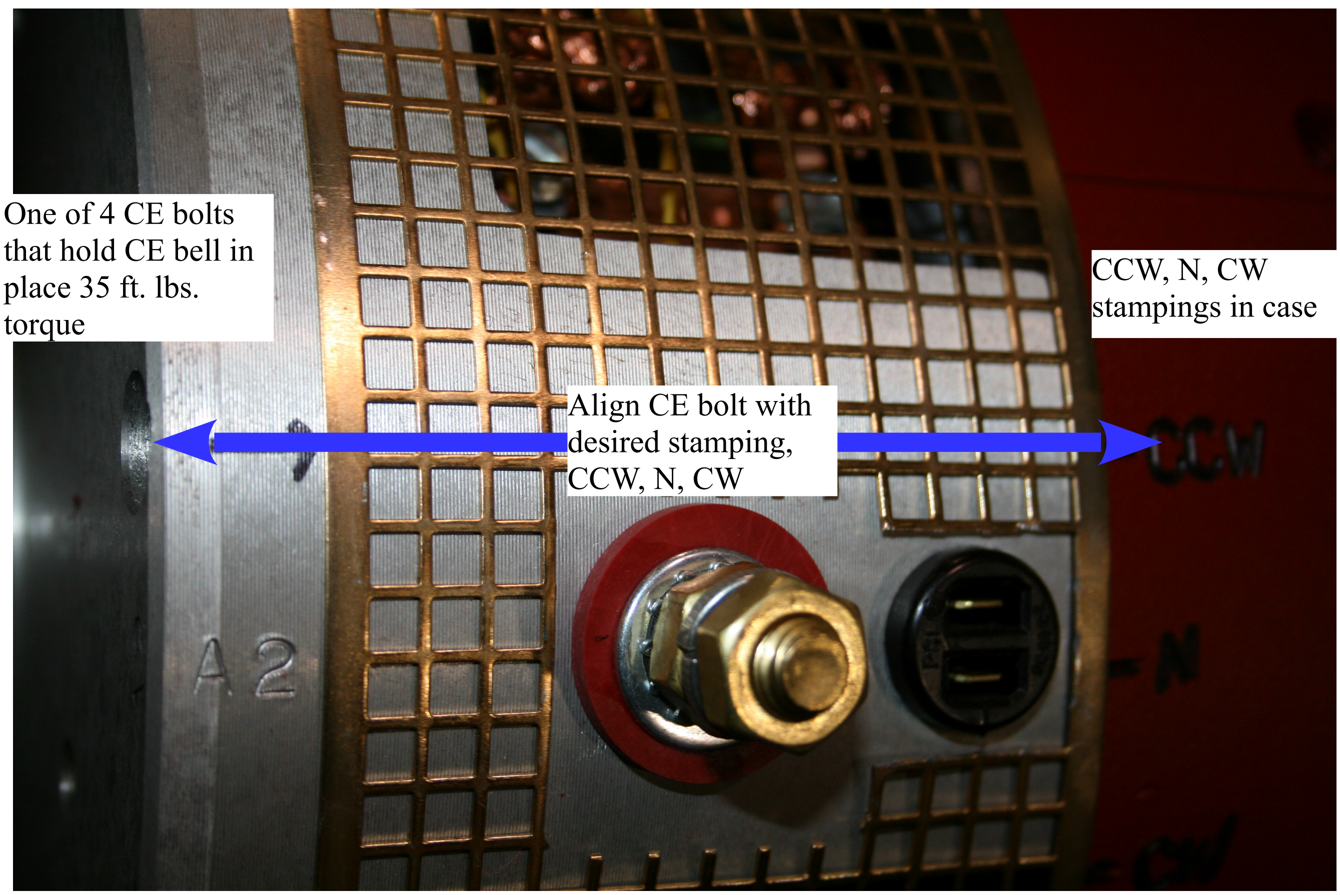


Illustration 26: Motor Timing - Bolt Alignment

Motor Timing

This image shows the 4 clusters of 3 timing holes drilled at 90-degrees to one another around the edge surface of the field-ring. Each cluster of three drilled holes and tapped holes represents a timing position for either neutral (center position of each cluster) or favored timing clockwise or counter-clockwise.

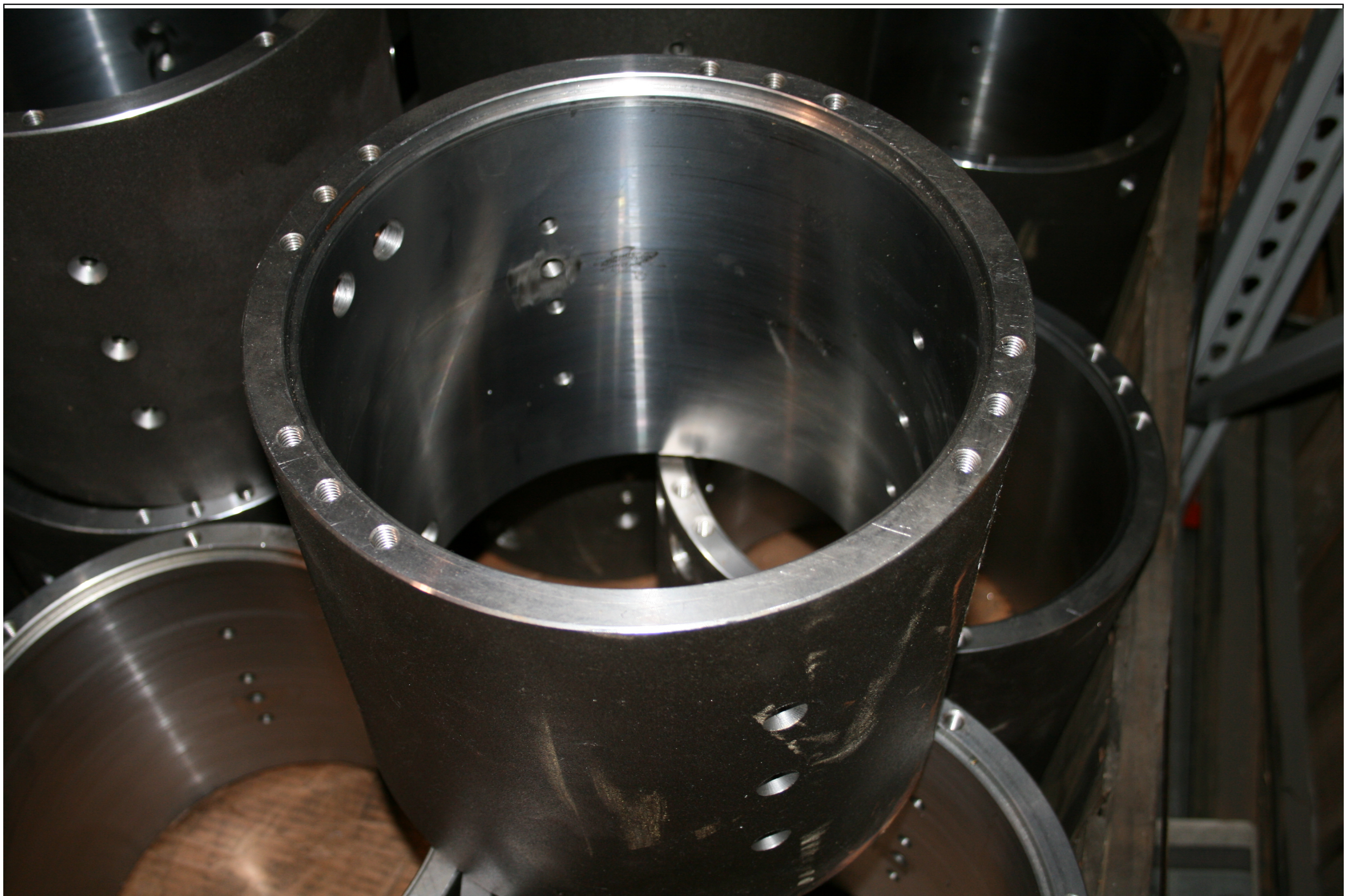


Illustration 27: Staic timing holes in field ring

The aluminum commutator end bell (CE head) will be bolted to this field ring for the appropriate timing.

Bolt Torque Specifications

It is important to fasten all bolts to the correct torquing specification. A bolt that has been over tightened can be just as lethal as one that hasn't been tightened enough. A bolt that has been tightened beyond recommended torque specs can easily break in service. Use the following data to determine the correct torque specification for each bolt. Please verify all dimensions with the matching engineering drawing for your motor.

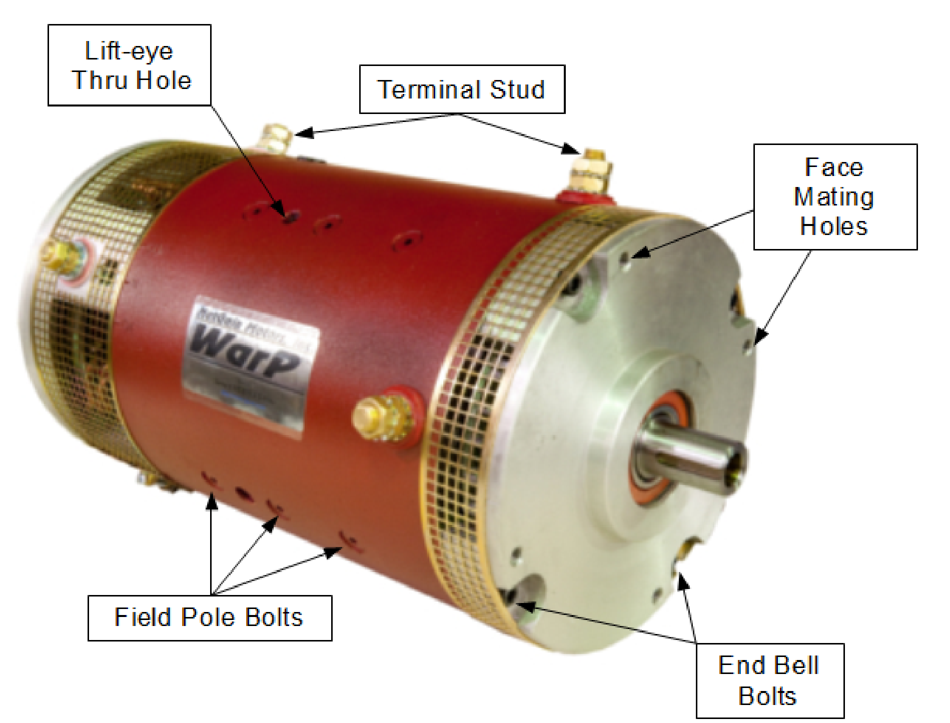


Illustration 28: New Style WarP 9 ™ Torque Specifications

Fastener	Torque (lb/ft)	Notes
Field Pole Bolts	25	
End Bell Bolts	35	
Terminal Studs – New Style	11	1/2”-13 x 2-1/2” Long
Terminal Studs – Old Style	9	3/8”-16
Face Mating Holes – Drive End	20	3/8”-16 x .80” Deep
Face Mating Holes – Commutator End	14	5/16”-18 Thru Hole
Lift-eye Thru Hole	**Do Not Torque**	Fasten no more than 9/16” bolt thread length

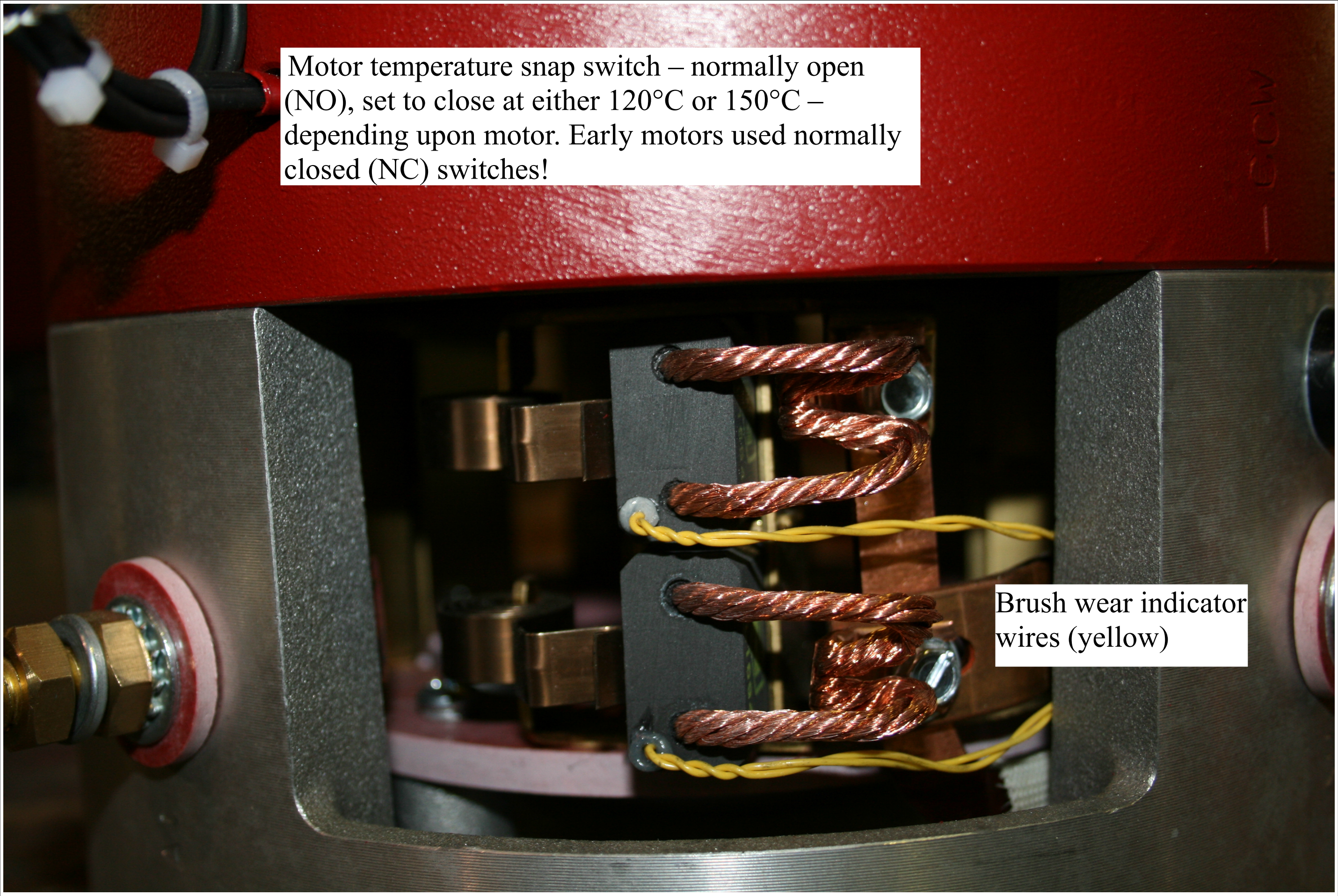


Illustration 29: Brush Wear Indicator Wires

Brush Wear Indicator

The thin yellow wires in this image are the "brush wear indicator wires". There is one going to every brush if your motor is so equipped. Not all models have this feature.

The brush wear indicator normally has no voltage on it. When brushes wear to the point where two brush sets at 90 degrees to one another both contact the armature, the armature voltage will be seen at the indicator plug (see next image). The indicator plug uses female 1/4" spade connectors.

NOTE: Motors produced prior to 1/1/2011 ***MAY*** use "NC" (Normally Closed) snap switches. You must check to determine what your motor has.

Brush Wear Indicator

Illustration 30: Brush Wear Indicator Plug

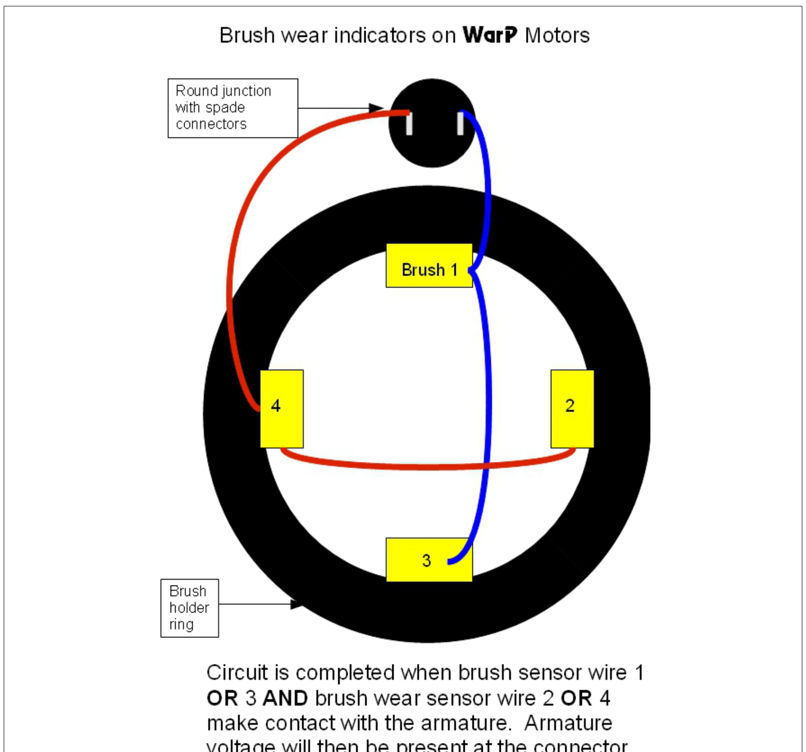


Illustration 31: Brush Wear Indicator Wiring

Brushes

General Brush Information

DC motor brush wear is the result of mechanical friction between the brushes and the commutator, as well as electrical erosion of the brush material. A brush compound that is well suited to an application will result in an electrical erosion of the brush material with very little physical residue. Brushes should typically last 2,000 hours. This time is very dependent upon various factors, including temperature, spring pressure, atmospheric conditions (humidity, ambient temperature), current loading, RPMs, and other factors. High humidity is generally better for brushes than low humidity.

