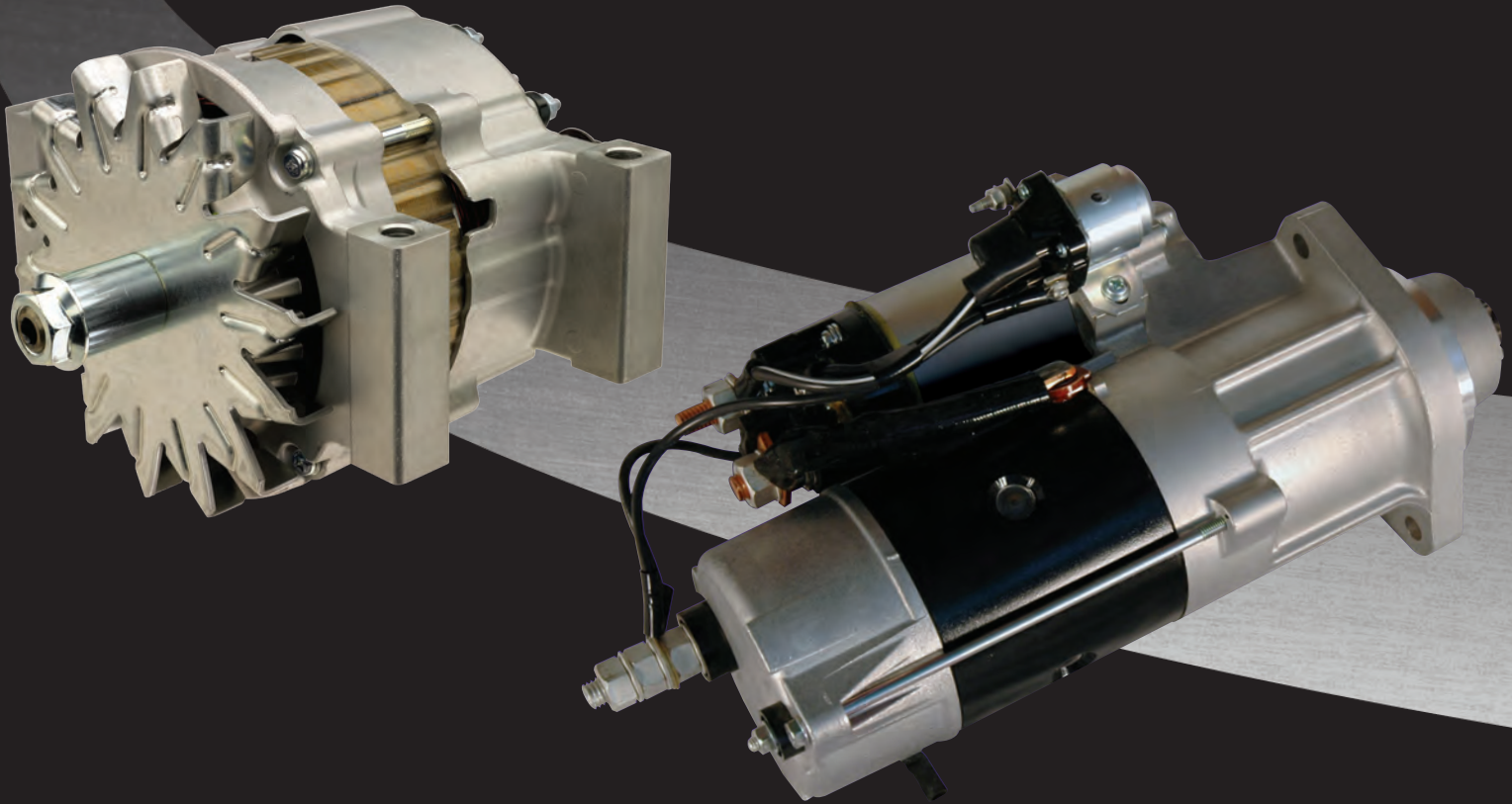


# Technicians Guide

## North American 12-Volt Systems



## Table of Contents

<b>Section 1: Introduction .....</b>	<b>1</b>
<b>Section 2: Electrical System Basics.....</b>	<b>2</b>
<b>Section 3: Common Failure Modes.....</b>	<b>7</b>
<b>Section 4: Battery System.....</b>	<b>8</b>
<b>Section 5: Starting System.....</b>	<b>14</b>
<b>Section 6: Charging System.....</b>	<b>26</b>
<b>Section 7: Conclusion.....</b>	<b>35</b>
<b>Section 8: Glossary.....</b>	<b>36</b>
<b>Section 9: Legal Disclaimer.....</b>	<b>39</b>
<b>Section 10: Information Acknowledgements.....</b>	<b>40</b>
<b>Appendix A: Ring Gear Wear Examples.....</b>	<b>41</b>
<b>Appendix B: Recommended Torque Values and Alternator Rated Outputs.....</b>	<b>42</b>

## Section 1: Introduction

This manual has been developed by Mitsubishi Electric Automotive America, Inc. (MEAA) with the objective of providing a step by step outline of the procedures for troubleshooting problems with your Mitsubishi 12 volt heavy duty electrical system as described below.

**Three elements will be discussed in this manual, and will be referred to collectively as the “electrical system”:**

- ▶ Battery system
- ▶ Starting system
- ▶ Charging system

The electrical system also includes the interconnecting wiring and electro-mechanical switches. For the electrical system to function properly and maintain a high level of operating efficiency, all three systems must properly work together.

Problems with a vehicle’s electrical system are often misdiagnosed as a starter or alternator problem. A significant number of products returned to MEAA under warranty and deemed “defective” by the customer are found to be “NTF” (No Trouble Found).

This manual’s main function is to provide recommended procedures to assist you in properly diagnosing electrical system problems.

**Proper diagnosis consists of three basic questions:**

- ▶ What are the symptoms?  
Basic observations seen, heard, felt or smelled
- ▶ What has caused the symptoms?  
Proper diagnostic tool use helps identify the cause of the electrical system problem or failure
- ▶ How is the problem fixed?  
This step involves part repair, replacement or adjustment

These procedures are designed to help you accurately troubleshoot the problem, avoid misdiagnosis and reduce NTF claims. All contribute to reduced operating costs.



**Reminder: It is not always an electrical component that is the problem. Vehicle wiring needs to be checked as well.**

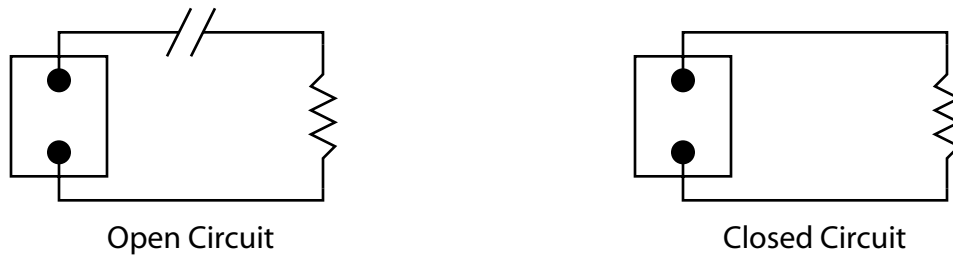
If you have questions or concerns, please visit our website: [www.diamond-gard.com](http://www.diamond-gard.com)

## Section 2: Electrical System Basics

### 2.1 Electrical Fundamentals

#### Open and Closed Circuits

A closed circuit provides a continuous path for current flow. This circuit contains a power source, wires and a load. When referring to a power source it can be either an alternator or the batteries. When referring to the load this can be lights, starter motor or any other device that consumes power.

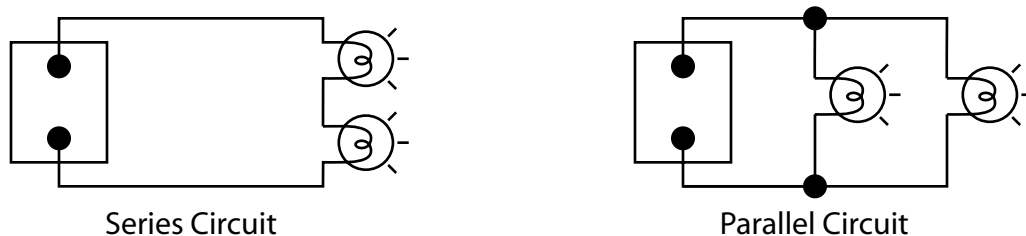


*Figure 1: Open and Closed Circuits*

An open circuit contains a disruption in current flow. This disruption is usually an air gap or an insulating material. Current is unable to flow in an open circuit condition.

#### Parallel and Series Circuits

In a series circuit current flows through a single path. A flashlight is an example of a series circuit. The current flows from the battery through a light bulb. If the bulb burns out, the path is disrupted and the circuit is open.



*Figure 2: Series and Parallel Circuits*

Current flows through multiple paths in a parallel circuit. Truck headlights are an example of a parallel circuit. Current flows independently to each headlamp from a power source. If one headlight burns out, the other still works.

#### Voltage

Voltage is the difference in electrical “pressure” between two points. For example, a properly charged battery has voltage across its positive and negative terminals of approximately 12 volts when it isn’t supplying current.

#### Current

Current is the flow of electrons through a circuit. Two conditions must be met for current flow to exist: a closed circuit and voltage. Voltage provides the “pressure” to move the electrons (current) through the circuit.

## Resistance

Resistance is the opposition to current flow. Think of resistance as a restriction in a hose's diameter.

## Relationship Between Voltage, Current and Amperage

Voltage, Current and Amperage are interrelated. This relationship is expressed through Ohm's Law:  $V=I \times R$ . In this equation  $V$ =voltage,  $I$ =current flow and  $R$ =resistance.

If two of the values are known, the equation can be manipulated to find the third value. An example is shown below.

- ▶ Consider the circuit in Figure 3 with resistance  $A = .01\Omega$ 
  - ▶ Connect a voltmeter to the leads of the load
  - ▶ Voltage across the load is 1.0 volt
- ▶ What is the current flow in the circuit with resistance  $A$ ?
- ▶ What is the current flow in the circuit with resistance  $B$ ?

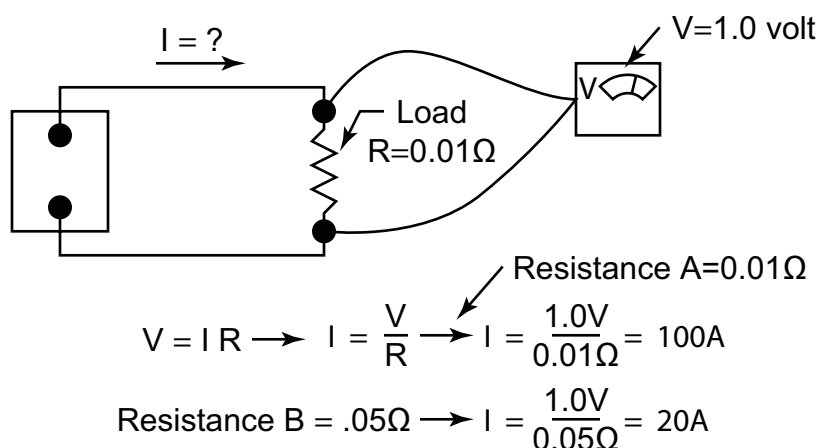


Figure 3: Ohm's Law Example



**This discussion's important point is: Increased resistance leads to reduced current flow. During electrical system troubleshooting, increased resistance is shown as an increased voltage drop in a circuit.**

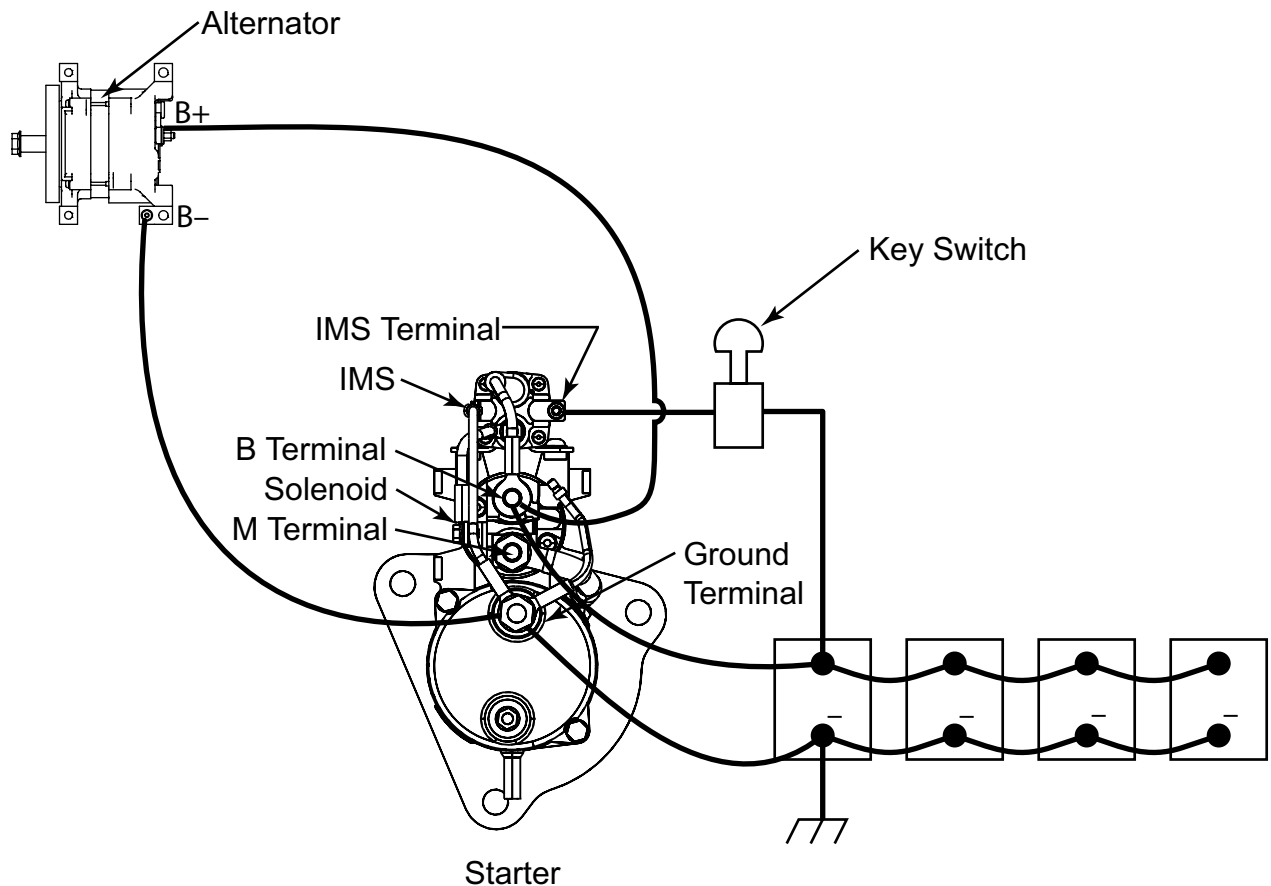
## What is Voltage Drop and why is it important?

Voltage drop is the voltage measured between two points in a closed circuit that contains a resistance. Each wire in the vehicle's charging and starting system has a resistance. This resistance is very low, but is still there. Voltage drop only occurs when current is flowing through the wire being checked.