There is a relatively high coefficient of friction between the brush carbon and the bare copper bars of a commutator. Over time, a patina or "film" will develop on the commutator. This "film" can reduce the coefficient of friction to 10% of the original bare copper bar value. A good patina is important and the use of commutator stones used to seat the brushes and shine the commutator should be discouraged.

Silicone sealer and any and all silicone products should be avoided in or around brushed motors! This includes silicone vapors! The use of uncured silicone products will result in extremely rapid degradation of the brush compound and may cause severe motor damage. Completely cured silicone products may be used.

The faster a motor spins, and the higher the amps fed to the motor, the more likely you are to see arcing and sparking. This arcing and sparking will greatly reduce the brush life. Arcing and sparking may also be the result of brushes that are not seated properly. The best method of seating brushes that have not been properly radius-ed to match a particular commutator is to cover the commutator with very fine emery paper and then spin the armature. Ideally, this would be done externally to the motor (i.e. a bench arrangement) so as to minimize the amount of carbon dust that can enter the motor.

Proper operation of a motor requires a good patina film be present. A good patina film requires:

- Proper brush size to carry the current being applied
- Proper brush pressure
- Humidity at proper level
- Commutator RPM within limits designed for motor operation
- Lack of abrasives and other contaminants
- Proper brush material and grade
- Mechanical integrity of brush rigging and commutator.

There is no single brush composition that will give good brush life in all applications. The application must be understood to arrive at a brush composition that will work well, and allow for proper patina filming to occur.

RPMs also affect brush life rather dramatically. A motor running at 3,600 RPMs will wear brushes approximately twice as fast compared to the same motor running at 1,800 RPMs.

To achieve the longest brush life, the brushes must be designed properly for the application and the environment. Brushes should never be used that will handle the maximum, but rather the normal load the motor will be faced with. If the motor is sealed, it should be periodically inspected and compressed air should be used to blow dust from the motor. It is best to start at the fan end of the motor and blow compressed air towards the brush area. Then blow compressed air into the commutator end of the motor and ensure that all dust is removed from around the brushes (they should travel freely), as well as around the commutator.

Saltwater is very corrosive to most metals, so one of the issues in this case is the corrosion of all of the copper parts. As the commutator becomes corroded the contact from the brush to the commutator will be compromised.

Brushes

To clean the commutator you may need a special brush grade that will incorporate some abrasive material to help with cleaning. The trade off is the abrasive material will also accelerate the wear of the commutator.

Brushes are somewhat porous and will absorb the saltwater and as the brush heats up the water will evaporate and the salt will be left behind within the brush. This will form an abrasive and help to accelerate the wear of the brushes and the commutator. Brush grades that are designed for operation in a chlorine environment may be a benefit in saltwater applications.

Brush Grades

This is a brief description of the various brush grades commonly used in AmP ™ and WarP ™ motors:

- **K254**: This grade was originally developed for use in low voltage fork lift truck applications. It should be used in motors that will see a max operating voltage of 80 Volts. In some specialized cases this could be increased to 120 Volts. This grade has a low contact drop and will take some overload but should be limited to roughly 350 Amps for 30 seconds or less. The amount and duration of current it can handle depends upon how well the motor is ventilated. This grade does not have the ability to clean the commutator after a current overload.
- **H60**: This grade was originally developed for use in traction applications. Traction applications consist of high overloads with periods of coasting and some low load operation. This grade has a high contact drop (good for high voltage motors) and good filming capability (better dry lubricant and wear life of the brush and commutator) and will work best in most “daily driver” EV applications. This grade can handle the occasional high current overloads from any size controller, as long as the ventilation is good and the overload amount and duration are not so extreme as to allow the brush to overheat. This grade has some cleaning ability and is very hard and strong and therefore will take some time to seat in. The long seat in time (typically as long as 48 hours) is an indication that it will provide a long wear life. A variation of this brush is suitable for cold weather applications (H60C) where the motor is being operated for extended periods in temperatures below 40º F.
- **H49**: This grade was also developed for use in traction applications. But, this grade is a little different from others in that it is designed for medium contact drop and low filming. This grade will work well in high voltage high power applications where there is very little operation at low loads or coasting. For proper life the motor will have to be maintained at or above 200 Amps per sq. in. of brush surface area. This grade would be best suited for racing and high performance applications. This grade can handle occasional high overloads from any controller, as long as the ventilation is good and the overload amount and duration are not so extreme as to allow the brush to overheat. This grade has more cleaning ability than other grades and is a bit softer than the others, so it may bounce slightly less. This brush seats very quickly, but it may also require the regular use of compressed air to expel carbon dust from the motor. Seating time will typically be as little as 6 hours.
- **H100**: The original brush used in AmP ™ and Warp ™ motors. The brushes originally used served well in applications where PbA (lead acid) batteries were used. The shunt wire diameters were increased over the original fork-lift design and the shunt wires were insulated in some models for better reliability and performance. In the proper application these brushes are a low-cost alternative to the higher performance compounds and still offer extremely long life, durability and performance when used with controllers under 1,000 Amps, or when used with PbA batteries.
- **T300**: The current brushes used for most EV's (other than OEM and dedicated racing). These are dual wafer design similar to the Helwig-Carbon brushes but they will run cooler in most street applications. They can handle high currents for brief duration (1400 Amp peak) and are a good choice for street driven EV's with Lithium batteries.

Brush Seating

In order to commutate most efficiently, brushes must be properly seated. The process of seating brushes can take minutes, hours, days or even weeks of time depending upon the brush composition (grade), and how closely it matches the motor specifications (brush angle, commutator contour, etc.). Here is a link showing how brushes should be replaced: http://www.youtube.com/watch?v=DM-PiNqYHC8

The seating process can be expedited in many ways. In some cases, the brushes may be contoured outside the motor. This is the preferred method and can generally get the brushes to within 5-10% of proper seating. This process is best accomplished at the manufacturer as it may require a specialized piece of equipment.

Another method allows for a non-metal bearing sandpaper or garnet paper (medium coarse grade) to be pulled under the face of the brushes. Emery paper should never be used for this purpose as the abrasive is normally conductive! Any dust that results should be vacuumed or blown out of the motor. After this process is complete, the motor should be run at no-load for the final wear-in process. Here is a link to a video describing the seating of brushes. http://www.youtube.com/watch?v=_opNhsiXzMs

If there is noticeable brush noise (i.e. chatter or squealing sound) coming form the motor it may indicate a commutator surface problem, or it may be caused by a contaminate in the brush area. If a squealing noise is heard, it is normally due to a lack of proper filming on the commutator. A bar of paraffin wax may be passed back and forth across the commutator in order to speed up the filming process and quiet squealing brushes. It is also possible that a chemical, such as silicone, has been used around the motor and damaged the brushes.

By far the most common method of seating the brushes is to use a commutator stone. These stones come in various grades and sizes. Normally, a course stone would be used to remove any old film on the commutator, followed by a finer grade to seat the brushes. It is only necessary to use the course grade of stone if the brush grade is being changed, or if the commutator contains abnormal contaminants (such as a black tar-like build-up that can occur in cold weather operation). The normal method of using a seating stone is to run the motor at low power, no-load (typically 12 Volts). The seating stone is then lightly pressed against the commutator bars just before they enter the brushes. Normally only one or two passes is necessary for properly contoured brushes. This process should be repeated for each brush pair.

Sparking may occur if the brushes are not properly seated. If the sparking is severe, the sparks will extend from beneath the brushes. The greater the arcing, the greater the potential damage to the brushes and motors is.

Brush grades should never be mixed within the same motor! All brushes should be changed at the same time. Brushes should be free to slide up and down within the holders and the springs should provide enough force to keep the brushes in constant contact with the commutator.

It is critical that brush dust be vacuumed or blown out of the motors on a regular basis. The process is to normally blow compressed air into the entire brush area (360 degrees). Forced air should then be blown from the fan end of the motor towards the brushes. This procedure should then be repeated. It is highly recommended that eye and nose protection be used so brush dust is not inhaled and kept out of your eyes.

Brush Sizes & Grades Table

Brush Part or #	Motor Model	Brush Grade	Brush Size T * W * L	Brush Sq. In.	Manufacturer
10327002		?T300?	.625" * 1.250" * 1.75	.781"	NGM
10345068		H82C	.5 * 1.125 * 1.75	.5625	ADC
10399300		H100	.9375 * .625	.5859	NGM
AmP 8 AmP 9		H100	.625 * 1.00 * 1.75	.70312	GE
Standard[1] Race[2] Cold[2] Long-Life[3]	***WarP 9*** ™ ***ImPulse 9*** ™ ***TransWarP 11*** ™	H60/T300 H49 H60C H38	.625 * 1.125 * 1.5 .625 * 1.125 * 1.5 .625 * 1.125 * 1.5 .625 * 1.125 * 1.5	.70312 .70312 .70312 .70312	Dual wafer with red-top by Helwig-Carbon or T300
Standard[1] Race[2] Cold[3] Long-Life[4]	***WarP 11*** ™ ***TransWarP 11*** ™	H49 H49 H60C H38	.625 * 1.125 * 1.5 .625 * 1.125 * 1.5 .625 * 1.125 * 1.5 .625 * 1.125 * 1.5	.70312 .70312 .70312 .70312	Dual wafer with red-top by Helwig-Carbon
10499500					
10427001					
10440300					
OEM[4]		K254	.625 *1.125 * 1.5	.70312	Dual wafer with red-top by Helwig-Carbon
FULL RACE[5]					Custom designs for each motor model.

1 Standard brush used for this motor – this will take effect after 7/1/2012 – prior standard was H49 Grade
2 Race grade brushes assume a minimum of 200 Amps/sq. in., and no coasting. These brushes will dust and wear quicker than H60
2 Should be used if vehicle is used exclusively in this environment – suggested for occasional usage in warmer environment
3 Requires extensive brush seating
4 Special OEM grade that handles high humidity and cool environments under 96 Volts!
5 This option requires special brush rigging, springs, brush holders, brushes, and motor modifications performed by Helwig-Carbon

Brush Properties

Grade	Resistance	Strength	Hardness	V Drop	Friction	Film	A/Sq. In High
H38	0.0021	5400	80	M	VL	2	80
H49	0.0025	2000	50	H	L	2	100
H60	0.0021	5300	75	H	VL	3	80
H82C	0.0015	5000	64	M	L	2	80
T300	0.0008	4000	60	H	L	0	80
H28	0.0017	2600	45	M	VL	2	80
K254	0.0009	3500	40	M	L	2	80

As the brush hardness increases it becomes very important to increase the spring force to prevent brush bounce that can result in chipping and brush fractures.

The increased spring force may increase the mechanical wear of the brush, but at the same time it will reduce the electrical wear of the brush. Since electrical wear of the brush is 4 times the mechanical wear of the brush, increasing the spring force may decrease the brush wear and actually extend brush life.

Brush Change Procedure

1. Be sure all power is disconnected and no voltage is present at the motor.
2. Remove commutator end cover band (brush guard).
3. Ensure the face of the new brushes closely matches the contour of the commutator.
4. Remove the screw that holds the brush shunt wire to the brush rigging.

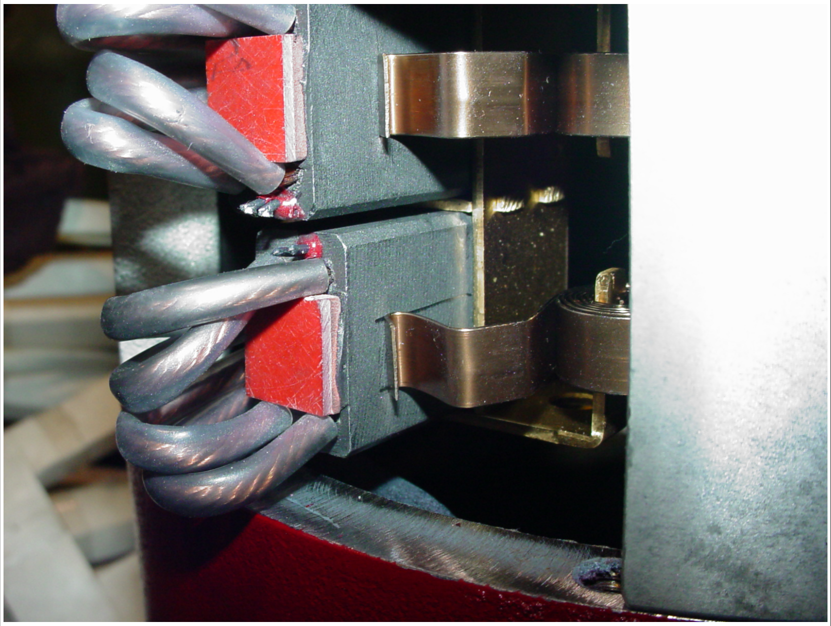


Illustration 32: Brushes Resting On Sides of Brushes

5. Lift the spring off of each brush, and then carefully lift the brush till it is out of the brush holder far enough that the brush spring can rest on the side of the brush.

6. While holding the brush spring away from the brush, remove the old brushes.

7. Making certain that the brushes are being inserted correctly for the normal rotation of your motor, insert a new brush in the position from which the old brush was removed. The brush should slide easily, NEVER force a brush into a holder.

8. Install the screw that connects the brush shunt wire pigtail to the brush rigging.

9. Replace brush spring and ensure it does not touch the shunt wires.

10. If shunt wires are not insulated, ensure they do not contact anything. Shunt wires may be bent away from any contacts.

11. Replace the cover band (brush guard)

Frame Ground Issues

One of the most common issues with brushed motors is a grounding issue that is normally due to accumulated brush dust. It is normal for the brushes to wear and therefore to create some dust. This dust is conductive and may, over time, form a path from the brush holder to ground. Any brush grade will demonstrate higher wear rate initially as the brush becomes seated. As the brush becomes perfectly worn to the comm in respect to the bottom bevel and the concave radius it will generate an abnormal amount of dust when compared to the wear rate after the seating has been completed. The time to properly seat the brushes varies from brush grade to brush grade.

The brush compound, humidity, voltage, amperage and numerous other mechanical, electrical and environmental factors can all affect how quickly brushes wear. If the proper brushes for an application are used, the minimum run-time hours should be greater than 1,000 hours. Under ideal conditions the run-time hours can be 3,000 to 4,000 hours (or more) on a set of brushes.

The dust that accumulates must be cleaned periodically from the inside of the motor. High velocity ventilation of the motor will help prevent the accumulation of this dust. It may be possible for a tube extension to be added to the compressed air blow gun will allow access to the inside of the motor.

If a frame ground condition is detected, the solution may be as simple as using compressed air to blow the accumulated dust from the motor. Ideally this would be done with the motor running so that the internal fans can assist with the expulsion of the brush dust. Compressed air will need to be blown from both ends of the motor, and, ideally, in 360 degrees around the motor. We highly encourage and recommend that appropriate masks and goggles be used for protection from the brush dust that is expelled during this operation.

If the frame ground is not cleared in the prior operation, a more aggressive method could be used that uses acetone. A squirt bottle filled with acetone will help to clean the inside of the motor and wash away the dust. The use of acetone is acceptable and will not damage the brushes or the comm, but the brushes will absorb the acetone and running of the motor prior to the complete vaporization of the acetone will cause this absorbed acetone to ignite. Compressed air may be used after the use of the acetone to help speed the vaporization of the acetone, but care should be taken as it could take some time to completely vaporize any residual acetone.

The most aggressive method of clearing a frame ground is to remove the motor from the vehicle, and to then remove the end-bells and armature. The above techniques can then be applied with greater access to internal components.

In many cases this will clear the problem without a complete rebuild of the motor. But, this is only appropriate for frame leaks caused by accumulated brush dust, and may not work in ALL instances, though the success rate is quite high.

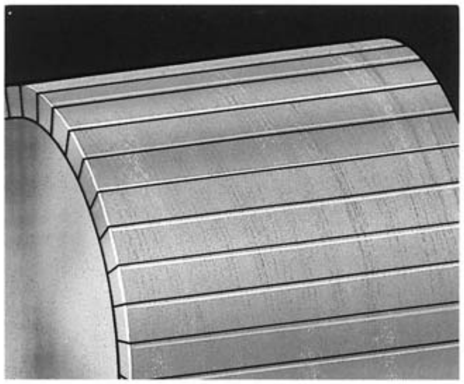
Commutator and Brush Rigging

Illustration 33: Commutator`

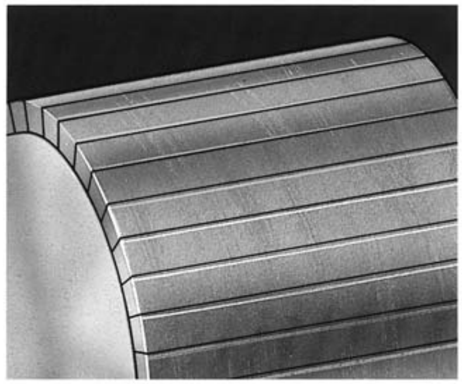
The brass bars of the commutator conduct the electricity fed to them from the brushes to the armature wires in order to create a magnetic field in the armature.