Too much resistance in the alternator and starter cables prevents these components from functioning properly. As resistance increases, voltage drop increases. **MEAA has calculated the maximum recommended voltage drops for proper function of its products. These values are provided in the troubleshooting sections of this manual.**

## 2.2 Electrical System Description

The electrical system covered in this manual consists of five main components: a starter motor, alternator, battery pack, main wiring and control circuit. They are all interconnected and each must function properly for the system to work. Figure 4 shows these components.



*Figure 4: Electrical System*

### Batteries

Batteries provide power for engine cranking and electrical loads when the alternator is not generating power. They also stabilize voltage levels in the electrical system.

### Alternator

Alternator generates power for all of the vehicle's electrical loads while the engine is running. This includes the engine's electronic controls, headlights, etc. It also recharges the batteries after cranking the engine or using the vehicle's electrical devices while the engine is off.

### Starter Motor

Starter motor converts electrical energy into mechanical energy needed for cranking the engine over.

## Main Wiring

There are two wiring subsystems related to the charging and cranking circuits:

- ▶ First subsystem
  - ▶ Supplies power from batteries to starter motor
  - ▶ Wires are most noticeable
    - ▶ Large enough to transmit several hundred amperes during cranking
    - ▶ Transmit power back to batteries from alternator for charging
- ▶ Second subsystem
  - ▶ Transmits power from the alternator to the batteries for charging
  - ▶ Usually connected from the alternator to the starter

## Control Circuit

Control circuit transmits power to starter's solenoid

- ▶ Includes key switch and associated wiring
- ▶ Starter motor receives “start” signal from control circuit
- ▶ Section 5.5, Step 4 provides an explanation of possible control circuit configurations
- ▶ Figure 4 illustrates typical control circuit configuration



## 2.3 Diagnostic Tools

The following tools are recommended for troubleshooting the batteries, starter and alternator on your vehicle:

### Carbon Pile Load Tester

Use this device for load testing batteries and cables in the starting and charging system. The illustration unit includes a voltmeter. The ammeter in these devices can be very sensitive to correct calibration. Check with the manufacturer for correct calibration intervals.



*Reproduced with permission*

### Clip-on Ammeter

A clip-on ammeter is used to measure the current flow through a cable. Note: Clip must be completely closed for accurate readings.



*Reproduced with permission*

### Voltmeter

Voltmeter measures voltage across two points. The connection between the voltmeter's probes and the contact points should be corrosion-free for accurate measurements.



*Reproduced with permission*

### Electronic Tester

An electronic tester combines the features of a carbon pile load tester, voltmeter and ammeter in one unit. This tester contains all the devices needed to accurately diagnose battery and starting problems.

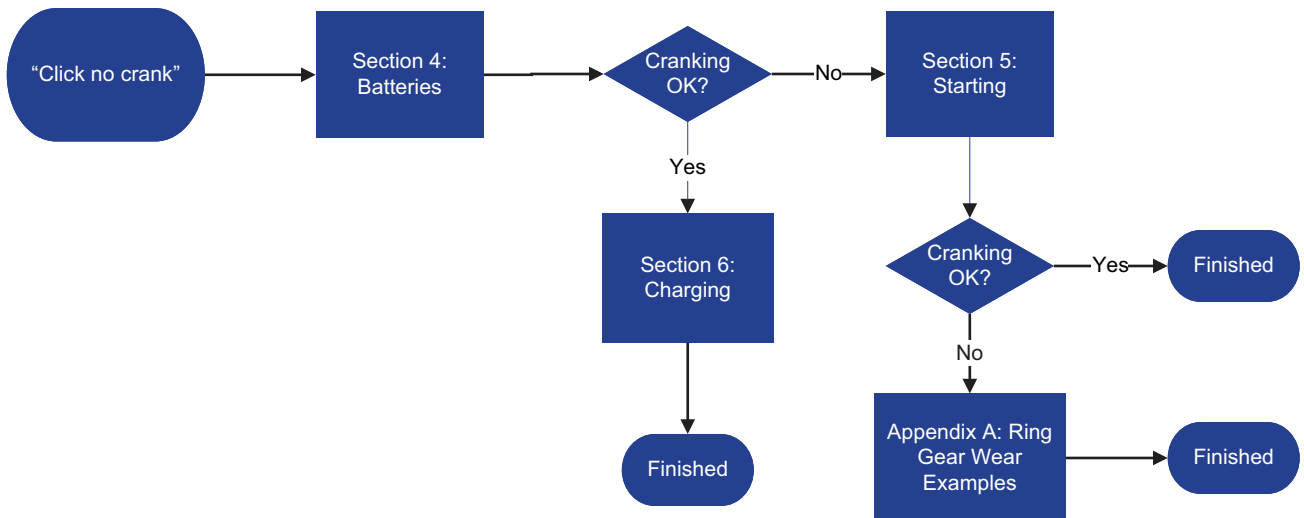
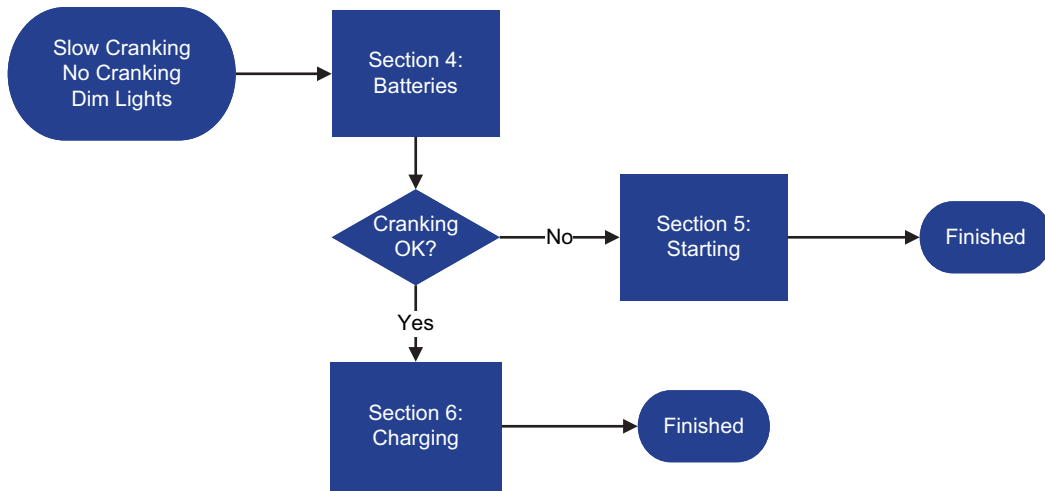


*Reproduced with permission*



## Section 3: Common Failure Modes

Below is a guide for determining the proper troubleshooting steps for some common failures. See Sections 4, 5 and 6 for detailed troubleshooting steps. Troubleshooting flowcharts are available at the end of each section.



## Section 4: Battery Systems

### Section 4.1: Battery Safety

**NOTE:** This section is for informational purposes only. Refer to your battery manufacturer for proper safety and testing procedures.



**Refer to the vehicle and battery manufacturers' safety procedures before any handling, charging or storage of the vehicle's batteries.**

### Section 4.2: State of Charge

State of charge is a measure of the amount of usable power remaining in a battery.

**General rule:** A battery needs a minimum of 75% state of charge for proper cranking.

Three methods are available for checking the state of charge in a battery: specific gravity, open circuit voltage and electronic battery testers.

Specific gravity test is a measure of a battery's electrolyte density compared to the density of water. A hydrometer is used to measure a battery's specific gravity. Some batteries have a built-in hydrometer.

- ▶ Batteries without a built-in hydrometer
  - ▶ Test can only be performed on batteries with removable vent caps
  - ▶ Refer to the battery manufacturer's specifications for hydrometer values
- ▶ Batteries with a built-in hydrometer
  - ▶ Refer to the vehicle or battery manufacturers' instructions for reading the built-in hydrometer

Open circuit voltage (OCV) test is a voltage measurement across a battery's terminals under a no-load condition.