- A commutator is in good condition when it is clean and smooth with a medium polish and a light brown color.
- Keep clean by occasionally wiping with a canvas pad.
- Do not use lubricants or emery abrasive.
- If a commutator becomes rough, it needs to be resurfaced.
- If the commutator does not show any unusual wear, the brushes should NOT be removed. Removing the brushes and checking them may shorten the brush life by 50% or more!

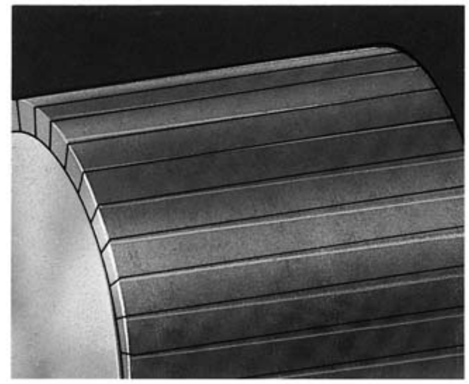
Guide To Commutator Appearance



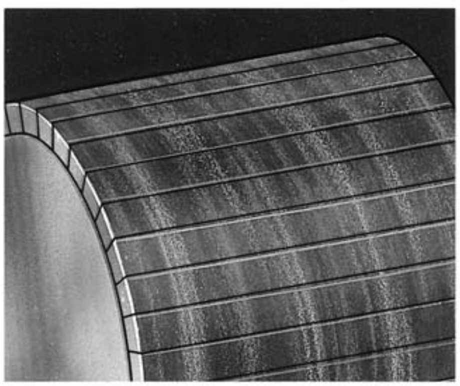
Light Film: Indicates good brush performance. Light load, low humidity, brush grades with low filming rates, or film reducing contamination can cause lighter color



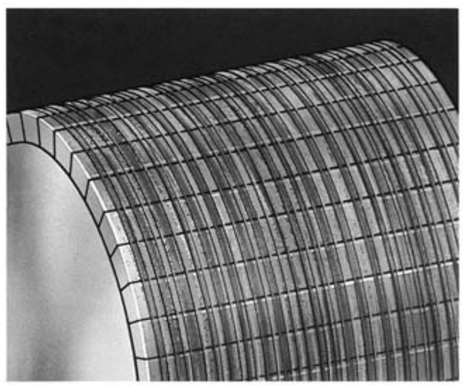
Medium Film: Is the ideal commutator condition for maximum brush and commutator life.



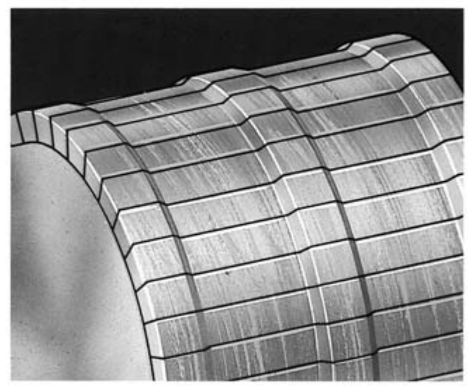
Heavy Film: Results from high load, high humidity or heavy filming rate grades. Colors not in the brown tones indicate contamination resulting in high friction and high resistance.



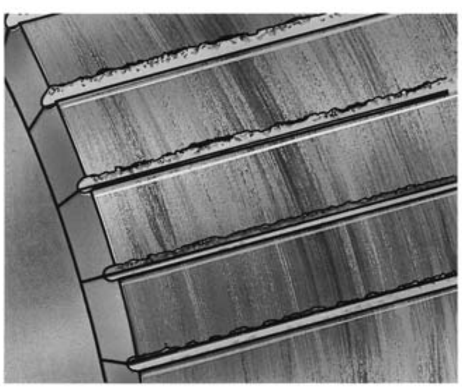
Streaking: Results from metal transfer to the brush face. Light loads and/or light spring pressure are most common causes. Contamination can also be a contributing factor.



Threading: Is a further development of the streaking condition as the metal transferred becomes work hardened and machines into the commutator surface. With increased loads and increased spring pressure this condition can be avoided.

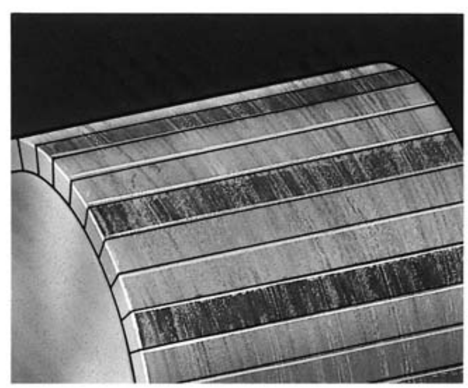


Grooving: May result from an overly abrasive brush grade. The more common cause is poor electrical contact resulting in arcing and the electrical machining of the commutator surface. Increased spring pressure reduces this electrical wear.



Copper Drag: Develops as the commutator surface becomes overheated and softened. Vibration or an abrasive grade causes the copper to be pulled across the slots. Increased spring pressure will reduce commutator temperature.

Bar Edge Burning: Results from poor commutation. Check that brush grade has adequate voltage drop, that the brushes are properly set on neutral and that the interpole strength is correct.



Slot Bar Marking: Results from a fault in the armature windings. The pattern relates to the number of conductors per slot.

6 Images and description used with permission of Helwig-Carbon, Inc.

Current and Voltage

When the motor is being ventilated by its own rotation (i.e. there is no separate fan or forced air cooling) the current (measured at the motor; we suggest that an ammeter should be installed between the motor and controller) in continuous running should not be over the figures given in the following table for the relevant voltage, also measured at the motor:

Motor Operating Voltages and Amperage							
Motor Model	**Minimum Armature Voltage**	**Maximum Armature Voltage**	**5 Minute Amperage Rating**	**1 Hour Amperage Rating**	**Continuous Amperage Rating**	**Maximum RPM**	**Maximum Continuous RPM**
WarP 7 ™ ***TransWarP 7*** ™	48	170	400	200	185	7800	5500
AmP 8 ™	48	170	400	200	180	5500	4000
ImPulse 9 ™	48	170	450	225	190	5500	4000
AmP 9 ™ ***WarP 9*** ™ ***TransWarP 9*** ™	48	170	450	225	190	5500	4000
WarP 11 ™ ***TransWarP 11*** ™	48	192	500	250	200	5000	3000
WarP 11HV ™	48	240	450	225	190	5500	4000
WarP 13 ™	48	170	550	275	225	4500	3000

Short-term current (~10 seconds) may be up to 2000A. (For racing or similar applications these figures may be briefly exceeded). RPMs should generally not exceed a speed of 5,500 RPM. The maximum RPM speed should not be exceeded even briefly; doing so can cause immediate damage, and there is a risk that the armature could suddenly burst apart with heavy pieces being ejected through the motor casing, liable to cause serious injury.

We highly encourage the use of a "scatter shield" around the commutator of the motors! The standard cover band or brush guard is not sufficient to handle an exploding commutator!

The bearings used in our motors are rated to 14,000 RPMs, and the commutator manufacturer claims all commutators are spun tested to 10,000 RPMs. Testing these claims is strongly discouraged!

The ***WarP 9*** ™ motor is UL listed. The ***WarP 9*** ™ motor is identically constructed as the 00-27001, 02, and 03 motors which are components listed in manufacturers UL File Au2489, and which meet the requirements of ANSI/UL 583 Standard for Fire and Shock Safety

Motor Cleaning

The outside of the motor may be cleaned with a damp or oily rag, or with a brush. Any cleaning products that are used should be sprayed on the rag or brush, but not directly on the motor. Do not clean the motor with a pressure-washer.

If the motor is subjected to salt water or road salt it should be rinsed with fresh water to remove the contaminants.

We highly encourage the use of a compressor to periodically blow carbon dust out of the inside of the motor case. Normally the air should be injected from the commutator end and blown towards the exhaust fan end of the motor. It is advisable to first blow the dust form the drive (fan) end of the motor, then from the commutator end. Ideally this would be done with the motor spinning so that the fan may help eject the carbon dust. It is suggested that eye protection and a mask be used to protect yourself from the carbon dust.

You can prolong the life of the motor brushes and commutator by ensuring that filtered air is blown into the motor through the commutator end of the motor. Kits are available to accomplish this. This is particularly important in dusty environments or any environment where an abrasive may enter the motor (i.e. road salt).

In cases where the vehicle is driven on salted roads, the motor should be shrouded in order to keep road salt and debris from accumulating on or in the motor.

In cold weather the owner should consider either cold weather style brushes, or a commutator stone for cleaning the buildup on the commutator. The normal brush grade suggested for use in cold weather conditions is the H60C. It is important to blow the commutator with compressed air to remove any abrasives if a commutator stone is used.

The paint used on non-OEM ***WarP***™ motors is a bright red made by James B. Day and Company, color code 26283. We have found it to be very close to the normal Rustoleum bright red. We also make motors that are black for some ***WarP***™ OEMs. The color code for our OEM ***AmP***™ series of motors is Pantone yellow 109C.

Motor Cooling

Motors come standard with high volume fans, however, these fans are only rotating when the motor is running. Consequently, we strongly encourage the use of a forced air cooling kit to help cool the motor when stopped at a stoplight, or when traveling at low speeds. Additionally, all 9” ***AmP***™ and ***WarP*** ™motors are equipped with a thermal snap switch that is **N**ormally **O**pen (**NO**) and closes at 120º C (248º F). All 11” and larger motors have a **NO** temperature snap switch that closes ay 150º C (302º F).[7] Additionally, all motors produced after 12/1/2011 are now being equipped with temperature thermistors. These thermistors may be used to monitor the motor temperature with a motor temperature gauge. The thermistor used on our motors is:

Digi-Key
 # 568-3254-1-ND (KTY84/130,113)
IC Temperature Sensor DO34
Lead Free ROHS COMPLIANT
Resistance in Ohms @ 25º C (77º F) = 603
Operating temperature range = -40º C (-40º F) - 300º C (572º F)

Contact **NetGain Motors, Inc.** for further information on Authorized Motor Dealers who can supply temperature gauges.

Cooling shrouds (Part Number: 10808219EE) are available directly from **NetGain Motors, Inc.** that allow you to connect your own 2” diameter (ID) hose and blower unit.

Illustration 34: Forced Air Cover-band for 9" Diameter Motors

Some Authorized Motor Dealers also sell entire kits, such as the one shown below:

Illustration 35: Forced Air Blower Kit for 11.45" Diameter Motors

Additional information may be found in the attached Special Update entitled: **Heat and RPM Protection Bulletin**

7 Motors produced prior to 12/1/2011 may contain snap switches that are **N**ormally **C**losed (**NC**) and open at the specified temperatures.

Routine Maintenance

The frequency with which maintenance is required depends on the severity of the application and the environment in which the motor is being utilized. In an application that does not involve high currents, dust or other contamination it could be every few thousand hours. In a vehicle used for racing, it is advisable to check the motor after each race, and, at a minimum, blow carbon dust from the motor. In racing applications it is essential to inspect the commutator often, but do not remove brushes unless a problem is suspected.

Turn the motor slowly in its normal direction of rotation at least one full revolution. There should be a faint, smooth rubbing sound from the brushes. Rasping or clicking sounds indicate a possible problem.

Take off the brush cover shroud and check that the flexible leads leading to the brushes have plenty of slack in them and are not close to being pulled tight between the terminals and where they pass into the individual brush channels. Gently pull each flexible lead to check that the brushes are free to move in their channels. In case of any doubt, see the section below on "Removing the brushes". If the motor has accumulated many hours of running, you should blow dust out of the armature with compressed air. Take care to avoid breathing the dust.

Try to shake the shaft. If there is significant play or if there have been unusual noises with the motor running, see the section below "Dismantling and reassembly of the motor". You should ALWAYS replace the bearings whenever the armature is removed from the end-bell.

Bearing grease will lose its lubricating ability over time, not suddenly. The lubricating ability of a grease (over time) depends primarily on the type of grease, the size of the bearing, the speed at which the bearing operates and the severity of the operating conditions.

WARNING: Do not touch electrical connections before you first ensure that power has been disconnected. Electrical shock can cause serious or fatal injury. Only qualified personnel should attempt the installation, operation and maintenance of these motors.

WARNING: Controllers may apply hazardous voltages to the motor leads after power to the controller has been turned off. Verify that the controller is incapable of delivering hazardous voltages and that the voltage at the motor leads is zero before proceeding. Failure to observe this precaution may result in severe bodily injury or death.

WARNING: Surface temperatures of motor enclosures may reach temperatures which can cause discomfort or injury to personnel accidentally coming into contact with hot surfaces. Protection should be provided by the user to protect against accidental contact with hot surfaces. Failure to observe this precaution could result in bodily injury.

Brushes: Brush pressure is correctly established at the factory for normal street driving and maintained at the correct value throughout the life of the brush by means of a constant pressure spring design. Brushes and brush−holders should be clean so that the brushes are free to move in the holders.

Brushes should not be removed unless a problem is suspected, usually by an abnormal commutator wear pattern (See: **Guide To Commutator Appearance**), or brush chipping. If for any reason a brush must be removed, it should always be placed back into the exact spot from which it was removed. Brushes should never be "swapped around" with one another, and brushes should all be replaced at the same time. We discourage the replacement of anything other than all brushes at the same time. Running with brushes of varying grades and or resistance may cause unusual commutator wear patterns, as well as other motor issues. If you have any question how or whether brushes should be replaced contact **NetGain Motors, Inc.**

Routine Maintenance

Replace brushes with new brushes of the same grade before wear permits any damage to the commutator. It is highly recommended to change out the complete set of springs at the same time, and in high power EV applications, new springs may also be considered. For racing applications the user may consider putting an extra ½ turn on each brush spring. This extra ½ turn will ~double the spring pressure. Racers should also consider the use of a 60 degree bevel tool between commutator bars. After the bevel has been completed on each bar the area between the bras should be cleaned with a razor blade knife, and then all resultant material should be carefully blown out of the commutator.

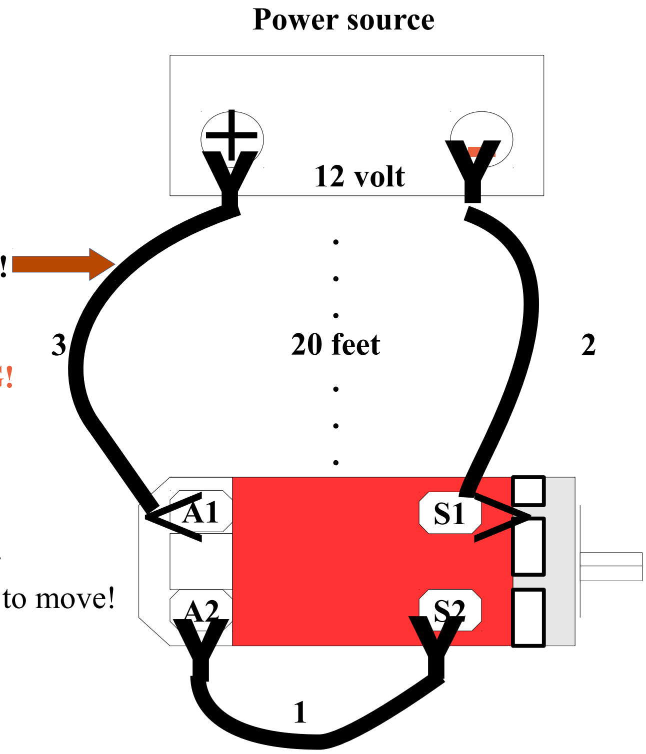
A brush seating stone should only be used when required by a worn commutator, or when a quick seating of the brushes is a necessity. Full power should never be applied to unseated brushes! Applying full-power will send almost all of the current through the seated portion of the brush and can result in lifted comm bars or damage to the brushes.

The brush holders in all motors are of constant pressure design and are normally not adjustable. (See High Performance Hints)

Bench Test Procedure

(Test at 12 volts ONLY)

CAUTION! Read completely!



Caution!!!!
Sparks can ignite gases emitted from batteries!

Use quick-connect cables for battery and motor!

DO NOT HARDWIRE MOTOR AND BATTERY CONNECTIONS WHEN TESTING!

Make certain that the motor is securely strapped or bolted in position. The motor must **not** be allowed to move!

If a battery is used instead of a charger, the battery must be at least 20 feet away from the motor in a well ventilated area or preferably outside of the building!

The cables **MUST** be **connected and disconnected** in the order shown!

Connecting sequence:

1. Connect cable #1 and cable #2 first.
2. **Connect cable #3, to power source positive terminal (+) at the power source first, NOT at the motor.**
3. Connect the other end of cable #3 to terminal (A1) at the motor which is 20 feet away from the power source.