- ▶ Use test to determine state of charge for batteries without removable vent caps
- ▶ OCV's negative aspect is the possibility of inaccurate voltage readings due to battery surface charge
  - ▶ Surface charge is an effect of charging lead-acid batteries
    - ▶ Can lead to inaccurate OCV tests
  - ▶ Refer to battery manufacturer's recommendations for identifying and removing surface charge
- ▶ Refer to battery manufacturer's specifications for state of charge percentages based on OCV values

Electronic battery testers display state of charge based on an internal algorithm

- ▶ Refer to battery manufacturer's recommendations for use of electronic testers

### 4.3 Battery Charging Basics

This section will help determine the time required to charge a vehicle's batteries, and is meant for informational purposes only. Refer to the battery manufacturer for proper charging procedures.

Batteries used in vehicle starting systems generally come with a reserve capacity rating.

- ▶ Good for comparing battery capacities
- ▶ Doesn't help determine charging times
  - ▶ Need to know battery's ampere-hour capacity

A battery's ampere-hour capacity is a measure of the electrical energy a battery can supply at a defined temperature, amperage and cut-off voltage.

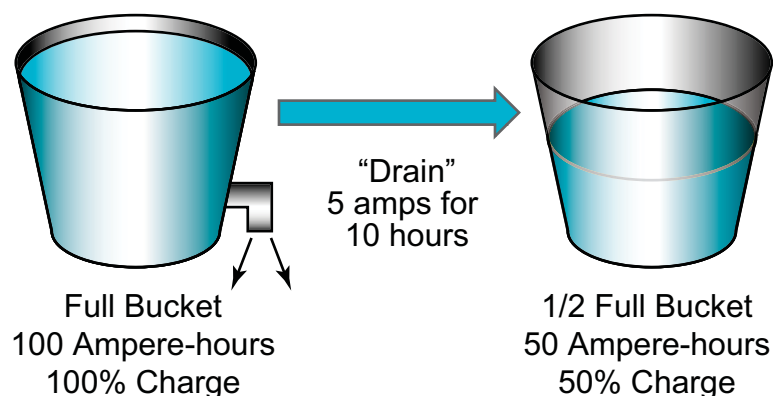
- ▶ Multiply reserve capacity in minutes by 0.6 to determine approximate 20-hour ampere-hour capacity
- ▶ Example: A 100 ampere-hour battery will supply 5 amperes for 20 hours
  - ▶ 12 volt battery at 80° F, discharged to 10.5 volts
- ▶ Equation 1: Ampere-hours=amps x hours

State of charge is a measure of the number of ampere-hours remaining in the battery pack.

Example: If 50 ampere-hours are used from a 100 ampere-hour battery pack, 50 ampere-hours remain and the battery pack is at a 50% state of charge.

- ▶ Equation 2: % charge = ampere-hours remaining ÷ ampere-hours at full charge
- ▶ Equation 3: Ampere-hours remaining = % charge × ampere-hours at full charge
- ▶ Equation 4: Ampere-hours used = Ampere-hours at full charge – Ampere-hours remaining

A simple way of visualizing this is to think of a battery as a bucket. The level of water in the bucket is equivalent to the number of ampere-hours remaining.

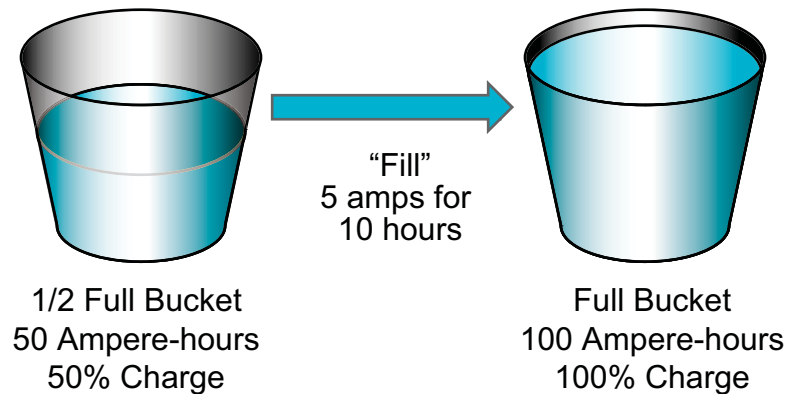


*Figure 5: Battery Discharging Visualization*



**This information is important because it determines the length of time necessary to charge a battery to an acceptable level for testing. The principles for “draining” the battery hold true for charging the battery. If you remove 50 ampere-hours from the battery as in Figure 5, it must be placed back to return the battery to 100% charge.**

Battery chargers are rated by the number of amps they can supply for charging. This rate is the “amps” listed in Equation 1.

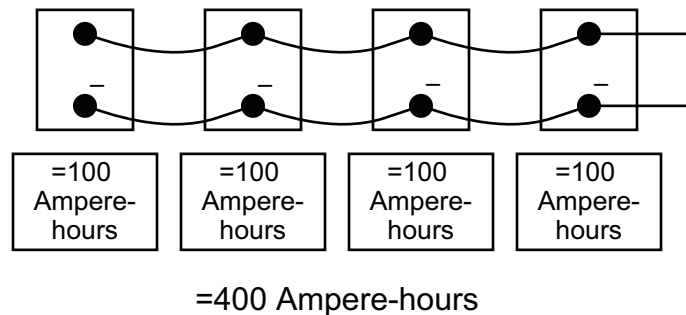


*Figure 6: Battery Charging Visualization*

As you can see from Figure 6, you need to put 50 ampere-hours back into the bucket to fill it up

- ▶ Would take at least 10 hours at a rate of 5 amps
- ▶ Above situation is ideal: Times will increase slightly due to charging losses

Add the capacity of each battery together to determine the number of ampere-hours in a battery pack connected in parallel.



*Figure 7: Batteries in Parallel*

If the batteries shown in Figure 7 were all at 50% charge and were charged with a 50 amp charger, it would take at least 4 hours to charge the batteries.



### **Consider two options for the above situation**

- ▶ Charge the batteries while still in the vehicle
  - ▶ Leads to downtime
  - ▶ Charge to at least 75% state of charge
- ▶ Charge the batteries after removal from vehicle
  - ▶ Spare battery pack needed

## 4.4 Proper Battery Maintenance

Make sure the battery manufacturer's recommended diagnostic tools are available before beginning diagnosis. Equipment commonly recommended for battery testing include carbon pile load testers or computerized test devices.

Properly charged and tested batteries are required for the proper diagnosis of the starting and charging systems.

- ▶ Discharged batteries indicate the possibility of problems with the starting or charging system or parasitic loads
- ▶ The first step in any charging or starting system diagnosis procedure is to determine whether the vehicle's batteries are at fault. Eliminating the batteries as a source of problems reduces the number of potential sources of failure

## 4.5 Battery System Diagnosis

### Step 1: Visual Inspection - Cables

Remove the cables from all batteries. Visually check the cables for loose connections, corrosion, missing heat shrink tubing, and grease in the terminal area. Clean and repair any problems with the cables.



**Note: Grease should not be applied to battery terminals or cable connections.**

- ▶ Grease is a dielectric and increases circuit resistance
- ▶ If used, apply to terminals after they are tightened

### Step 2: Visual Inspection - Batteries

- 1) Check to ensure that all of the batteries used in the battery pack are of the same manufacturer, CCA rating, type and age
  - ▶ Internal resistances differ between manufacturers
    - ▶ Battery packs with mixed resistances can lead to premature failures
  - ▶ Check with your battery manufacturer for maximum differences in in-service dates
- 2) Visually inspect the battery for physical damage
  - ▶ Check for cracks in the casing, loose terminal studs, and dirt on surface of battery
    - ▶ Many battery terminals use a threaded stainless steel stud surrounded by a lead pad
      - ▶ Studs can come loose in the relatively soft lead pad and cause connection problems
  - ▶ Dirt on surface of battery creates a path for electrical discharge

### **Step 3: State of Charge & Testing**

After performing the visual inspection, determine the state of charge as discussed in Section 4.2 and test per the battery manufacturer's recommendations for each battery in the pack.

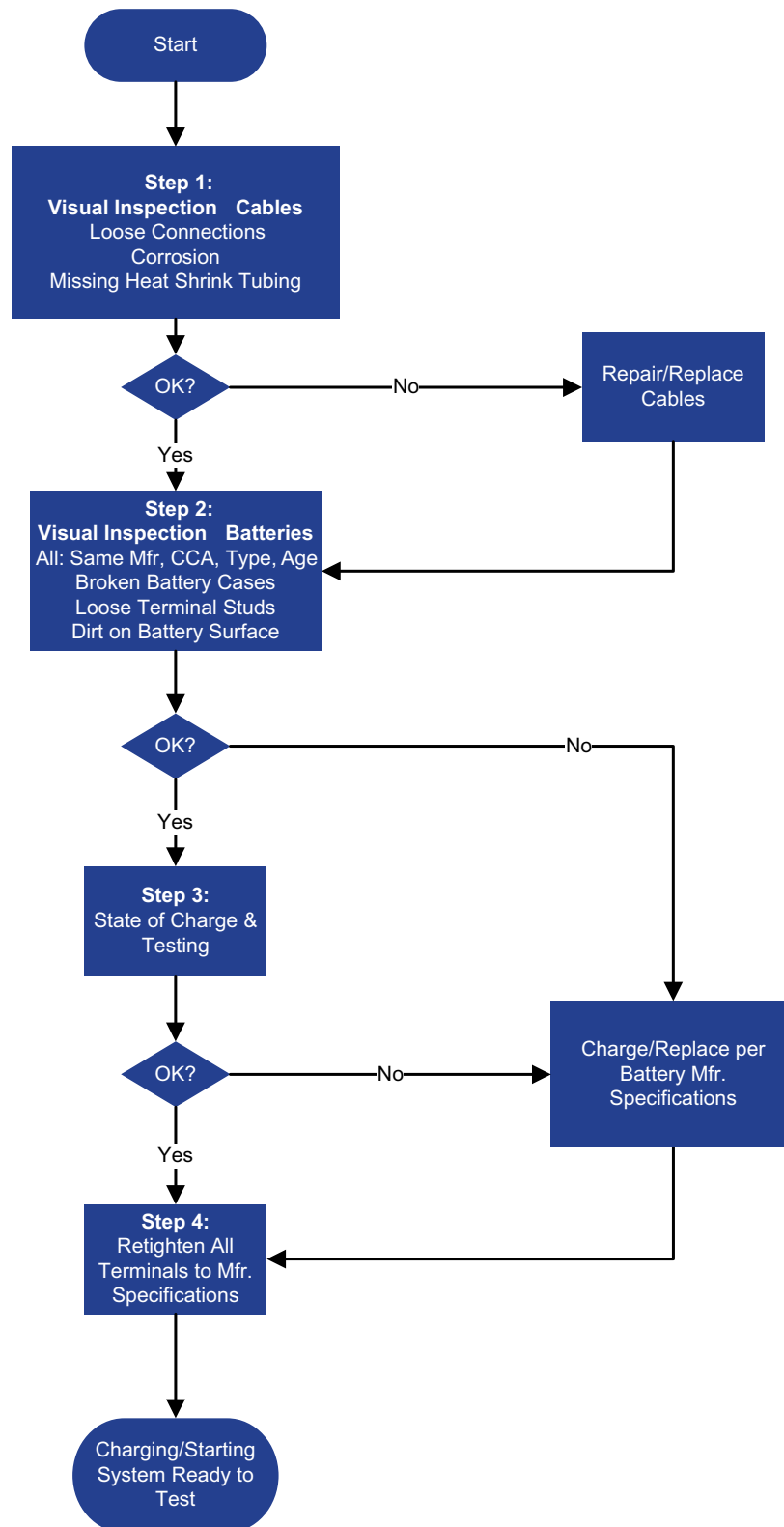
- ▶ Testing determines the battery's ability to supply cranking current
- ▶ Check with battery manufacturer for replacement guidelines if any batteries in the pack fail

### **Step 4: Retighten Cables**

The completion of the above steps ensures that good batteries are installed in the vehicle and removes one variable from the troubleshooting process. It is now time to proceed to the charging or cranking portion of the manual, depending on the particular problem.

## Battery System Flowchart

- Refer to Section 4.5: Battery System Diagnosis for detailed instructions





## Section 5: Starting System

### 5.1 Safety



**Be sure to follow proper safety techniques as outlined by your shop or employer. This includes wearing safety glasses and gloves at all times, and disconnecting the vehicle's batteries during any repair of the starting system. Make sure the vehicle is out of gear, parking brake is set and the wheels are chocked. Also avoid wearing jewelry or loose fitting clothing.**

**The components tested in this section may continue to have power supplied to them even when the ignition switch is off. Use extreme caution at all times.**



**Caution: Do not attempt to start the engine by connecting the starter's B terminal to the M terminal. Extremely high levels of current can flow through the device you are using to connect the terminals and is extremely dangerous.**

### 5.2 Tool Requirements

Three basic tools are needed for starting system diagnosis:

- ▶ Ammeter
- ▶ Multimeter capable of measuring voltage
- ▶ Carbon pile load tester (load tester)

An electronic tester can be used in place of the above tools.

### 5.3 Overview of the Mitsubishi Electric Class 8 Planetary Gear Reduction Starter – Model 105P55

105P55 =

105 - 105mm yoke outside diameter

P - Planetary Gear design

55 - 5.5 kW output

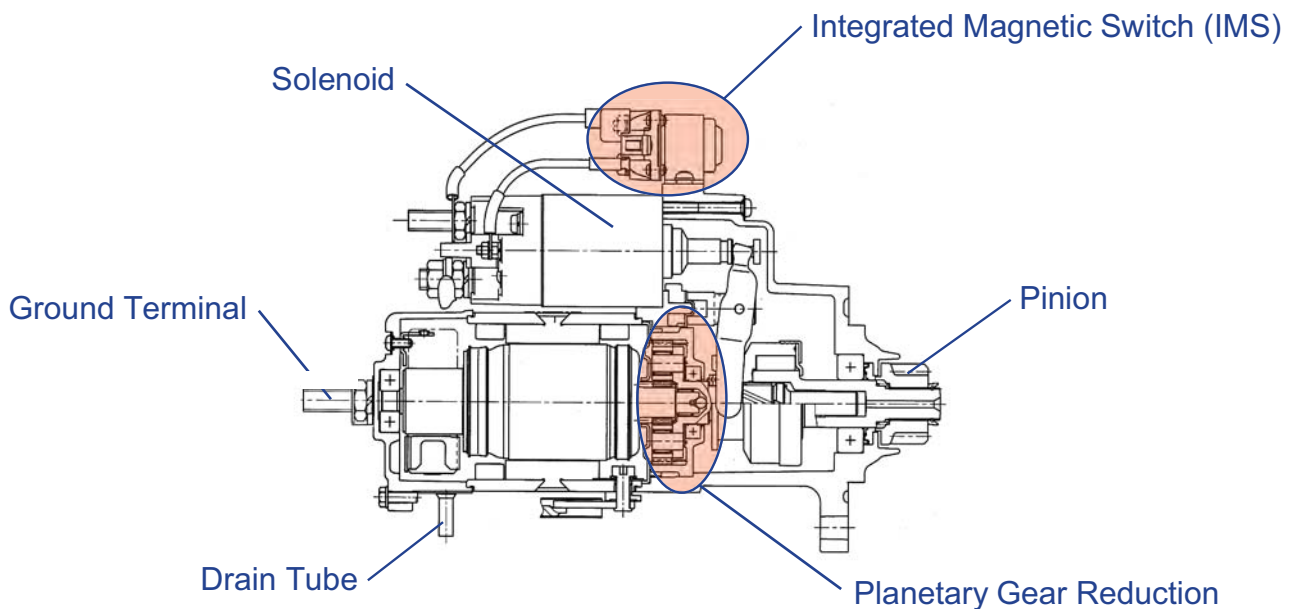
Mitsubishi Electric pioneered the introduction of the planetary gear reduction starter in 1983 and MEAA introduced it in North America for heavy duty truck applications in 1998. This planetary gear reduction technology was a significant improvement over previous direct drive and offset gear reduction technology by providing a smaller, lighter, higher output, and more durable design. Such high output in a small package is achieved by the use of gear reduction technology that allows the armature to rotate at a much higher RPM, creating higher torque at the output shaft and at the starter pinion.