Disconnecting sequence:

1. Disconnect cable #1 first. (This deactivates the motor)
2. Disconnect cable #2 and then #3 from the power source.

Motor Short - Test Procedure

In order to test a motor and determine whether there are any shorts the following points should be probed and the results should be as shown:

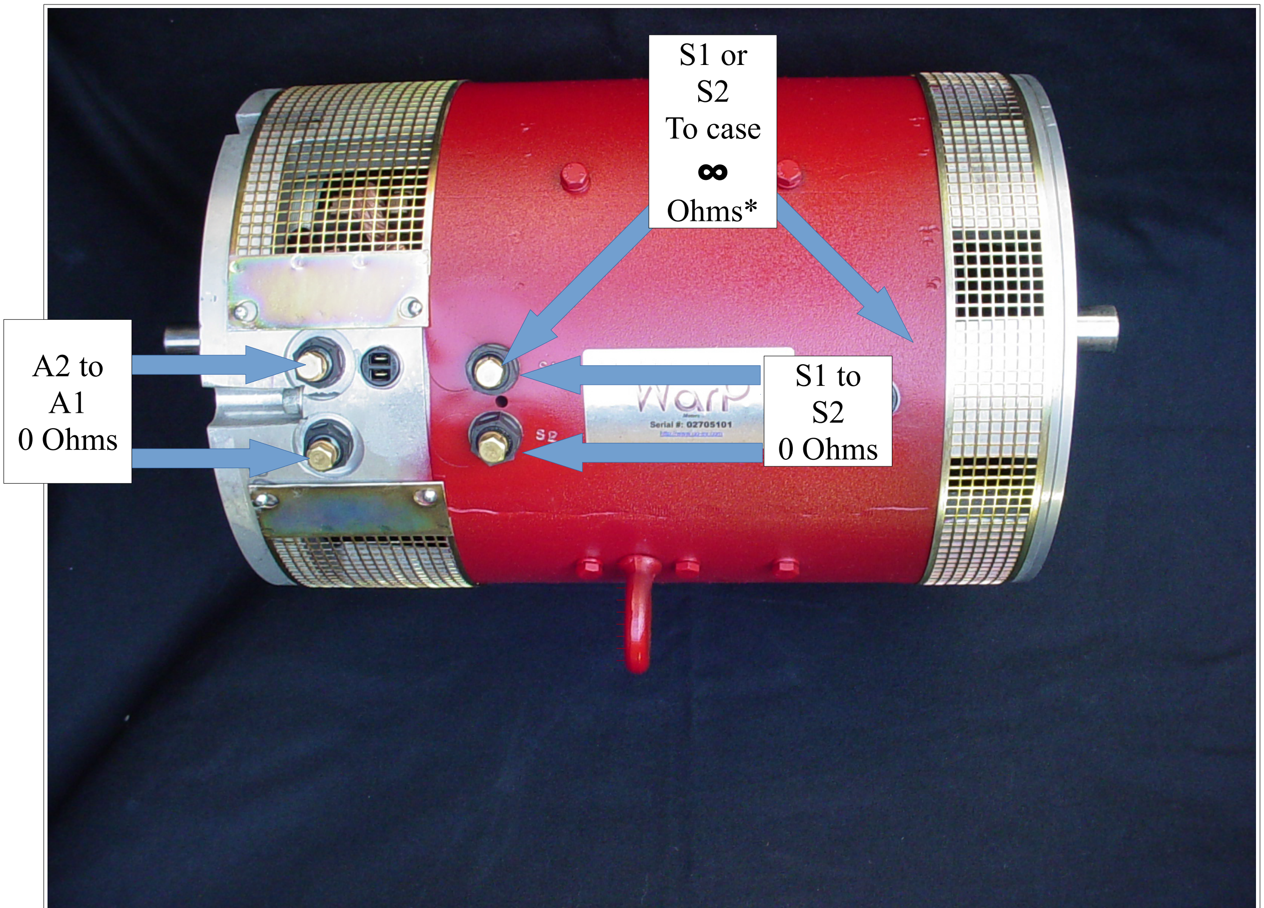


Illustration 36: Motor Short - Test Procedure

* Infinity ohms in theory, but may be > 50,000 Ohms on ***AmP*** ™, ***WarP*** ™ and GE Motors, and > 100,000 on other manufacturers Motors, If the amount is lower than 100,000 Ohms on a **NetGain** motor, you may wish to use compressed air to blow dust from the motor and then continue to check.

Dismantling and Reassembly

Tools required: **[THIS SECTION TO BE ENHANCED AND EXPANDED...]**

- A bench vice with soft jaws (alternatively slip a piece of copper pipe over the motor shaft to protect it from damage by the vice jaws)
- A large spanner
- A large regular screwdriver and a Phillips screwdriver
- A strong Allen key (long-arm type, or of the socket type that can be used with a torque wrench or T-handle)
- Three long lengths of heavy threaded rod (studding) each with two nuts locked against each other at one end so they can be turned with a spanner (not to be used with reinforced armature versions of the motor; see page x for description of a tool to be used instead)
- Internal cir-clip (snap ring) pliers (only for some models)
- A small hammer
- A length of steel rod about 1.5 inches diameter
- A drift suitable for pressing on the outer race of the bearing,
- A short [SIZE] screw and some thick washers that fit it
- A [SIZE] length of [SIZE] threaded rod (studding) and a nut
- A piece of steel tube with (1 inch) inside diameter and length of [SIZE] to [SIZE]
- Anaerobic adhesive
- Anti-seize assembly compound (245 Blue recommended!)
- Commutator surfacing stone
- Here are some videos from Mathieu in Germany who did a good job of showing how to disassemble and re-assemble a ***WarP*** ™ motor.

http://www.youtube.com/watch?v=BxRYY6s67fY

http://www.youtube.com/watch?v=FXmelRFPLtQ

Dual Motor Wiring

There are multiple methods of wiring dual motor combinations. Normally, the armatures and fields are wired in series in order to provide maximum torque. When wired in series, both motors see full amperage, but only receive ½ the available voltage. This will limit the RPMs to about ½ of what they would receive if the armatures and fields were wired in parallel. People racing electric vehicles have used this technique for years, but few people have explored the other wiring options and their resultant behavior.

The attached table briefly describes the effect of the 4 methods of wiring multiple motors. None of these methods should be seen as an endorsement or recommendation from **NetGain Motors, Inc.** Our motors are series wound and the normal methods of wring the motors is as described in the first paragraph and in options 1 and 2 below. It should be noted that options 3 and 4 can do serious damage to the motors if the user is not familiar with how the voltage and current are applied across the fields and armature.

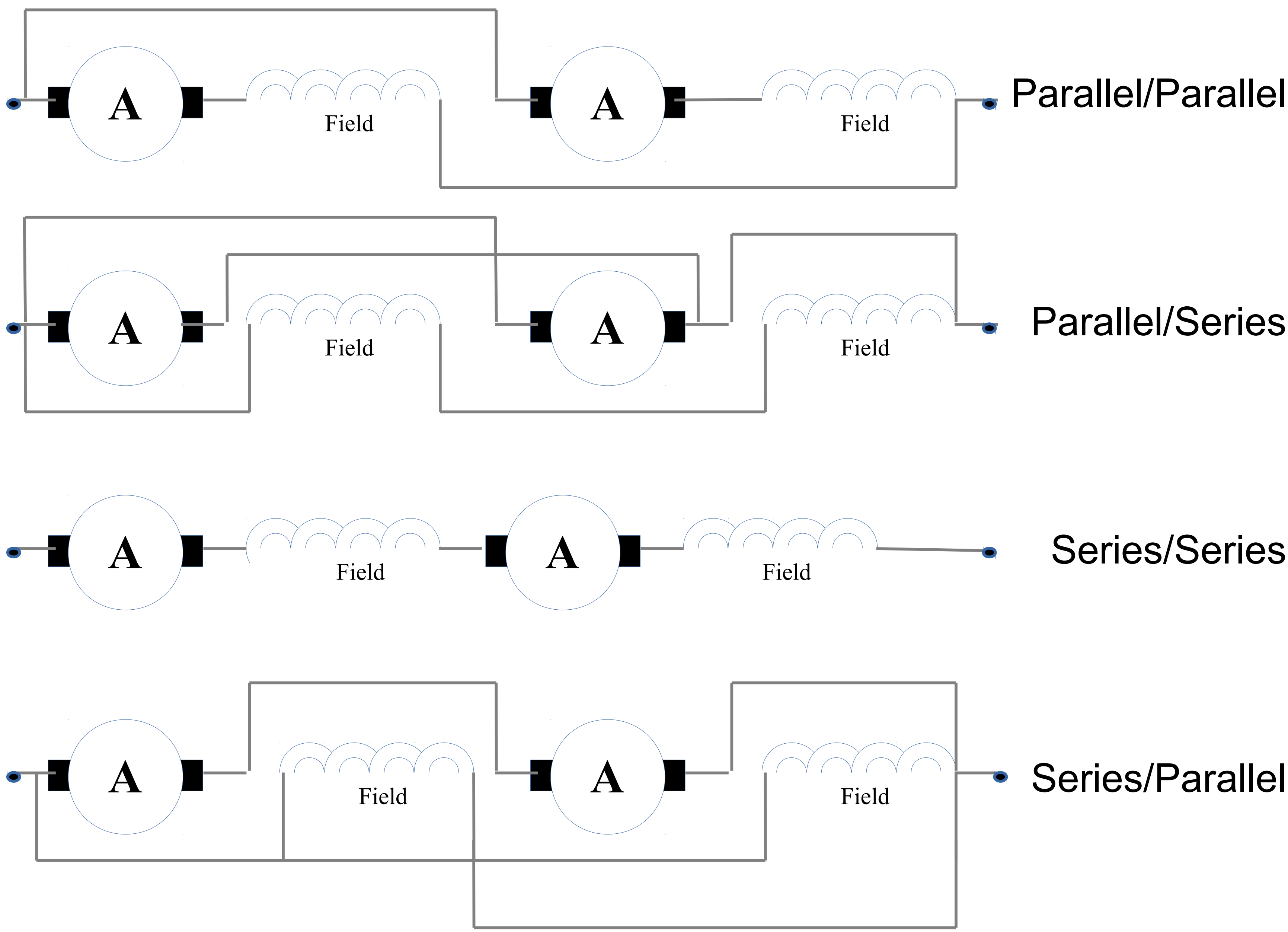
Wiring Method	Armatures Wired as:	Fields wired as:	Result (as compared to a single series wound DC motor)
1	Parallel	Parallel	Alternate wiring, both motors see full voltage and ½ amperage. Torque is much lower, but RPMs are much higher resulting in higher HP – (100% field)
2	Parallel	Series	Very low RPM/volt, but 4X the torque as the field is at 200%
3	Series	Series	Normal wiring, both motors see full amperage and ½ voltage, RPMs limited to ½ of parallel/parallel wiring – (100% field weakening)
4	Series	Parallel	Higher RPM than parallel/parallel as field is weakened 50%. Torque is also ½ of series/series – (50% field weakening)

For some of these wiring configurations you will need to know the field impedance – which varies by motor. This table is provided for your information.

Field Coil Resistance		
Model	**Part #**	**Resistance**
WarP 7 ™ ***TransWarP 7*** ™	**00-08207** **00-08217**	**9.29 Milliohms (mΩ)**
ImPulse 9 ™	**00-08259** **00-08269** **00-08249**	**3.29 Milliohms (mΩ)**
WarP 9 ™ ***TransWarP 9*** ™	**00-08219** **00-08309**	**3.92 Milliohms (mΩ)**
WarP 11 ™ ***TransWarP 11*** ™	**00-08311** **00-08711**	**7.80 Milliohms (mΩ)**
WarP 11HV ™	**00-08911**	**7.56 Milliohms (mΩ)** **6.18 Milliohms (mΩ) (interpoles)**

The normal air-gap is .065. The next page contains rough electrical diagrams for these wiring methods.

Dual Series Wound DC Motor Wiring



Motors Specifications at a Glance

Description	AmP 8™	ImPulse 9™	AmP 9™	WarP 9™	WarP 11™	WarP 13™
CE Shaft, Advanced Timing	AmP-08218	00-08259	AmP-08219	00-08219	00-08311	08513 / 08413
CE Shaft, No Advance	AmP-08206		AmP-08209	00-08209		
No CE Shaft, Advanced Timing	AmP-08210	00-08269	AmP-08239	00-08239		
No CE Shaft, No Advance	AmP-08200		AmP-08229	00-08229		
.750 CE Shaft, No Advance	AmP-08203					
Diameter	8 inches	9.25 inches	9.25 inches	9.25 inches	11.45 inches	13.25 inches
Length (case)	14.42 inches	13.7 inches	15.93 inches	15.93 inches	17.027 inches	20.4 inches
Weight	106 lbs.	129 lbs.	156 lbs.	156 lbs.	250 lbs.	367 lbs.
Bearing Type						
Drive Bearing	10222130	10222220	10222220	10222220	10222161	10222162
Com Bearing	10222220	10222140	10222140	10222140	10222240	10222240
Communtator						
Com Bars	49	49	49	49		
Springs #	11894400 * 8	11880020 * 8	11880020 * 8	11880020 * 8	11840510 * 8	11805010 * 8
Brushes #	10399300 * 4	10327002 * 2	10327002 * 2	10327002 * 2	10345064 * 4	10345060
Brush Holder	10499500	10427001	10427001	10427001	10440100	10445046
CE Head	10608203	10627001	10627001	10627001	10608311	10640031
DE Head	10908203	10908249	10908209	10908209	10908311	10973250
Armature	3002308203FN	3002308249FN	3002308209FN	3002308209FN	3002308311FN	3002308513FN
Field Coil Set	11108203	11108249	11133001	11133001	11145080	11108413
Insulation	>Class “H”	>Class “H”	>Class “H”	>Class “H”	>Class “H”	>Class “H”
Mounting Pattern	ADC 8”	WarP 8/ADC 8”	ADC 9”	ADC 9”	WarP 9/ADC 9”	Foot
DE Length	1.250”	1.250”	1.500”	1.500”	1.500”	4.00”
DE Diameter	1.1250”	1.1250”	1.1250”	1.1250”	1.1250”	1.750”
DE Keyway	0.250” * 0.130”	0.250” * 0.130”	0.250” * 0.130”	0.250” * 0.130”	0.250” * 0.130”	Splined
DE Pilot	3.250”	3.250”	4.00”	4.00”	4.00”	NONE
DE Mounting Hole	5/16” – 18	5/16” – 18	5/16” – 18	5/16” – 18	5/16” – 18	½” – 13
CE Length	1.850”	2.00”	2.00”	2.00”	2.00”	2.00”
CE Diameter	0.750” -> 0.875”	1.125”	1.125”	1.125”	1.125”	Max 1.18”
CE Mounting Hole	¼” – 20	¼” – 20	¼” – 20	¼” – 20	¼” – 20	¼” – 20
Case Steel	1020 or similar	1020 or similar	1020 or similar	1020 or similar	1020 or similar	1020 or similar
Shaft Steel	1144 stress proof	1144 stress proof	1144 stress proof	1144 stress proof	1144 stress proof	1144 stress proof

High Performance Hints

Some motor modifications have been shown to improve the motor performance under race conditions. None of these changes are authorized or recommended. **Any attempt to modify a motor is done completely at the owner's risk and expense and will likely nullify the warranty and/or result in denial of warranty.** That being said, many motor owners want to “hot rod” their motors, and there are certainly a number of techniques we have learned over the years that can assist racers.

Brush Rigging

Helwig-Carbon offers custom brush rigging for some of our motors that the top racers utilize. The custom brush rigging and brushes may cost close to the amount of the motors themselves. Included in this “kit” is a machined brush holder that covers more commutator area than the standard brush holders. The kit also includes special brushes and springs. Notice in the picture below that the brush ring itself is also slotted to allow for additional motor timing options.

Illustration 37: Ultra High Performance Brush Rigging from Helwig-Carbon

Motor Timing

All of our series wound, brushed DC motors come standard with advanced or “favored” brush timing, with the exception of the ***WarP 11HV*** ™ motor which has interpoles. The default timing is advanced for Counter Clock-Wise when viewed from the drive end of the motor (CCWDE). Running the motor in the opposite direction (CWDE) can damage these motors, especially if high power is applied. When a motor is neutrally timed it will produce about the same power at the same RPMs in both rotations. When favored timing is installed, the motors will generally perform better when rotated in the direction of the favored timing, especially at higher power and RPMs. The favored timing on our motors is generally around 12 degrees. This has the effect of producing about 10-12% less torque than a neutrally timed motor, but it allows the motor to handle higher voltages and currents without arcing. It also will produce about 10-12% greater RPMs at high power levels. Though we suggest a maximum voltage of 170 Volts be used with out motors, it has been shown that when using the Helwig-Carbon brush holders and well seated brushes that the motors have withstood in excess of 208 Volts.

Many owners have asked for “adjustable” or dynamic brush timing. It is certainly feasible to implement this concept. The concept is that maximum torque will be generated with the brushes in a neutral position, and as the motor RPMs increase so will the brush advancement. The theory is sound, however, it is difficult to implement. Moving brushes on a commutator spinning at high RPM can be a disaster if any mistakes are made. It is very easy to create a "flash-over" event that will destroy the motor. The implementation must be very well thought out, including what happens if the accelerator pedal pressure is reduced and then increased repeatedly.

In the first image, the timing is neutrally timed. As the armature begins to spin at higher and higher RPMs, the field becomes distorted as shown in the second image.