In addition to the advantages of the planetary gear reduction design, MEAA also introduced its existing electrical “Soft-Start” technology to the North American Heavy Duty truck industry in 1998. The Soft-Start feature allows the pinion to fully engage the ring gear before full current is applied to the starter and before the starter begins to crank the engine. A secondary circuit within the starter is used to slowly rotate the pinion as it is engaging the ring gear. This feature nearly eliminates pinion and ring gear wear and milling, which is a common failure mode in direct drive type starters. The function occurs almost instantaneously and is not noticeable to the driver starting the truck.



**The conversion of electrical energy to mechanical energy by the starter motor produces large amounts of heat, which can eventually damage the starter motor.**

**Maximum recommended continuous crank time for Mitsubishi Electric starters is 30 seconds. If the engine is continuously cranked for 30 seconds, allow the starter to cool completely before cranking again.**



*Figure 8: 105P55 Starter*

Figure 9 shows the three main electrical connections on this starter.

- ▶ Battery terminal is located on the starter’s solenoid – B terminal
  - ▶ Connected to the positive side of vehicle’s batteries
- ▶ Ground terminal is located on starter’s rear bracket
- ▶ Starters with an Integrated Magnetic Switch (IMS)
  - ▶ Control circuit terminal is on starter’s IMS
  - ▶ Indicated by the letters IMS
- ▶ Starters without an IMS
  - ▶ Control circuit terminal is on starter’s solenoid
  - ▶ Indicated by the letters Sw

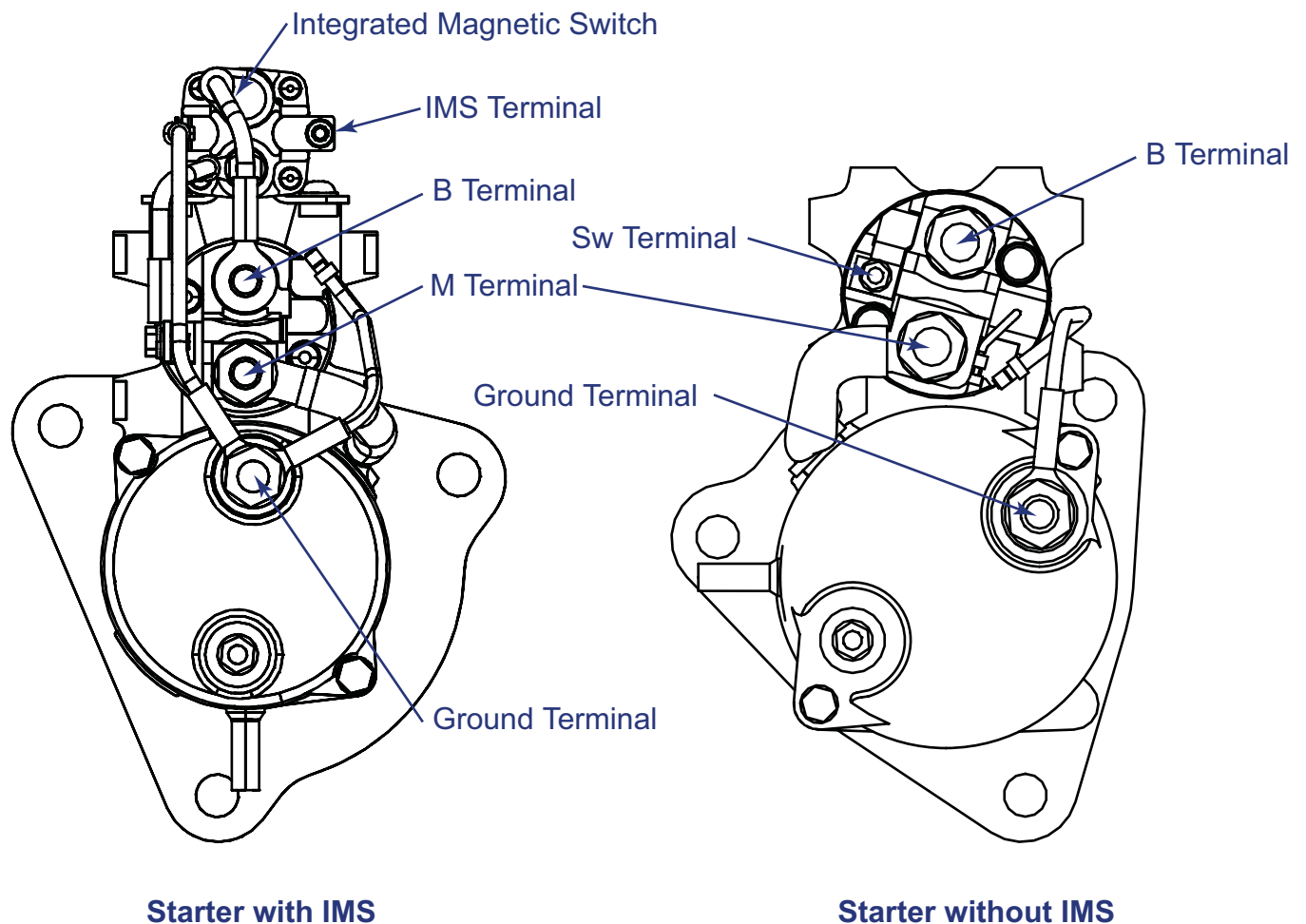


Figure 9: Starter Terminal Locations

#### 5.4 Important Considerations before Troubleshooting

Starting an engine requires more current draw than any other electrical operation. For this reason battery condition and electrical connections are very important.

- ▶ Charge the batteries to a minimum 75% state of charge before testing the starting system
- ▶ Otherwise test results will be inaccurate
- ▶ Maintaining proper state of charge ensures batteries have needed energy to crank engine
- ▶ Low state of charge increases time starter must work
  - ▶ Leads to earlier failure
- ▶ Newer engine control systems may not supply fuel to the engine's cylinders if cranking speed is below a certain RPM
- ▶ Complete the voltage drop tests in Section 5.5, Step 3
  - ▶ Ensures cables can transmit required current
  - ▶ High voltage drops may result in longer cranking times



**Connecting a voltmeter to the starter to determine if voltage is present is not a sufficient substitute for Step 3.**

## 5.5 Starting System Diagnosis

### Step 1: Battery Check

Check vehicle's batteries as outlined in Section 4. Properly charged batteries are needed to perform the voltage drop tests detailed later in this section. Confirmed properly charged batteries also remove a variable in the diagnosis of the starting system and ultimately save time.

### Step 2: Visual Check

Inspect all cables and connections in the starting system for corrosion, loose connections and frayed cables.

- ▶ Cable insulation bulge is an indicator of corrosion inside cable
- ▶ Use a wire brush to clean all corroded connections to bare metal and retighten
  - ▶ Check all connections for proper torque
    - ▶ Starter torque specifications can be found in Appendix B
- ▶ Check with the vehicle manufacturer for battery torque specifications. Proper operation of the starting system depends on good connections between electrical components



**Visually checking cables is not a substitute for load testing the cables as provided in Section 5.5, Step 3. Load testing can reveal problems that a visual check can miss.**

### Step 3: Starter Circuit Troubleshooting

The following are instructions for using a carbon pile load tester and voltmeter. Consult the tester's manual if using an electronic load tester that combines the features of a load tester and voltmeter.

#### Step 3A: Main Cables

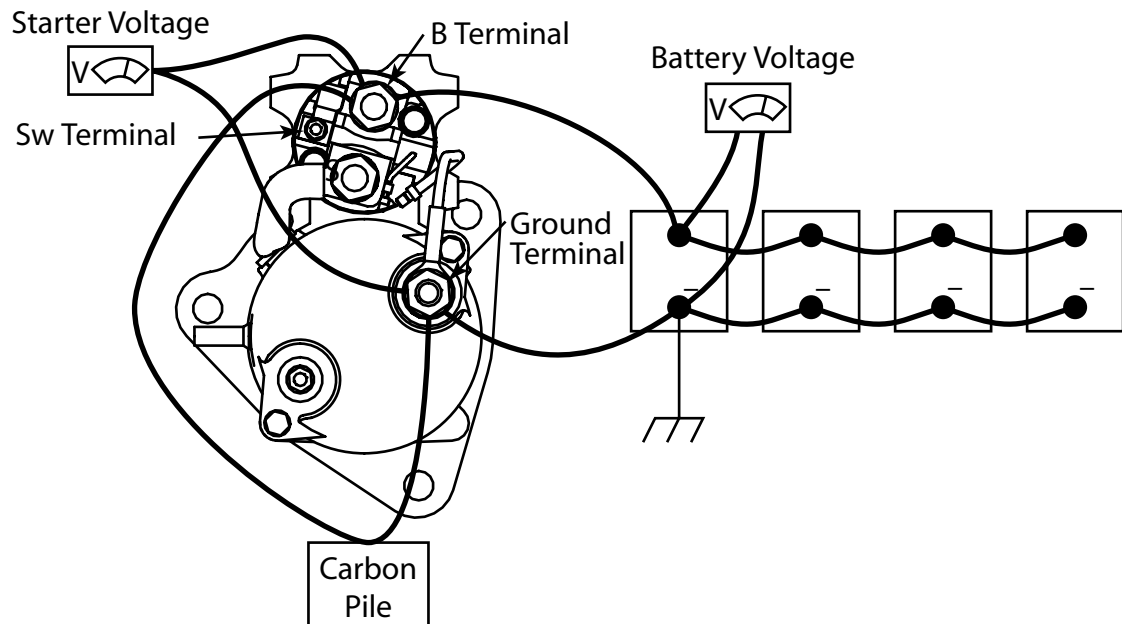
Begin by testing current carrying capability of main cables

- 1) As shown in Figure 10, connect a carbon pile load tester to B and ground terminals of the starter
  - ▶ Maintain a load of 500 amps while performing the step below
- 2) Using the wiring configuration in Figure 10, obtain:
  - ▶ Starter Voltage
  - ▶ Battery Voltage
- 3) Use the formula shown below to calculate the voltage drop
  - ▶ Go to Step 3B if voltage drop exceeds 1.0 volt
    - ▶ Indicates problem with cables
  - ▶ Go to Step 4 if voltage drop is below 1.0 volt
    - ▶ Main cables are OK

Voltage Drop = Battery voltage - Starter Voltage

You may also use an electronic load tester for this step. Follow the instructions included with the load tester. The output from this type of tester will usually be the number of amps passed by each cable at 0.5 volt drop.

- ▶ Confirm positive and negative cables deliver at least 500 amps at 0.5 volt each
- ▶ If either cable cannot deliver 500 amps at 0.5 volt, replace the cable with excessively high voltage drop
- ▶ Go to Step 4 if voltage drop is OK



*Figure 10: Step 3A – Main Cables*

### Step 3B: Main Cable Loss Identification

If the resistance of the main cables is higher than recommended, determine which cable is at fault.

- 1) As shown in Figure 11:
  - ▶ Connect a carbon pile load tester to B and ground terminals of the starter
  - ▶ Maintain a load of 500 amps while performing the step below
- 2) Using the wiring configuration in Figure 11, obtain:
  - ▶ Positive Cable Voltage
  - ▶ Negative Cable Voltage
- 3) Replace the cable with excessively high voltage drop
  - ▶ Sum of positive and negative voltage drops must equal less than 1.0 volt

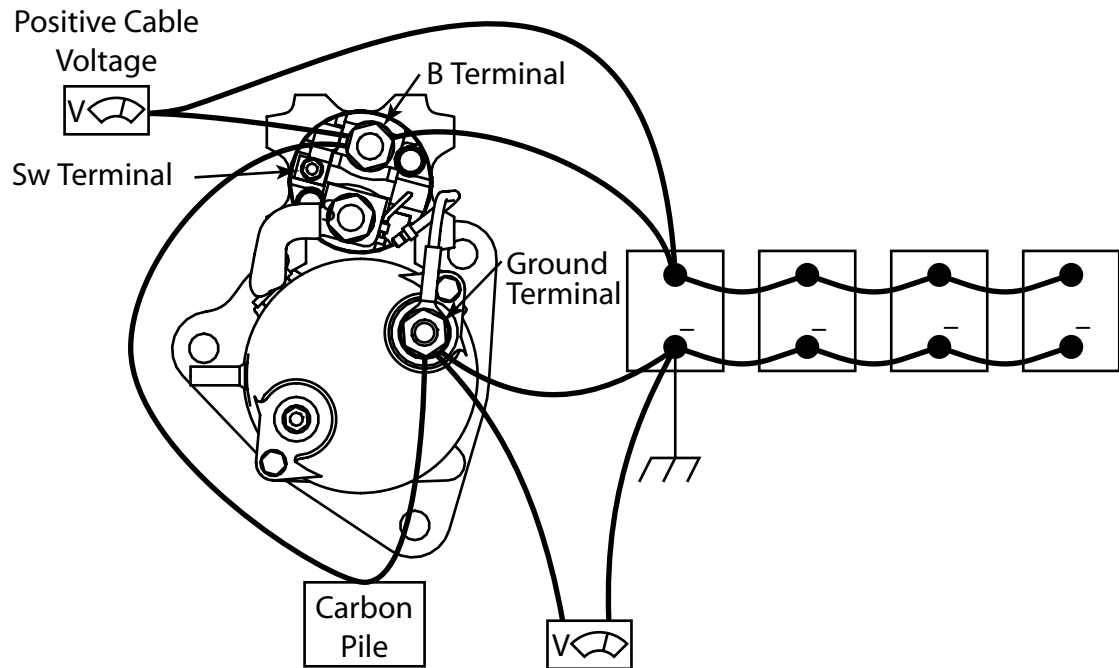


Figure 11: Step 3B – Main Cable Loss Identification

#### Step 4: Control Circuit

This step tests the vehicle's ability to send a "start" signal to the starter. Continue to step 4A if your starter is equipped with an Integrated Magnetic Switch. Continue to step 4B if your starter does not have an Integrated Magnetic Switch.