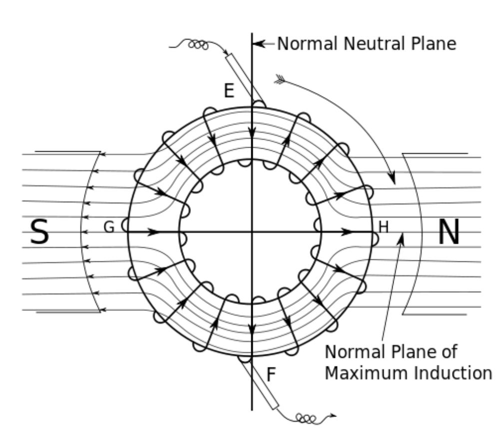


Illustration 38: Neutrally timed motor

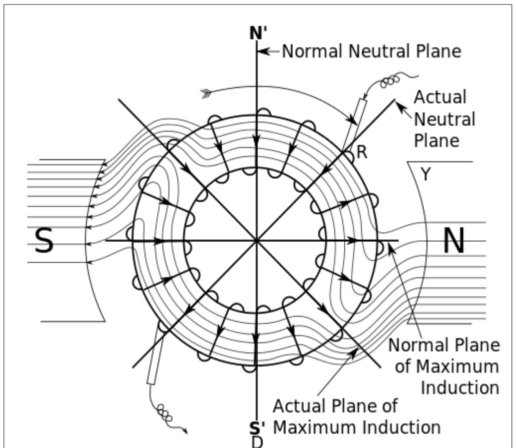


Illustration 39: Favored brush timing

It should be clearly visible why a motor with advanced brushes should not be reversed at high power levels or RPMs.

Commutator Modifications

There are numerous methods of modifying your commutator in ways that can improve performance at high power levels. Obviously, ensuring that the commutator is perfectly round is important. Our commutators are pressed onto the armature shaft, the armature wires are inserted into the armature stack laminations, banded, and then the armature wires are welded to the commutator. Then, the entire assembly is preheated, coated with class "H" insulating varnish and baked. Finally, the commutator is undercut, and the commutator is precision, diamond cut on a lathe that is zeroed at least twice a day. The armature shaft is then balanced and finally inspected bar-to-bar to ensure there are no armature shorts.

The commutators used on our production motors is a high quality "molded" commutator. These are the most cost effective commutators, and the commutator bars are designed not to "lift" at high RPMs and power levels. However, under extreme conditions (i.e. 2000+ Amps, 6000+ RPMs), commutators can come apart for various reasons. For this reason we strongly encourage all motors that will see extreme duty have a safety shield surrounding the commutator region. The standard cover-bands supplied with the motors are designed to keep road debris (stones, etc.) from entering the motors and are not strong enough to withstand an exploding commutator. To help prevent high RPMs from destroying a commutator, they may be banded with Kevlar or fiberglass banding. But, even this will not make the motors safe to operate at high RPMs, so a "scatter-shield" is strongly encouraged for any brushed DC motor!

It is also possible to bevel the edges of each commutator bar. This has a couple of beneficial results. First, it increases the bar-to-bar distance, and secondly it reduces the likelihood of a brush catching an edge of a commutator bar and chipping the brush. There are special tools for performing this task available from **NetGain Motors, Inc.,** as shown below: It is also possible to use a square file for this purpose. You may also request that your commutator be V-notched at the factory for an additional fee.

After all the edges have all been chamfered, it is necessary to remove any mica or material that may be between the comm bars. A razor-blade knife or a slot-scraper made for this purpose may be used. Any remnants should be vacuumed and blown out of the motor. This is a tedious and time consuming project, that can take hours to perform. The entire commutator must be completed before the motor is run on power.

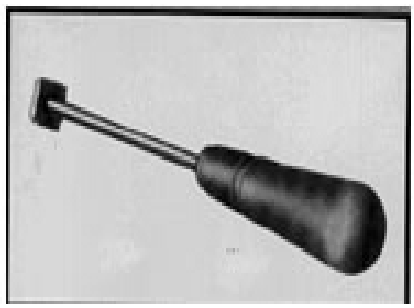


Illustration 40: Commutator bar chamfer tool

Motor Cooling

Cooling the motors is important in many applications, and is essential in motors used for racing. Motors run best when they are properly cooled. The hotter a motor gets the less efficient it becomes. And, the less efficient it becomes, the hotter it gets, and so on. The type of racing will determine the amount of cooling necessary. The internal fan can consume 3-4 HP, so some drag racers have eliminated the internal fan. It should be noted that the internal fan serves multiple purposes. One is to cool the motors, but equally important is the expelling of brush dust. If the internal fan is removed, the brush dust should be blown out of the motor with compressed air after every pass! The buildup of dust can lead to a frame leak, or an arc-over event. If the internal fan is removed, it is suggested that some sort of forced air still be injected into the motor and possibly use a reverse air flow that forces air from the drive end of the motor to the commutator end of the motor. The fans used in our motors draws air from the commutator end and expels it at the drive end. The rational is that the greatest cooling effect is achieved, however, this comes at the expense of draining carbon dust into a motor that can cause a frame leak.

For longer races the internal fan should not be removed, but one or more external forced air blowers may be added. Additionally, air filters should be used to filter the incoming air. It is important that the amount of air being provided by the blowers is greater than that being expelled by the internal fan, or the blowers could have a negative impact by limiting the incoming air.

In addition to fans (external and internal), the addition of cooling fins can greatly aid the motors cooling. In some cases, just the addition of fins has been sufficient to eliminate motor overheating. Overheating a motor will cause the breakdown of insulating material and will eventually destroy the motor. After repeated overheating and cooling, the insulation material will crack and melt. The melted insulation varnish, solder and other substances damaged by the heat will easily fill the air gap between the armature stack and the field windings and eventually destroy the fiberglass banding on the motors. It is even possible for the mixture of fiberglass “fluff” that has been created, along with the accumulated varnish to burst into flames under extreme abuse conditions. Forced air cooling is extremely beneficial in cases where the motor may stop running (i.e. stop lights), or is running slowly. In these cases the internal fan is not moving much air, but an external blower can have an enormous effects!

High Performance Hints

Liquid cooling of brushed DC motors has been a very challenging obstacle to try to overcome. Ideally, the heat should be removed as close to the source as possible. But this is difficult to do with this style motor, except at great expense (i.e. gun drilling the armature, addition of internal "plumbing"). However, even external plumbing has been shown to have advantages. Copper tubing has been drawn into a rectangular shape and wrapped around the exterior of the motor to help wick away heat, but by the time the exterior of the motor has become hot, the internal temperature is likely very hot! In other words, air should be continually circulated through and around the motors for the best results.

Some owners have injected distilled water directly onto the brushes to help cool them while racing, and used compressed gasses directed on the brushes. Care must be taken in solutions like these that the differential in temperature is not so great as to cause components to fracture.

Field Weakening

In a series wound brushed DC motor, the fields and armature are in series with one another. This means the same energy flowing through the armature flows through the fields. (and consequently, approximately ½ the heat generated in these motors is in the armature, which is difficult to cool without massive air flow...) Speed of a DC motor is governed by two variables, the armature voltage and field voltage. Armature voltage and speed are directly proportional to each other. Field voltage and speed are inversely proportional to each other. If the field voltage is reduced while the armature voltage is kept constant, the RPMs of the motor increase.
[to be continued.....]

Spring Pressure

Proper spring pressure is critical in racing applications, just as it is on the street. Depending upon the type of brush being used you may benefit by greater spring pressure. Though the normal spring pressure of 3-4 lbs suffices for T300 grade brushes, if using Helwig-Carbon brushes it is suggested that the spring pressure be doubled. This can be accomplished by clocking (or twisting) the spring an additional ½ turn. Care must be given to ensure the arm that the spring is secured on does not bend. Doubling the spring pressure with Helwig-Carbon brushes (dual wafer, red-top style) will greatly improve their life and performance.

Air Gap

Closing the air gap will increase the torque created per amp supplied to the motor. Closing the air gap will also allow higher voltage to be run, but the motor will also spin slower. The typical air gap used on ***AmP***™ and ***WarP***™ motors is around .065". This gap can be shimmed to around .030" to .035" for high performance applications, but we do recommend making it any closer. (though some people have closed theirs to .020"). Closing the air gap will allow you to run at higher voltages with reduced arcing, but it will also come at the cost of lower RPMs per volt. This process is not as simple as it may seem. All of the ***AmP***™ and ***WarP***™ motors are produced by flooding the field ring with insulating varnish and then baking the insulation. This step is critical as it holds everything together. We would highly discourage anyone from simply removing the field pole shows and shimming them as this will destroy the insulation in the process. If a closer air gap is required, you may wish to contact us directly to see if we can arrange to have your motor modified or a motor built to your specifications.

High Performance Hints

General EV Related Performance Hints

Gear ratios (transmission, differential), tires, tire pressure, tire diameter, alignment, vehicle weight, RPM range [to be continued.....]

Is bigger always better? It depends upon what you are trying to accomplish. In many cases, multiple smaller motors will outperform a single large motor. A single large motor may be easier to deal with than trying to mate multiple motors together, but it might not suit the application as well as multiple smaller motors. In general, the smaller the diameter, the faster the motor will spin per volt applied (= higher HP). A larger motor will normally produce more torque per amp applied. The following image shows the comparative size of a ***AmP 8***™, ***WarP 9***™, and ***WarP 11***™.

Illustration 41: Comparative sizes of 8", 9.25" and 11.45" motors

Miscellaneous

Improved insulation, Glyptal®, powder-coating, armature balancing, ceramic bearings, armature and commutator banding, armature brushes, silicone vs glass vs no shunt wire insulation, shunt wire size, voltage, amperage [to be continued.....]

Selecting EV Components

The Vehicle

There are numerous factors to consider in trying to select the appropriate components for a particular conversion product, and they go hand-in-hand. The intended user of the vehicle should first define their intended application. Some people define “performance” as being able to achieve the greatest range with their vehicle. Others may define performance as achieving a particular speed in a specific time. It is important to determine what the performance goals are for a vehicle before choosing the vehicle. If someone is looking for range and chooses a vehicle for conversion that does not have room for batteries, they will likely be disappointed in the end result. Similarly, if someone is looking for the quickest 0-60 miles per hour time and selects a heavy vehicle they might also be disappointed. Knowing the performance expectations can help determine an appropriate vehicle for conversion.

An ideal vehicle is one that has the existing braking capacity, as well as the suspension capacity to handle the weight of the batteries and other components installed during the conversion.

It is advisable to measure the height to the top of each wheel opening on the vehicle before any conversion is undertaken. Ideally, this should be the height after the conversion is completed. Obtaining the proper ride height and suspension travel is crucial to the vehicles handling and safety. It may be necessary to have a company that specializes in suspension suggest alternatives after the vehicle has been converted.

In some cases a vehicle that is already owned is chosen for conversion simply because the customer already owns it. It may not be an appropriate vehicle, but the decision has already been made.

The Batteries

The rule-of-thumb when using lead-acid batteries for a conversion is that the vehicle will end up weighing about 1,000 lbs more than it did before the conversion and usually have a range of 20-30 miles. Certainly, some people have converted vehicles with 50+ mile ranges using lead-acid, but the extra range comes at the expense of load carrying capacity. It is best to know and consider the effect of adding 1,000 lbs of weight will have on the vehicles handling and braking capacity.

Besides the weight of the lead-acid batteries, the voltage is known to sag severely during heavy amperage draw. Lead-acid (PbA) battery range may be cut in ½ during cold weather. The typical life of PbA batteries is normally around 2-3 years in an EV application. The normal “starting” batteries used in ICE vehicles are generally not considered a good candidate for EV's as they usually cannot handle the heavy charge and discharge cycles. The most commonly used PbA battery are the golf-cart style batteries. But, these “flooded” batteries will require constant checking of the electrolyte levels, and they generally cannot deliver the amperage required in modern EV's. Flooded golf-cart style batteries can provide the best range of PbA batteries, and their life can be 4+ years if properly maintained. This does come at the cost of a lot of weight.

Lighter and more powerful PbA batteries known as “absorbed glass mat”, and even better “spiral wound” batteries will allow higher amperage draws, but the range will typically be around ½ of what the large flooded batteries will deliver. But these types of batteries can generally deliver higher amperage over a longer period than flooded type batteries.

Whenever economically feasible, Lithium Iron ($LiFePO_4$, $LiYFeSO_4$, or similar) battery chemistry should be considered. Besides the improvement in the amperage that can be delivered, the LiFe batteries are not nearly as sensitive to cold weather or high temperature, and the voltage does not sag as deeply under heavy amperage draw. It is not unusual for someone to have a Li powered vehicle that has a 70-90+ mile range, and perform very well. In part the improved performance is due to the much lower weight of the Li batteries, but also due to their ability to supply high amperage.

The Controller

In most vehicles being converted a 1,000 Amp or higher controller should be considered. Certainly, 500 Amp controllers have worked well for many years, and since the older style PbA batteries may have only been capable of 300 Amps discharge, a 500 Amp controller was sufficient. Indeed, if a vehicle only requires 150 Amps to travel at it's average speed, so the use of a 1,000 Amp controller will not offer any advantages – EXCEPT at start-up! And, the difference between 500 Amps and 1,000 Amps at start-up can be quite significant with most motors capable of close to 4 times the torque at 1,000 Amps that they produce at 500 Amps. LiFe batteries exist today that can discharge 4,500 Amps, and the potential of these batteries is improving rapidly.

If you have a heavy vehicle, you need the higher amperage controllers. Often times, people think it is easier on a motor to only provide it 500 Amps rather than 1,000 Amps. Though 500 Amps will produce less heat than 1,000 Amps, you must take into consideration whether the amperage will provide the necessary torque the motor needs to start rotating. If the amperage isn't high enough to start the armature spinning, all of the 500 Amps will be split between just a couple of commutator bars. If the armature doesn't turn it is considered a stall condition, and the heat build-up can quickly cause a commutator bar to raise. A stall condition is not covered under warranty, and the condition is quite easily determined by the scorch marks 90 or 180 degrees apart on the commutator.

The speed that the vehicle will be able to obtain is determined (in part) by the voltage that is delivered to the motor – not necessarily by the voltage that is delivered to the controller. When a new off-shore manufacturer of controllers entered the market a few years back, we were swamped by calls from users of this new 120 Volt 1,000 Amp controller who could not get their vehicles over 30 MPH. Users naturally accused the motor of not being able to power their vehicle, when the actual cause of the problem was that the controller was only able to deliver 36 Volts to the motor. Volts = RPMs in a nearly linear manner with series wound motors. If the voltage to the motor doubles, the motor RPMs will double. Since most losses are fixed, the RPMs may increase slightly more than double.

EV racers found it necessary to build 336 Volt + battery packs due to the fact that 12 Volt PbA batteries would sag to 5.5 Volts when 1,400 Amps were drawn from them. If the motors are capable of handling 168 Volts, and the PbA battery pack is 168 Volts nominal, then the motor would only see about 77 Volts when 1,400 was drawn from the battery pack. In order to deliver the maximum voltage to the motor, it became necessary to increase the PbA battery pack voltage. As LiFe chemistry battery voltage typically sags far less under heavy amperage draws (25% vs 50%), the battery pack voltage need not be as high as a comparable PbA battery pack voltage.

The Motor

Matching all the components of an EV is a critical aspect of any conversion. Choosing batteries that can't discharge high enough current may mean that the controller won't be able to supply the motor with the amperage it may need for a particular job. Choosing a controller that can't supply the motor with the current it needs to perform will likely result in a conversion that doesn't meet expectations. Choosing a battery pack that is too low a voltage may limit the speed the vehicle is able to attain. Choosing a motor that is too small for a vehicle will lead to the motor heating up and being overworked and possibly leading to motor failure. Choosing a motor that is too big for an application may lead to the motor "lugging" which will normally result in commutation problems over time, and eventually to other motor problems.. For the best electric vehicle experience, it is essential that the electric motor be carefully sized to the vehicle for which it is intended. Simply using a "bigger motor" for a larger or heavier vehicle is not necessarily the best way to match components. Likewise, choosing a motor that is simply too small for an intended application is also likely to end up with an undesired result as the motors may overheat.

Many factors are used to determine which motor is suitable for the weight (and aerodynamics) of the vehicle to be propelled and the speed which is to be maintained. There are some online tools which can tell you how a vehicle might perform under varying conditions, such as: http://www.evconvert.com/tools/evcalc/ But, even excellent tools such as this cannot take all the various battery, controller, and motor options into account.

NetGain Motors, Inc. is will assist Authorized Motor Dealers or their customers in trying to size the right motor for their particular application, however we prefer to provide the Authorized Motor Dealer with the information so that they remain the primary point of contact with the customer. In order to assist Authorized Motor Dealers in motor selection, we need to be provided with as much of the following pieces of information as possible:

- Battery Pack Information
  - Voltage
  - Internal resistance
  - Discharge capabilities
- Motor Controller
  - Voltage capabilities
  - Amperage capabilities
- Vehicle Characteristics
  - Vehicle weight (after conversion)
  - Top speed to be maintained on level terrain
  - Top speed to be maintained on grade
  - % grade
  - Gear ratios of transmission
    - Gear efficiency
  - Rear differential gear ratio
  - tire diameter
    - Type of tire/surface (i.e. rubber on concrete)
  - Coefficient of drag
  - Frontal area

It is possible that the customer will have unrealistic goals, objectives, or understanding of a technology they are unfamiliar with. It is unlikely that you could suggest a motor combination that would provide a 0-60 MPH of 2.9 seconds and a top speed of 250 MPH with direct drive in a 4,000 lbs vehicle at 48 Volts.

Direct driving a vehicle with an electric motor sounds simple, and it is the first thing that many people believe they want. However, to properly direct drive a vehicle considerations must be given to the safety of the vehicle and the workmanship of the conversion. A mistake in wiring a direct drive conversion leaves little room for mistakes. It is unlikely that the brakes of the vehicle would be sufficient to stop an electric motor receiving full-power. Without a manual disconnect (such as a clutch, or neutral transmission gear), it could prove extremely dangerous or fatal for the driver and occupants of the vehicle or even bystanders. There are benefits to direct drive, in that the normal transmission losses may be eliminated. This is useful when racing, but offers little benefit to a "daily driver" type of vehicle. Although direct drive works well for racing, it is not advisable for around town driving as the motors should normally spin 2000 - 4000 RPMs in order to properly cool. Forced air cooling is highly encouraged to help cool direct drive motors, as well as vehicles that are used in stop and go (around town) driving.

There are also significant drawbacks to the use of direct drive vehicles, beyond just the safety issue. Direct drive will normally require twice the motor and twice the controller of a vehicle with a transmission (a 2000 Amp controller rather than a 1000 Amp controller) Either a larger motor will be needed for direct drive, or a second motor which will add additional weight and consume additional space will be needed. This will normally offset the customer's expected savings of a direct drive configuration. Additionally, dual motors will require a more complicated wiring scheme in order to allow for reverse direction movement of the vehicle. Dual motor direct drive also decreases the overall electrical efficiency of the system slightly.

The motors enjoy spinning at 2,000 - 4,000 RPMs. You should always design your conversion so that the normal operating RPMs of the motor are within this range. You may accomplish this by modifying the gear ratios (transmission and rear differential) and tire diameters. In general, the electric motors prefer spinning about 1,000 RPMs higher per gear than the original internal combustion engine did.

PbA Battery Vehicle			
Direct Drive Motor Selection[8]			
Motor	**Vehicle Weight**	**Dual Coupling Motor**	**Vehicle Weight**
TransWarP 7 ™	~1,400 lbs	***WarP 7*** ™	~2,800 lbs
TransPulse 9 ™	~1,600 lbs	***ImPulse 9*** ™	~3,200 lbs
TransWarP 9 ™	~1,750 lbs	***WarP 9*** ™	~3,500 lbs
TransWarP 11 ™	~2,100 lbs	***WarP 11*** ™	~4,200 lbs
TransWarP 11HV ™	~1,900 lbs	***WarP 11HV*** ™	~3,800 lbs

The use of a transmission allows you to double the figures of the first table:

PbA Battery Vehicle	
Transmission-ed Vehicle Motor Selection	
Motor	**Vehicle Weight**
WarP 7 ™	~2,800 lbs
AmP 8 ™	~3,200 lbs
ImPulse 9 ™	~3,200 lbs
WarP 9 ™ or ***Amp 9*** ™	~3,500 lbs
WarP 11 ™	~4,200 lbs
WarP 11HV ™	~3,800 lbs

8 Direct Drive assumes that a differential with additional gearing is stil being utilized.

Dual motors also allow for alternative wiring schemes (series/parallel) that can provide greater flexibility and performance.

The motors enjoy 120-156 volts, no higher than 170 to the armature is recommended – though people utilizing the motors for racing are, in some cases, providing the motors with 208+ Volts. You should never apply full power to a motor unless the brushes are 100% seated. The battery pack should be as stout as the controller can handle as the voltage of PbA batteries will sag to 6-7 volts when drawing 1000 amps at start-up (from lead-acid batteries, Lithium will also sag, but not as significantly, generally around 20-25%). With series wound DC motors, **Volts = RPMs** in a nearly linear manner - double the volts and you double the RPMs and horse power (hence the need for a stout battery pack). **Amps = Torque**. The motors will draw all the amps they can to start spinning (max torque at stall). Amps and Torque are a non-linear relationship – doubling the amperage will quadruple the torque until saturation of the motor occurs.

Lithium Battery Vehicle			
Direct Drive Motor Selection[9]			
Motor	**Vehicle Weight**	**Dual Coupling Motor**	**Vehicle Weight**
TransWarP 7™	~1,200 lbs	***WarP 7***™	~2,400 lbs
TransWarP 9™	~1,600 lbs	***WarP 9***™	~3,200 lbs
TransWarP 11™	~2,000 lbs	***WarP 11***™	~4,000 lbs
TransWarP 11HV™	~1,600 lbs	***WarP 11HV***™	~3,200 lbs

The use a transmission allows you to double the figures of the first table:

Lithium Battery Vehicle	
Transmission-ed Vehicle Motor Selection	
Motor	**Vehicle Weight**
WarP 7™	~2,400 lbs
AmP 8™	~2,800 lbs
WarP 9™ or ***AmP 9***™	~3,200 lbs
WarP 11™	~4,000 lbs
WarP 11HV™	~3,200 lbs

With a transmission, you can usually double the weights normally associated with a single motor direct drive. The following table may be used as a general reference, but may not be applicable to all situations. The frontal area, and coefficient of drag greatly effect power requirements with speeds greater than 45 MPH. The gradient, gear ratios and surface of the road will have a significant effect on the vehicles ability to perform as expected.

9 Direct Drive assumes that a differential with additional gearing is being utilized.

Selecting EV Components

The use of Lithium batteries will also affect the decision on which motor[s] should be used. Due to the fact that Lithium powered vehicles can drive for extended periods of time, the one hour rating on motors may be exceeded. Consequently, either a larger motor, more motors, or lower weight will be required to not exceed the motor ratings.

Though figures from both tables are considered conservative, you must consider the additional load placed on the vehicle by the weight of the vehicle operator and passengers. Pulling or carrying an additional load is not considered in these figures, nor the affects of high-speed operation (both RPMs and MPH). These figures are "approximate" (~) and you may have better or worse experiences depending upon other variables in your application. If in doubt, we suggest you contact us to discuss your application.

Motors may be stacked, or combined in-line with one another in order to handle additional loads. The terrain (i.e. hills) will greatly affect the motor choice.

Driving an EV

People who are new to driving EV's should understand a few of the basic differences between the ICE vehicles they are used to driving and EV's. Whereas the typical ICE develops horsepower and torque as the RPMs increase, the typical series wound DC motor produces maximum torque at stall. Thus it is possible to start a vehicle from a dead-stop in 2^{nd} or 3^{rd} (sometimes 4^{th}) gear! Of course it is easier on the electric motor to start in a lower gear, and the motors enjoy being run in the 2,000-4,000 RPM range, so choose your gear appropriately.

Never try to "hold position" on an incline with your electric motor. If someone is stopped at a stoplight on a hill and tries to hold position using the electric motor, a "stall condition" will occur and likely damage the electric motor. It is highly encouraged to use the brakes to hold position rather than the electric motor.

Don't try to move the vehicle forward if the motor is spinning in the reverse direction. In other words, if you are rolling backwards, make certain the motor is stopped before applying power to move forward. This only pertains to direct drive vehicles. In vehicles with a transmission the electric motors are not affected by the direction or movement of the vehicle. But, even if you have a transmission, it is far easier on the motor if the vehicle isn't rolling backwards.

You may be able to pass a vehicle quicker by up-shifting with an electric motor powered vehicle, rather than down-shifting as is normal in ICE vehicles. When an increased load is placed on the electric motor (such as by up-shifting), it will draw greater amperage and produce greater torque and allow quicker acceleration.

It is not necessary to "rev" the electric motor when moving from a standstill. The electric motors torque curve actually decreases as the RPMs increase, so you may have better performance by not revving the electric motor. Of course, if a clutch is used, the electric motor can certainly be revved to allow easy acceleration as was normal with the ICE. But, it is not required. "Slipping the clutch" may be useful on hill starts, but normally not required.

Choosing the right gear for a given speed can take some time to determine. Though not necessarily the optimum, it is "generally" best to run the electric motor at about 1,000 RPMs higher per gear than then the ICE was used. The motors prefer to spin 2,000 to 4,000 RPMs to properly cool themselves. If running below 2,000 RPMS for extended periods, or in stop and go traffic, a forced air blower can be utilized to cool the motor, and can make a significant difference in motor temperature. To determine whether you are in the correct gear, you may need to up-shift and down-shift for awhile till you find the gear where the motor is spinning in the 2,000 to 4,000 RPM range, AND, the amperage draw is the lowest.

EV Routine Maintenance

In addition to the "normal" maintenance that may be required on any vehicle you own or operate, some special considerations must be given to electric conversion vehicles. It is critical that some routine maintenance be performed on your electric vehicle. Whether your vehicle is a daily driver, a race vehicle, a boat, or any type of electric vehicle, you must perform some routine maintenance to ensure long life of your components and continued operational safety.

The exact routine will vary by the type of vehicle, the components utilized, and the use of the vehicle. For instance, if you have a vehicle that utilizes flooded lead-acid batteries, you will need to check the water in the batteries on at least a monthly basis. Regardless of the type of batteries you are using, you should plan on checking the tightness of all electrical connections on some regular basis. A loose or corroded connection can cause loss of power, or arcing and sparking that could prove hazardous! Arcing and sparking can lead to a fire, so it is strongly encouraged that an appropriate fire extinguisher be readily accessible in your electric vehicle.

We highly encourage the use of Nord-Lock (http://www.nord-lock.com/) lock washers wherever suitable! At the very least, the use of Belleville style or toothed lock washers are required. This includes all motor terminals, as well as all battery connections. This is even more critical when the EV is used near salt water. The Nord-Lock washers are corrosion resistant. Their standard steel washers are zinc flake coated with Delta Protekt® and endure a minimum of 600 hours of salt spray test in accordance with ISO 9227.

If you have a racing vehicle, it is important to use compressed air after EVERY race event in order to help expel carbon dust that accumulates. This is important with all brushed DC motor vehicles. Blowing out the carbon dust is required and reduces the possibility of a ground to the frame through the electric motor or an internal shorting or arcing situation.

You should protect the electrical connections and the motor from environmental contamination, such as salt spray, that could corrode components and/or damage the motor. Contaminants, such as dust, will act as an abrasive on the brushes and commutator. Dust can even be sucked through the motor and wear the internal insulation and even cause internal arcing to occur. We highly encourage the use of forced air blowers and air filters on most motors. If you do not use a filter and blower to protect your motor, you should consider a shroud of some sort to help avoid road debris from entering the motor. It is safe to use a LIGHTLY oiled rag to wipe down and remove dirt from the motor case.

Remember, NEVER use silicone around brushed DC motors. This includes silicone fumes. Silicone can cause the rapid degradation of the brushes used in brushed DC motors and also lead to damage of the commutator and other motor components.

Special Updates and FAQs

Special Update

Date: April 13, 2005
To: All Authorized Motor Dealers
Subject: **Motor Wiring**

Several sources have recently inquired as to what the proper method was for wiring the terminal lugs on the cases of ***WarP***™ motors. This ***Special Update*** clarifies the proper wiring method.

All ***WarP***™ motors cases have four terminals, **A1**, **A2, S1, S2** stamped on the case at the factory. Motors are designed to normally operate in **C**ounter **C**lock **W**ise rotation at the **D**rive **E**nd (**CCWDE**)for forward vehicle operation. When a motor is specified as "advanced timing", it is assumed to be relative to the normal **CCWDE** rotation. Motors that do not have advanced **CCWDE** timing may be wired for **C**lock **W**ise rotation at the **D**rive **E**nd (**CWDE**). These instructions should help clarify the proper wiring method for both rotations.

WarP™ motors (except the ***WarP 13*** ™) should ALL be jumpered according to these instructions (battery polarity does not matter):

For **CCWDE** rotation wire as follows:*

CCWDE preferred connection method:
Connect **A1** to **S1**
Connect **A2** to one input power terminal and **S2** to the other input power terminal

CCWDE alternative connection method:
Connect **A2** to **S2**
Connect **A1** to one input power terminal and **S1** to the other input power terminal

For **CWDE** rotation wire as follows:

CWDE connection method:
Connect **A1** to **S2**
Connect **A2** to one input power terminal and **S1** to the other input power terminal

CWDE alternative connection method:
Connect **A2** to **S1**
Connect **A1** to one input power terminal and **S2** to the other input power terminal

Motors that have "advanced timing " for **CCWDE** rotation should not be run in **CWDE** mode. Doing so may damage the motor and void the warranty.

Dealers may request a motor be timed advanced for **CWDE operation by specifying this on their Purchase Order. This will be considered a "Special Order " and may involve an additional cost.*

Special Update

Date: October 24, 2006
To: All Authorized Motor Dealers
Subject: ***TransWarP 11***™ **Motor Wiring**

Normal wiring for **C**ounter **C**lockwise **R**otation when viewed from the **D**rive **E**nd (**CCWDE**) of a ***WarP***™, ***ImPulse***™ ***AmP***™ or ***TransWarP 9***™ motor is: **A1-S1** or **A2-S2**.

However, on the ***TransWarP 11***™ the wiring for **CCWDE** is: **A1-S2** or **A2-S1**. For **CWDE** the wiring on these motors is **A1-S1** or **A2-S2**.

Additionally, all of the **NetGain Motors, Inc.** 11-inch and 13-inch motors incorporate a 150° C snap switch. Other motors utilize a 120° C snap switch.

Wiring information for other ***WarP***™ motors may be found in the ***Special Updates*** dated 04/13/2005 and 03/01/2006.

You may locate copies of these and all other ***Special Updates*** on our Web Site at:

http://www.go-ev.com/dealers-only/Dealer_Manual

All motors produced in 2007 will incorporate 2 lifting holes to aid installation. These holes will be positioned 90 degrees apart in order to allow better positioning of the terminal studs.

Broken fins, which occasionally occurred on ***ImPulse 9***™ and ***WarP 9***™ motors due to the placement of advanced timing holes, will now be machined during assembly.

Dealer input is always welcomed, if you have any suggestions on how we might improve our motors, please contact us!

You may locate copies of these and all other ***Special Updates*** on our Web Site at:

http://www.go-ev.com/dealers-only/Dealer_Manual

Special Update

Date: February 13, 2006
To: All Authorized Motor Dealers
Subject: **Heat and RPM Protection Bulletin**

Throughout the year we have had inquiries about the effects of heat and RPMs on **AmP** ™ and **WarP** ™ motors. This **Special Update** summarizes many of our conversations with individual dealers and shares the same knowledge across our entire dealership network. As in our other **Special Updates** , this information does not cover every aspect of the motor's usage. If you have a situation that you are unsure about, please call someone that has the expertise or seek more detailed information. Please act responsibly and protect yourself and your customer from personal harm or damage to the motor.

Motor Heat

1. All **AmP** ™ and **WarP** ™ motors are rated over Class H, which is 180 degrees C, but one still needs to protect the motor from overheating
2. If you are using your motor for drag racing, with 10-20 seconds of high load, the brushes and comm will heat up faster than the other parts of the motor. To protect your motor in this case, measure temperature in the brushes and the comm surface area using an infrared device that can react quickly. Heat can build very fast, as you would expect and may already know!
3. If your motor is used for normal vehicle travel, the ends of the pole shoes and the motor case by the shoe bolts will generally be the area of greatest heat build up. To protect your motor in this area, the normal temperature snap switch is installed. Connect it to give the driver a warning light or to automatically open the circuit if it indicates overheating. Heating will build slower here, but fast action needs to be taken to protect the system.
4. Consider setting a temperature of 110-120 degrees C for your action starting point as a safe way to manage a potential overheating situation.
5. Lastly, always ensure that sufficient and proper air circulation through the motor is not impaired!

Motor RPM

1. All **AmP** ™ and **WarP** ™ motors have commutators that were tested to over 8,000 RPM, but that does not mean they can be run at that speed indefinitely!
2. Most motor commutators built now are composite. Steel commutators were used in the past, but are now made for custom orders and very expensive. Steel core commutators are generally able to withstand higher RPM speeds.
3. We lencourage safe speed ranges from 2000- 3500 RPM, even though we know some of our **AmP** ™ and **WarP** ™ motors are peaked around 5,500 RPM for small intervals of time. When working with a customer, please be sure to design gearing so that the customer gets the speed he wants, but the motor will not be at a high RPM band for long periods of time.
4. Lastly, utilize one of the many ways available to protect the motor from exceeding 8,000 RPM and make sure it is installed and working properly. It just needs to work once to pay for itself, save the motor and protect all the people around the vehicle!

Special Update

Date: February 15, 2006
To: All Authorized Motor Dealers
Subject: **Care and Maintenance**

This **Special Update** summarizes many responses we have given to dealers and customers alike about motor care and maintenance. As the sphere of users continues to grow for electric motors used in vehicles, knowledge about motors needs to be communicated to all those users across our entire dealership network. As in our other **Special Updates** , this information does not cover every aspect of the subject.

Here are a few simple steps one should take to make the **AmP** ™ and **WarP** ™ motors give years of great performance.

1. Protection from the elements is important. Utilize good design concepts and materials to protect the motor from rain, snow and ice.

2. Design the motor mounting area to allow for good air flow. The motor needs a continuous supply of clean fresh air to cool properly.

3. Protect the motor from "dirty air" that may be used to cool it. Most airborne grit will act as an abrasive, which will eventually cause harm to the internal parts of your motor.

4. Clean the brushes and comm area regularly from the dust/dirt that occurs during normal operation.

5. Regularly check connections, voltages, tolerances and alignment to assure they are within normal specifications.

6. If you suspect or question the motor's operation, immediately shut it down. Record any visual signs, audio sounds or scents at the time and ask an expert for an opinion prior to operating the motor again.

7. Always operate the motor within the normal safety ranges for voltage, amperage, temperature, and RPM

8. Follow all the safety rules available to you.

9. Remember your motor will take care of you, if you take care of it.

Special Update

Date: January 1, 2009
To: All Authorized Motors Dealers
Subject: **Motor Troubleshooting**

The Dealer's Manual, and the Owner's Manual that is included with all new motors, includes a bench test and safety procedure for motors. A copy of the Owner's Manual may be found under the Dealers Only area of our web page (http://www.go-ev.com/dealers-only) Look under Section V – End User Supplements -> Owner's Manual.

We occasionally receive end user questions asking whether their motor is operating correctly. Seldom is the problem in the motor. Usually, the problem is somewhere else in the wiring, the controller or operation of the vehicle.

For example, we receive calls from people who indicate that at full throttle the vehicle will only accelerate to 30 MPH. The first thing to check, if the customer is using the typical 0-5K potentiometer is whether the potentiometer is actually functioning properly. A potentiometer that only puts out 2K ohms when fully depressed will limit the speed of the vehicle.

We also receive numerous questions from customers who are interested in the motor's performance at higher voltages – other than the 72 Volts found in our graphs. Voltage affects the motor's RPMs in an almost linear manner. Doubling the voltage will double the RPMs of the motor. Usually, the increase is slightly more than double since most losses occur at start up or are fixed. Amperage affects the torque of the motor – but in a non-linear manner. If the amperage is kept constant, and the voltage is doubled, the motor will produce the same torque, but at twice the RPMs.

The following information may be of interest to you or your customers in troubleshooting electric vehicles. The Owner's Manual will also be updated in order to include this information for your customers.

Feel free to contact us with any suggestions, additions or recommendations you may have concerning our motors.

Sincerely,

George F. Hamstra

Series Wound DC Motor Troubleshooting

Safety Considerations

Caution!!! Before working on the control, control circuits, motor, motor circuits, battery and any circuit or circuits of an electric vehicle, be aware of all applicable safety considerations.

The following is a list of some typical safety guidelines for working on electric vehicles – the list does not consider every possible safety aspect. If you are unsure about something you should contact someone knowledgeable. And, as always – use good judgment and common sense!

Caution!!! This list may not be complete for the electric vehicle you're servicing.

Typical Safety Checklist

- Remove all metal jewelry and metal objects from hands, wrist, fingers, etc. before working on any electric vehicle.
- Use only an industry approved battery lifting device for removing and installing electric vehicle batteries. **Do not use a chain!!!**
- Make sure the vehicle is positioned securely with the drive wheels safely clear of the floor and blocked up so that the drive wheels cannot make contact with the floor under any circumstances. Block the non–drive wheels that remain in contact with floor so that the vehicle cannot roll in either direction. Guard the drive wheels to protect personnel.
- Before troubleshooting or working on an electric vehicle, disconnect the battery pack and discharge all capacitors. Reconnect the battery only as needed for specific checks or tests.
- Make sure you know where the closest functioning eye wash station is before working on or testing the battery pack.
- Do not defeat any safety circuits or safety devices.
- Pushing in any contactor while the battery pack is connected can cause injury, property damage, and/or death.

Caution!!! **Under no circumstances** should you push in any contactor of the electric vehicle while the drive wheels are in contact with the floor. Pushing in a contactor when the drive wheels are in contact with the floor can cause property damage, personal injury, or death.

Voltage Measurement

These readings must be taken with the throttle at full-speed – make certain all safety precautions are in place before beginning.

1. Record voltage reading at battery pack half of the battery connector. _______ Vb
2. Record voltage reading at motor from terminals S1 & S2. _______ Vs
3. Record voltage reading at motor from terminals A1 & A2. _______ Va
4. Add readings from steps 2 & 3 to get motor voltage. _______ Vm
5. Subtract motor voltage Vm from battery voltage Vb, and record the value. _______ Vd

The voltage difference Vd should be about 0.5 volts with the drive wheels off the floor running at full speed. (Approximately 100 amps of motor current)

Finding Voltage Losses

A voltage loss is a voltage drop that appears across a wire, cable, connector, contactor tips, or other electrical item that normally has virtually no losses. These losses can prevent a contactor from working properly, a motor from running at full speed, a lamp from shinning at full brilliance, or improper operation of other electrical components.

Note: An unwanted voltage drop can occur on either the positive or negative side of the circuit. Therefore both sides of the circuit may have to be checked to locate the voltage drop.
One way to find a voltage drop is to use a schematic and a voltmeter to trace around the "live" circuit, first on the positive and then if necessary on the negative side. See example below.

1. Start by connecting the Black lead of the meter to B- at the battery.
2. Then touch the Red lead to point "G", the positive side of the load.
3. The reading at "G" should = battery voltage BV. If it does, go step (6). If it does not go to step (4).
4. If the voltage at "G" is less then BV probe back to "F", then "E" and so on until BV is read.
5. In this example if the voltage at "F" is less than BV but the voltage at "E" is BV, then the switch is defective.
6. If the voltage at "G" in step (3) equaled BV then C, then connect the Red lead to B+ and probe the negative side of the circuit starting at "H" working back to B- until BV is read.

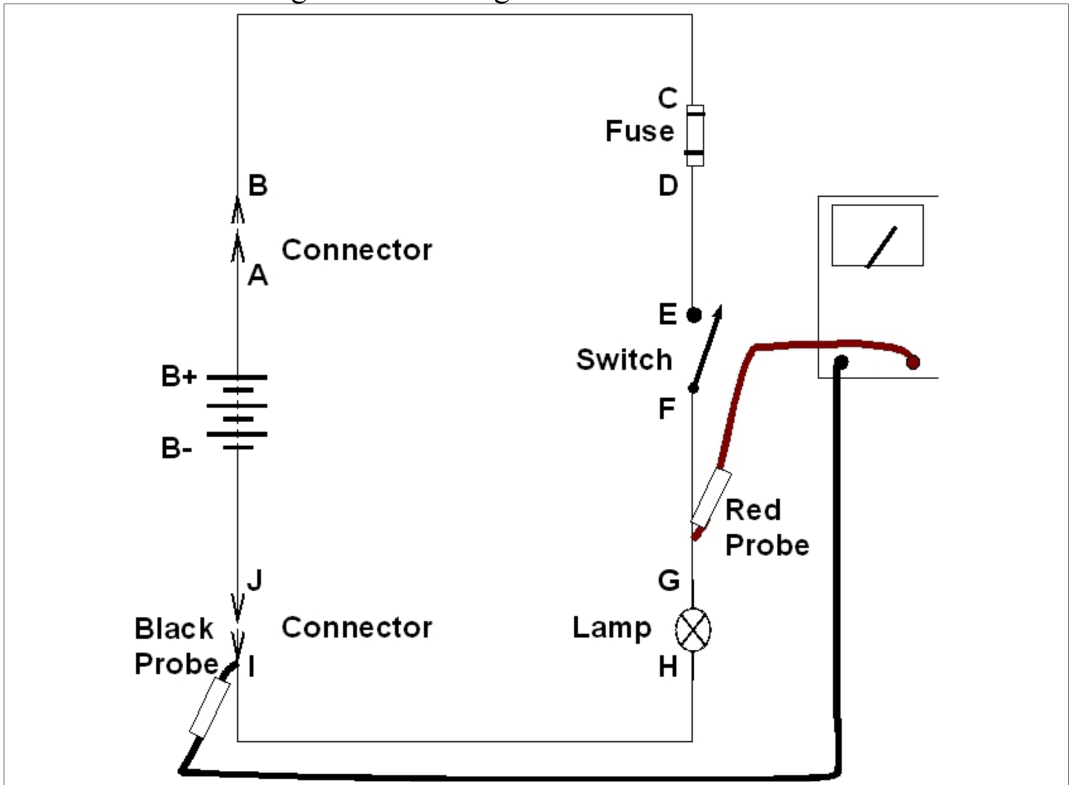


Illustration 42: Finding Voltage Losses

Frequently Asked Questions (FAQ)

FAQ's

Last updated: May 20, 2014

Welcome to the **NetGain Motors, Inc.** Frequently **A**sked **Q**uestions (**FAQ**). This document will attempt to answer many of the questions that we are asked related to our products. It is not intended to provide answers to all your questions. We suggest you contact one of our **Authorized Motor Dealers** for further assistance and guidance.

1. **Where did the *WarP* ™ name come from?**

   We do enjoy *Star Trek,* however, that had very little to do with the original name selection for our motors. The name was a natural way of showing that we intended on incorporating new and advanced thinking in the enhanced designs of the motors we planned on building. The "***War***" portion of the name comes in part from the name of a motor manufacturer that was instrumental in our original designs (and subsequent designs, as were John Wayland and numerous others...). The capital "***P***" at the end of the name is also significant. It stands for "Phil Brown", a close friend and supporter of our original electric dragster concept vehicle. Unfortunately, Phil was taken by cancer prior to the project gaining momentum. We intend to maintain this metho d of honoring **P**hil in the naming of our ***ImPulse*** ™ , and ***TransWarP*** ™ motors as well. The ***HyPer***™ motors are our new line of AC motors, while the ***AmP*** ™,***WarP*** ™, ***TransWarP*** ™ and ***ImPulse*** ™ motors represent our DC line of motors. All of the ***TransWarP*** ™ motors have a 32-tooth involute spline shaft that matches the transmission output shaft of a Chevrolet Turbo 400 transmission.

2. **Where did the *AmP* ™ name come from?**

   The "***Am***" portion of the name comes from the name of the motor manufacturer that actually contract manufacturers our motors for us. The capital "***P***" at the end of the name still stands for "Phil Brown"

3. **Which *AmP* ™, *WarP* ™, *ImPulse* ™ or *TransWarP* ™ motor should I use?**

   The answer to this question depends upon MANY factors! We would be happy to discuss which motor we feel meets your needs the best, and to run your requirements through our motor selection software. The first question you should ask is: What is the intended purpose of the vehicle? Will it be used as a "daily driver"? Will it be used strictly for racing? Will it be a performance vehicle, or will it be designed for greatest range between charges? In addition to knowing the answers to these questions, you should have some realistic thoughts relating to:

   I. Top speed to be maintained on level terrain ______________________
   II. Top speed to be maintained on grade ______________________
   III. Percent grade the vehicle will travel on ______________________
   IV. Wind resistance (frontal area) of the vehicle ______________________
   V. Total vehicle weight (with driver/passengers/load) ______________________
   VI. Final gear ratio ______________________
   VII. Tire Diameter ______________________
   VIII. Voltage to be supplied to the motor ______________________
   IX. Coefficient of drag ______________________
   X. Battery internal resistance ______________________

4. **What is the difference between *AmP* ™, *WarP* ™, *ImPulse*™, *TransWarP* ™, and *HyPerDrive*™ *motor*s?**

The ***AmP*** ™ line of motors are the newest addition to our DC motor offereings. **The *AmP*** ™, motors are particularyly well suited to street driven EV's, whereas the other motors are primarily suited to racing applications. The ***ImPulse*** ™ line of motors were designed to be lower power and/or smaller motors than our traditional ***WarP*** ™ series motors. The ***ImPulse 9*** ™ is shorter than a ***WarP 9*** ™, and is less powerful. However, it is more powerful than the 8" diameter motor it was designed to replace. In addition to being more powerful than an 8" motor, it shares many of the beefy components of the ***WarP 9*** ™ motors (commutator, bearings, brushes, etc.). The ***ImPulse 9*** ™ also has the same bolt pattern and mounting characteristics of an 8" motor. The ***WarP*** ™ Motors are our most common motors. The ***WarP 9*** ™ and ***WarP 11*** ™ were designed to be interchangeable with one another. The ***WarP*** ™ motors are the most common motors we make for EV conversions. The ***TransWarP*** ™ motors were designed to meet the needs of direct drive, racing applications, as well as being used by the now defunct ***EMIS*** ™**.** The "rule of thumb" when dealing with direct drive applications is that #1 it is not good for use as a daily driver #2 it will require twice the motor and twice the controller of a vehicle with a transmission. Our latest offering is the ***HyPerDrive 9*** ™ motor. These are actually two specially race prepped ***WarP 9*** ™ motors with different shafts, brush rigging, etc. from our normal ***WarP*** ™ motor. The ***HyPerDrive***™ were orginally set of two matched motors that were designed to be fitted together and work as a single motor. The "***Pe*** " portion of the name is my thanks to Mike **Pe**thel who helped with the development of this radical design. Since we no longer plan to produce these motors, we are planning to use the name for our new line of AC motor controllers.

5. **How do I become a dealer of *AmP*™ and *WarP* ™ *motors*?**

You should visit our Web Page (http://www.go-ev.com) and print a copy of the **Dealer Application**. Fill out the form completely and FAX it back to us. You must have a valid existing business with a state resale sales tax number in order to even begin the process. We also consider proximity to other Dealers, experience converting vehicles to electric, and other factors, web only Dealers will no longer be considered.

6. **What is an ICE, what is an EV, Hybrid?**

ICE stands for **I**nternal **C**ombustion **E**ngine. **EV** stands for **E**lectric **V**ehicle. A hybrid vehicle is one that uses a mixture or combination of technologies to propel the vehicle. Hybrids are generally one of two types: series or parallel. A parallel hybrid uses multiple, possibly combined, means of powering the vehicle, while a series hybrid generally uses a source to produce electricity in order to power an electric motor that actually drives the vehicle. Almost all ICE vehicles "could be considered hybrids since they include an electric motor to start the ICE, but we won't go there...

7. **What do the abbreviations "*DE*" and "*CE*" stand for?**

"**DE**" stands for "**D**rive **E**nd". This is the end of the motor that usually contains the fan and usually has a larger diameter shaft. "**CE**" **stands** for "**C**ommutator **E**nd". This is the end of the motor where the brushes and commutator are. Motors that are specified as "no **CE** shaft" do not have a shaft extending from this end. "**CE**" is also the abbreviation used by Dennis Berube for his world record holding electric dragster: **C**urrent **E**liminator.

8. **What do the abbreviations "*CCW*" and "*CW*" mean?**

"**CW**" stands for "**C**lock**W**ise" rotation and "**CCW**" stands for "**C**ounter-**C**lock**W**ise" rotation. These abbreviations are normally used in conjunction with "**DE**" and "**CE**" to indicate the perspective of the armature rotation. For instance: "**CCWDE**" would indicate **C**ounter-**C**lock**W**ise rotation when viewed from the **D**rive **E**nd – this is the default for all ***AmP*** ™, and ***WarP*** ™ motors with the exception of the ***TransWarP 7***™ which is neutrally timed from the factory (but may be ordered with advanced timing. **CWDE** would indicate "**C**lock**W**ise rotation when viewed from the **D**rive **E**nd. Most vehicles require **CCWDE**, however, some vehicles (i.e. Honda transmissions) may require **CWD**E. You should verify the rotation prior to ordering as the timing can be requested to be advanced timed for the rotation of the motor.

9. **What is "Timing" on an an electric motor?**

Timing an electric motor refers to the area of the commutator that is being energized has been moved from a normally centered position. Normally, brushes are fixed into a position on the commutator during the manufacturing process. The position they are normally set at from a manufacturer is a "neutral" position. A "neutral" position allows the motor to operate and perform almost identically in **CCWDE** and **CWDE** rotations at normal voltages. A normal voltage for most series wound motors in a neutral timed arrangement is generally less than 96 volts. Above this voltage motors should almost always be advanced in the direction of their normal rotation in order to reduce arcing, improve RPMs, and to provide increased performance at higher voltages. **CAUTION: If a motor is advance timed and then powered to run in the opposite direction of the advancement, significant arcing and damage could result if high power is applied! Regen should not be attempted with motors that have been advance timed!**

10. **How do I know how much to advance the timing on a motor?**

All new ***AmP*** ™ **and** ***WarP*** ™ motors have pre-drilled holes that allow the commutator end-bell to be removed and the brushes repositioned in a neutral, or an advanced position, either **CWDE** or **CCWDE**. The ***WarP*** ™, ***ImPulse*** ™, and ***TransWarP*** ™ motors are each advanced ~12 degrees. ***AmP 8*** ™ motors are advanced ~10 degrees. The amount of advancement is based upon the width of the brushes, the number of commutator bars, the diameter of the commutator and various other factors that are monitored when the motor is run on a dynomometer. The proper terminology used to describe an advanced timed motor would be "advanced timed, **CCWDE**" or "advanced timed **CWDE**". The term "retarded" that is often used to describe the timing of **ICE** (**I**nternal **C**ombustion **E**ngine) vehicles is not applicable to electric motors. In order to change the timing, you may simply loosen 4 bolts and rotate the bell housing in the direction you desire to advance the timing from the neutral position. All of our motor cases are stamped with “CW” “N” and “CCW” - you can determine the advance state by seeing which commutator **end bell bolt** is aligned with the letters stamped in the case. **THE TERMINAL STUDS SHOULD NOT BE USED TO DETERMINE POSITION OF THE END BELL!**

11. **How can I order *AmP* ™, and *WarP* ™, motors?**

AmP ™ **, and** ***WarP*** ™ motors may only be ordered through an Authorized Motor Dealer. A list of Dealers is available on our web page at http://www.go-ev.com

12. **What if I need something other than the "standard" motor?**

NetGain Motors, Inc. will work with our motor manufacturers in order to ascertain your specific needs and develop a motor to meet your needs. Custom motor options, such as special materials, components, shaft splining, special composition brushes, or other variances from standard configurations are available at an additional cost. We also have some motor models that we do not advertise (such as a Sep-Ex ***WarP 9***™). Additionally we make many private label OEM motors. Though we cannot sell these motors to anyone other than the OEMs, the designs may be similar to others needs and can keep the cost of a design within reason. Contact **NetGain Motors, Inc.** with your needs and we can provide a quote.

13. Where can I get replacement parts for my motor?

Replacement parts and components can be ordered through any Authorized Motor Dealer or directly from NetGain Motors, Inc..

14. Will an alternator, generator, windmill or solar panels on my vehicle keep the battery charged?

In brief: "NO"! We receive this question on almost a daily basis! If you figure out a method of actually getting more energy out of something than you put into it – please let us know immediately! To date, no one has figured out how to accomplish this feat – and though you aren't going to receive a ticket for trying, there are certain laws that you would be in violation of. Though windmills and solar cells may certainly be used to help charge batteries, most of the motors we sell are for use in vehicles that can draw between 340,000 watts (for a short time), and 15,000+ watts at highway speeds. If you have the time and plenty of sunlight and wind, these resources could certainly replace at least some of the energy consumed – just not as fast as people generally use it, or as quickly as you may want.

15. Can I use your motors in marine applications?

Certainly, but don't submerge them, and protect them from saltwater. Also, pay particular attention to previous questions. It is extremely difficult to create a watercraft with 10-12 hours worth of wide-open power with generally available battery technology.

16. What are the two wires that come out of the motor case and how do I use them?

These wires are connected to a normally closed 120C thermal switch. On 11” and 13” diameter motors a 150C thermal switch is used. This switch is used to determine whether a motor is nearing a temperature that could cause internal damage to the motor. Some people refer to this switch as a “nuisance switch”. We do not suggest that this switch be used to automatically disable the motor if a heat condition arises as circumstances may require driving the vehicle to a safe area before shutting down. Some people use this switch to keep a contactor open by applying 12-volts to the switch. If the voltage is dropped (by the switch opening), then a light could be lit, or a buzzer sounded to indicate a potential problem exists. The two wires were changed to a recessed plastic connector that has two 1/4” mail spades on newer motors. This makes it extremely easy to connect with. Additionally, the Normally Closed (NC) switch has been replaced with a Normally Open (NO) switch. This also makes it simpler to wire a warning indicator.

17. What is the round black connector on the commutator end bell used for?

Some motor models have been made with a brush wear indicator. If you look carefully into the connector you will see that the round black connector actually accepts flat, female, tab connectors. When the brushes wear to a point where the brush wear indicator wire touches the commutator, **a voltage equal to the commutator voltage will be fed through the brush wear indicator connector**. As this could be a high voltage, appropriate care should be given if this connector is used. Once the brushes wear to the point where the wire touches the commutator surface it is necessary to replace the brushes quickly or damage to the commutator could occur from the indicator wire. This feature has been removed from most motors as it was difficult to use with the pack voltages of typical EVs.

18. What are *TransWarP* ™ Motors?

The ***TransWarP*** ™, motors are not a motor with a builtin transmission. The Drive End (DE) of the ***TransWarP*** ™ motors have a 1.375”, 32-tooth, involute splined shaft that matches a Chevrolet Turbo

400 (T400) transmission output shaft. The drive end bell has been pre-drilled to accept an optional "shorty" T400 tail-shaft housing. The output shaft accepts an optional industry standard 1350 series slip-yoke for easy connection to almost any manufacturers drive-shaft (with matching 1350 series yoke. The commutator end shaft has also been increased in size to 1.125" with a 1/4" key-way. This allows easy coupling of ***WarP***™ motors to ***TransWarP***™ motors. These motors were designed to be part of the ***EMIS***™ System which was also available from **NetGain Motors, Inc.** You can couple a ***WarP***™ motor to a ***TransWarP***™ motor of the same size for direct drive applications.

19. Can I direct drive my vehicle using your *TransWarP*™ motors?

Our motors like to spin 2000-4000 RPMs. Running the motors at very low RPMs will generally draw significant amperage and not allow the fan to cool the motor. Direct drive works well in racing applications, however it is not the best choice for a daily street driven vehicle. The generally accepted rule of thumb is this: Direct drive will require twice the motor and twice the controller of vehicle with a transmission. This means you would have to use a ***WarP 9***™ coupled to a ***TransWarP 9***™ in an application where a single ***WarP 9***™ would normally suffice if a transmission was used. Additionally, if a single **Zilla 1K** controller could have been used, you will need a **Zilla 2K** for a direct drive application. Additionally, you must force cool air into direct drive motors if the normal RPMs of the driven vehicle are below 2000 RPMs.

20. How do Volts and Amps affect a motors performance?

VOLTs=RPMs in an almost linear manner. If you double the voltage you will double the RPMs of the motor. Usually, RPMs increase just slightly more than double as most losses are fixed. You will notice that the performance graphs for our motors are all at 72 Volts. If you plan on running at 144 volts you can simply multiply the RPMs by 2. AMPs=Torque. Torque will remain constant if the amperage does not change, regardless of the RPMs. If you look at our 72 Volt graphs and find a ft. lbs. of torque and the amps required to produce that torque, you can simply double the RPMs if you are planning to run at 144 volts, - the torque will be produced at twice the RPMs if the amperage doesn't change. If you increase the AMPs, the torque will increase, but in a non-linear manner that is difficult to extrapolate. If you increase the voltage you will basically extend the torque curve of the motor.

21. What voltage and amperage should I run at?

Your budget and performance expectations will normally be the deciding factor, but generally speaking, for a daily driver vehicle, you should consider a voltage between 120 and 156 volts to the motor armature. Motors should never see more than 170 volts to the armature (except when prepared for racing). However, the battery pack voltage should be as high as the controller will allow if using lead-acid batteries. You should generally have a higher pack voltage (ideally) than the motor voltage due to a condition referred to as "voltage sag". When most lead-acid batteries are requested by the controller to deliver 1000-2000 Amps to the motor, the battery voltage can easily sag to 5-5.5 volts per battery (on 12 Volt batteries). Lead-acid batteries have been known to explode during racing applications from heavy discharges – a credit to the **Zilla** controllers! However, if the voltage of a 12 volt PbA battery sags to 6 volts, the motor may only see ½ the voltage you intended, and consequently only spin at ½ the RPMs you thought it should! It's generally not the motor that is the reason for poor EV performance, it is more often related to the batteries or controller. (assuming the motor selected is appropriate for the vehicle...)

22. What motor controller should I use with these motors?

For many years the only controller that was **ever** recommended in a pure electric vehicle application by **NetGain Motors, Inc.** were the **Zilla** Controllers from http://www.cafeelectric.com! The Zilla is still available and is still a top-notch controller. Two more recently developed controllers are the **WarP-**

Drive ™ controllers manufactured by ***http://www.ngcontrols.com***, and the **Soliton 1** previously produced by evnetics.com. Both of these controllers are excellent choices as well. You may certainly use other controllers, such as the ever popular **Curtis 1231C**, **Alltrax**, **Sevcon**, **Raptors**, **Synkromotive**, and **MaxForcer** – just to name a few of the more popular and highly regarded EV controllers. Your budget and vehicle performance expectations will be heavily impacted by the controller decision you make.

23. How much power can these motors produce?

Series wound DC motors, such as these, are renowned for the massive torque they produce from 0 RPM. These motors will suck every AMP the controller can deliver in order to try and start the armature spinning. Though our motors are regularly abused by **Zilla** controllers delivering 1000-2000 Amps, or Soliton Shiva capable of greater than 3,500 Amps for brief periods, the 9" motors (and 11HV) are actually rated at 450 Amps for 5 minutes, 225 Amps for 1 hour, and 190 Amps continuous duty. The normal 11" motors are rated at 500 Amps for 5 minutes, 250 Amps for 1 hour, and 200 Amps continuous. We believe these are conservative ratings. The difference in the variously sized motors is the amount of torque and RPM at which the torque will be delivered. If the ratings of a single motor are exceeded, you can divide the figures in ~½ and use multiple motors. There are additional losses of around 8-10% when using dual motors.

24. Where can I obtain an adapter plate made for my vehicles transmission?

Many ***AmP*** ™ and ***WarP*** ™ motor dealers specialize in making transmission adapter plates, as well as providing the other components used in EV conversions. Our **Authorized Motor Dealers** are listed on our web-site at http://www.go-ev.com/dealers.html. You can check the annotations in each Dealers listing to locate the best match for your specific needs. Some **Authorized Motor Dealers** are capable of making adapters that are not listed on their web sites, so be sure to work with one of our **Authorized Motor Dealers** for further information and advice.

25. Can I run the motors at 10,000 RPMs?

With no load and high voltage these motors can spin to excessive RPMs **EXTREMELY** quickly! The motors should ONLY be spun at no load with a maximum of 12 volts applied. The bearings are rated to ~14,000 RPMs, however we do not recommend running these motors beyond 5,500 RPMS (7,800 RPM for the 7" motors). For short durations (i.e. drag racing) the motors have been known to approach 10,000 RPMs, but this is strongly discouraged! If high RPMs are an essential requirement of your application you should consider requesting Kevlar banding and other optional modifications (belly banding) that can be performed at the factory or by a few of our **Authorized Motor Dealers**. It is extremely dangerous to run these motors at high RPMs without shielding that can withstand a possible commutator explosion. World records have been set with these motors never exceeding 3,400 RPMs by gearing them properly. If extremely high RPMs are required on a normal basis a more appropriate motor design should be considered.

26. Where can I get additional assistance with my conversion?

An excellent resource is your local chapter of the Electric Auto Association. These groups have been doing conversions to pure electric for 40+ years and have extensive knowledge. Some of the Members of the EAA are world renown for their abilities. There are numerous books available, (i.e. ***Build Your Own Electric Vehicle*** by Seth Leithan and Bob Brandt or ***ICE FREE*** by John Hardy) and most of our **Authorized Motor Dealers** are willing to discuss your project with you and offer guidance advice at no cost. There is also a very active discussion group on the Internet called the EVDL (http://www.evdl.org/index.html) and the DIY forums (http://www.diyelectriccar.com/forums/). Our **Authorized Motor Dealers** are some of the best resources in the world. They have generally completed numerous conversions and will work with you to supply parts and insight into a vehicle conversion, as well as supplying you with the various components you'll need.

27. What is the EVDL and how do I subscribe?

The **EVDL** is the **E**lectric **V**ehicle **D**iscussion **L**ist. You can find all the details needed to subscribe and view the archives at: http://www.evdl.org/. You might also be interested in what other people have by checking out: http://www.evalbum.com/

28. What components do I need to make an electric vehicle?

You will obviously need an electric motor. You'll also need a motor controller, and a device to act as the throttle that will signal the motor controller as to the power requested - a 5K potentiometer is by far the most typical method, but the Hall Effect method is a safer/better alternative. You'll also need batteries. A battery charger(s), possibly a battery management system, possibly a transmission adapter plate, battery boxes/enclosures, a DC-to-DC converter, a transmission adapter plate, lots of cable, lugs, contactor[s], connectors, gauges and wiring.

29. What makes a good conversion vehicle?

First pick a vehicle you like that is in good condition. It is not uncommon for people to keep EVs for many years. As the weight of the vehicle will probably increase (I've never seen one that decreased if lead-acid was being used), consider the gross vehicle weight constraints. Choose a lightweight vehicle with strong suspension and brakes - sports cars and small pick-up trucks make ideal candidates. Do not change the ride height of the vehicle, or the ride characteristics. The heavier the vehicle, the more likely you are to be dissatisfied with the range and performance. Small pickup trucks make good candidates, as the batteries can be placed under the bed along the frame rails, and they are designed for carrying additional weight (i.e. Batteries). They also have brakes designed to stop the vehicle with the extra weight you may add.

30. I want to go 300 miles on a charge at 75 miles per hour in my Suburban – okay?

NO! The typical range of a lead-acid EV is 25-50 miles on level terrain – depending upon the batteries and weight of the vehicle. Even with the most advanced PbA battery chemistry currently available a 300 mile range is beyond current PbA technology. But, conversions using the various Lithium batteries currently available are claiming 75-150+ mile range. We are headed in the right direction, just not at 300 miles for conversion vehicles yet, though the Tesla Model S claims a range of 306 miles for it's 85 kWh battery pack. The same answer goes for recharging the batteries in 5 minutes – it won't happen for quite awhile. Tesla claims 58 miles of range per hour of charging and 20-30 minute charging at it Supercharger stations (which are also free for Telsa owners to charge at!) The **PulsaR**™ and **QuasaR**™ Power Distribution Units (PDU) from ***http://www.ngcontrols.com*** have the potential for even faster DC-DC dump charging at a theoretical 150 kW and 300 kW. Though the PDU may have this potential, most battery packs could not withstand this sort of input to the batteries. EV components must be matched for safe operation and usage – consult with a knowledgeable source or contact one of our Authorized Motor Dealers before attempting a potentially dangerous operation on an EV.

31. I want to use a small generator to run the electric motor while I am driving on the highway.

At first this sounds plausible, but using $5.00/gallon fuel (gasoline) to derive $1.00 per gallon fuel (electricity) is only the beginning of the issues surrounding this. Generators are noisy. Most generators are not designed to operate in a mobile environment and fuel can spill from their tanks and create a hazardous situation. If you try to quiet the generator you may reduce its ability to produce electricity.

When generators are running they typically produce more pollutants in one hour that 250 hours of driving an ICE. Even in a lightweight vehicle you will require around 150 amps at 144 volts to maintain 60 MPH – that's more than a 21 kW generator!

If the question is "Trains do it why can't a car?". The simple answer is that trains run level, and straight as much as possible, with few stops, at a constant speed, and cost millions of dollars. Trains are not concerned about their 0-60 MPH time, or merging with traffic. It only takes a small fraction of the power needed to obtain a desired speed that it takes to maintain the desired speed. Additionally, steel wheels on steel tracks offer 1/50th of the rolling resistance of rubber on concrete. A typical EV will use 144 Volts and 500 to 1000 Amps to get started from a dead stop. This is 144 kW of power! This would require a VERY large generator – probably larger than the EV itself, and probably requiring more fuel than the original ICE vehicle. My suggestion is that if you really want to attempt this that you only use a generator when the vehicle is parked and not in motion.

32. Can I use capacitors to power the vehicle?

Probably not entirely. Though capacitors offer very high power density, their energy densities are very low (the opposite of fuel cells). Super-capacitors (aqueous based) and ultra-capacitors (organic based) usually become a slave to the batteries. There is potential for the use of capacitors in EVs, particularly when used with regen braking, but regen braking should not be done with series wound DC motors. The use of capacitors might be beneficial in obtaining a speed, but probably doesn't make much sense to use them to maintain speed. If a DC-to-DC converter were used between a battery pack and the capacitors they might prove to be an excellent addition to an EV. See: http://www.powershow.com/view1/26cee4-ZDc1Z/Hybrid_Advanced_Power_SourcesHAPS_Project_Highlight_VTB_Annual_Review_2002_powerpoint_ppt_presentation

33. Do I really need a transmission?

Whether you need a transmission depends upon many factors. The short answer is "YES", but depending upon the vehicle, there are instances where no transmission may be required. For instance, if you are planning on just racing the vehicle and not driving it on the street, then you may not need a transmission. But, the transmission can be used to keep the vehicle in its power-band and thus improve the vehicles performance. If the vehicle is extremely lightweight you may also consider not using a transmission. But, once again, there are caveats. The motors normally enjoy spinning 2,000 to 3,000 RPMs . Spinning the motor slower may not provide enough ventilation to the motor, causing it to run hot. Additionally, very low RPMs may cause the motor to use more amperage and run hotter. A forced-air cover-band is highly recommended along with an external blower than can force cool air into the motor if the motor is going to be run at low RPMs for considerable amounts of time.

The use of a transmission will normally allow you to achieve far better performance and reduce the risks of motor damage due to poor cooling or high amperage. And, a transmission may also provide two other important items for you to consider beyond the gearing advantages:

I. A transmission can act as a mechanical safety disconnect! In case of an emergency the clutch may be depressed, or the transmission shifted to neutral. These motors can be extremely powerful, and brakes alone may not be enough to stop a vehicle if the motor is applying force.
II. A transmission can be used to park the vehicle. Some automatic transmissions have a locking feature (Park) that will keep the transmission from turning – and thus the car from moving if it is on an incline. In an ICE vehicle you always have the engine compression, emergency brakes and transmission (in Park) to keep the vehicle from moving on an incline. In an EV you should maintain a parking brake, but the motor will spin freely, so having a transmission that locks could be a benefit.

34. Should I keep the clutch?

The EV community has always been split on this topic. Certainly it is easier to eliminate the clutch, and the electric motors normally have enough power so that a vehicle can start in 3rd gear without the use of a clutch. But, I personally prefer keeping the clutch If starting on an incline without a clutch, the motor can be required to produce a lot of torque (draw a lot of amperage) depending upon the gear you start in. By using a clutch, it is easier on the motor as you can raise the RPMs and gradually get the vehicle moving. Keeping the clutch also makes it easier to shift gears. The EV community is split 50/50 on whether to keep the clutch. Be aware that if you keep the clutch and insist on driving it like an automatic (i.e. starting in 3rd gear) that it most likely you will burn up your clutch if you make repeated fast starts.

NOTES

NOTES