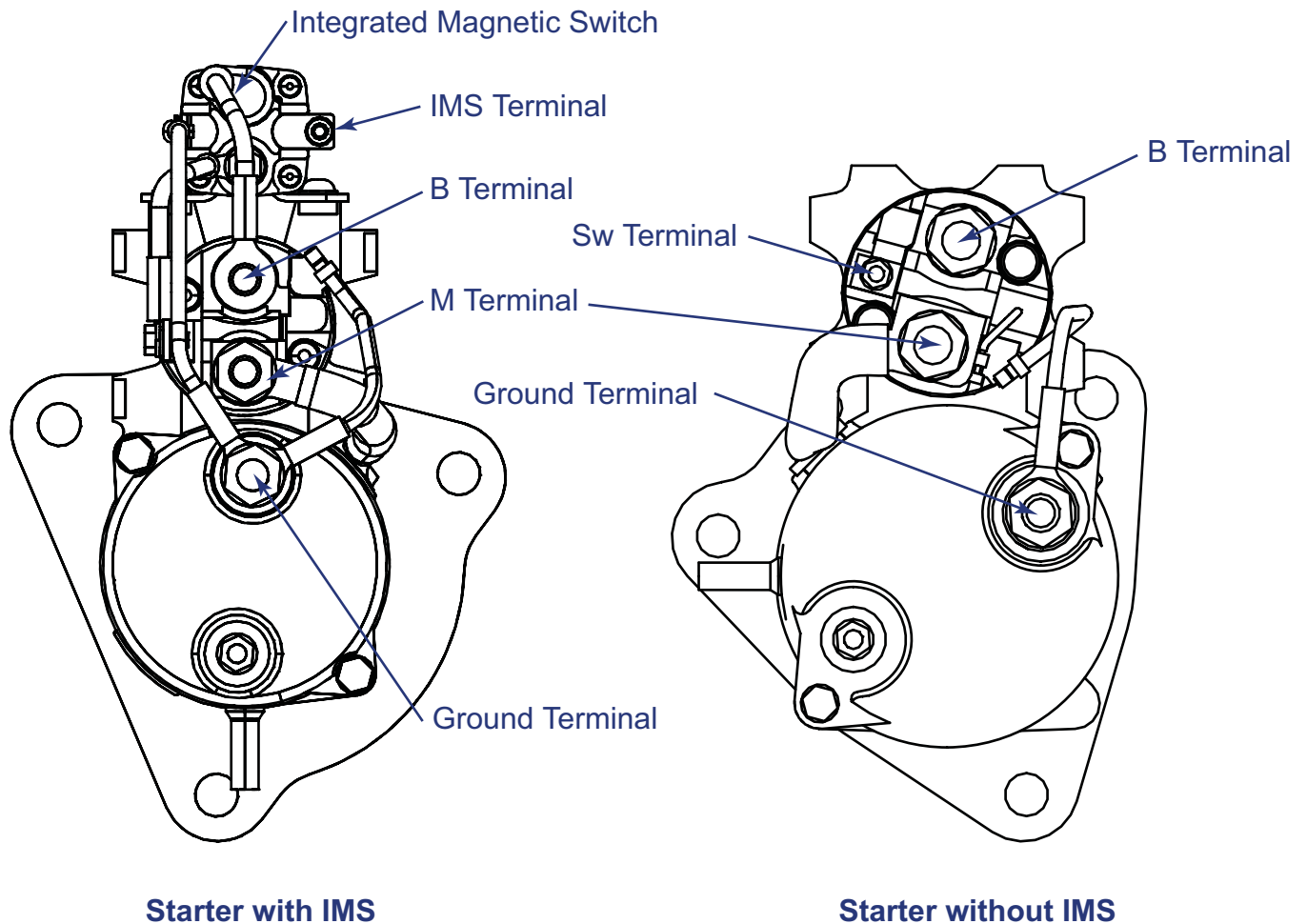


Figure 12: Starter Type Identification

#### Step 4A: Starter with Integrated Magnetic Switch

- 1) Disconnect wire from IMS terminal on the Integrated Magnetic Switch
  - ▶ See Figure 13 or 14 for key switch circuit diagram, depending on vehicle's electrical system
- 2) Connect a test light between ground and disconnected cable in above step
- 3) Turn the key switch to the "start" position
  - ▶ Continue to Step 5 if test light operates
  - ▶ Troubleshoot key switch, key switch wiring if light does not operate
    - ▶ Some vehicles require the clutch to be disengaged or the vehicle to be in park for control circuit operation
  - ▶ Perform at least 3 times
    - ▶ Some remote mounted relays contain a disc with more than one contact point



**Step 4A is the only test in this manual where a test light is used.**



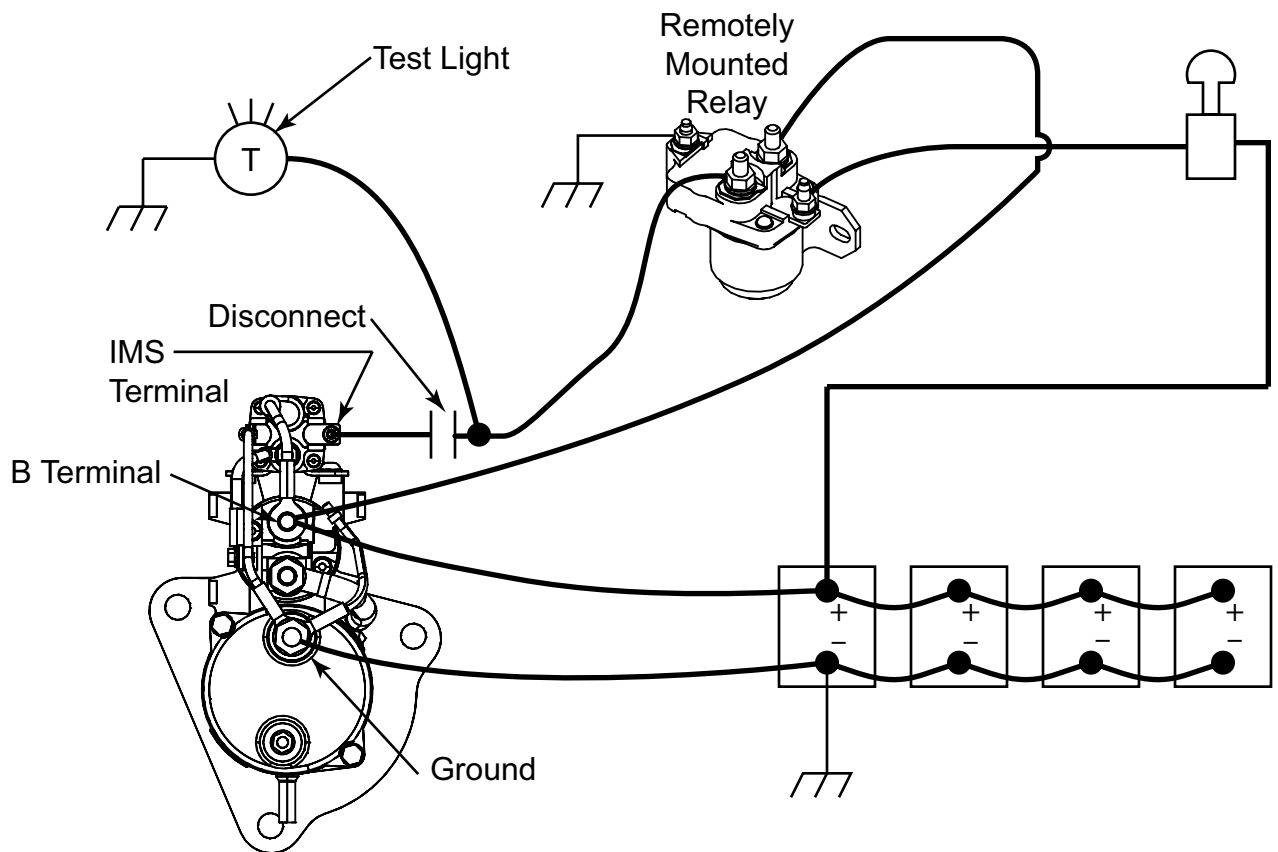


Figure 13: Step 4A – Key Switch Circuit w/ Remote Mounted Relay

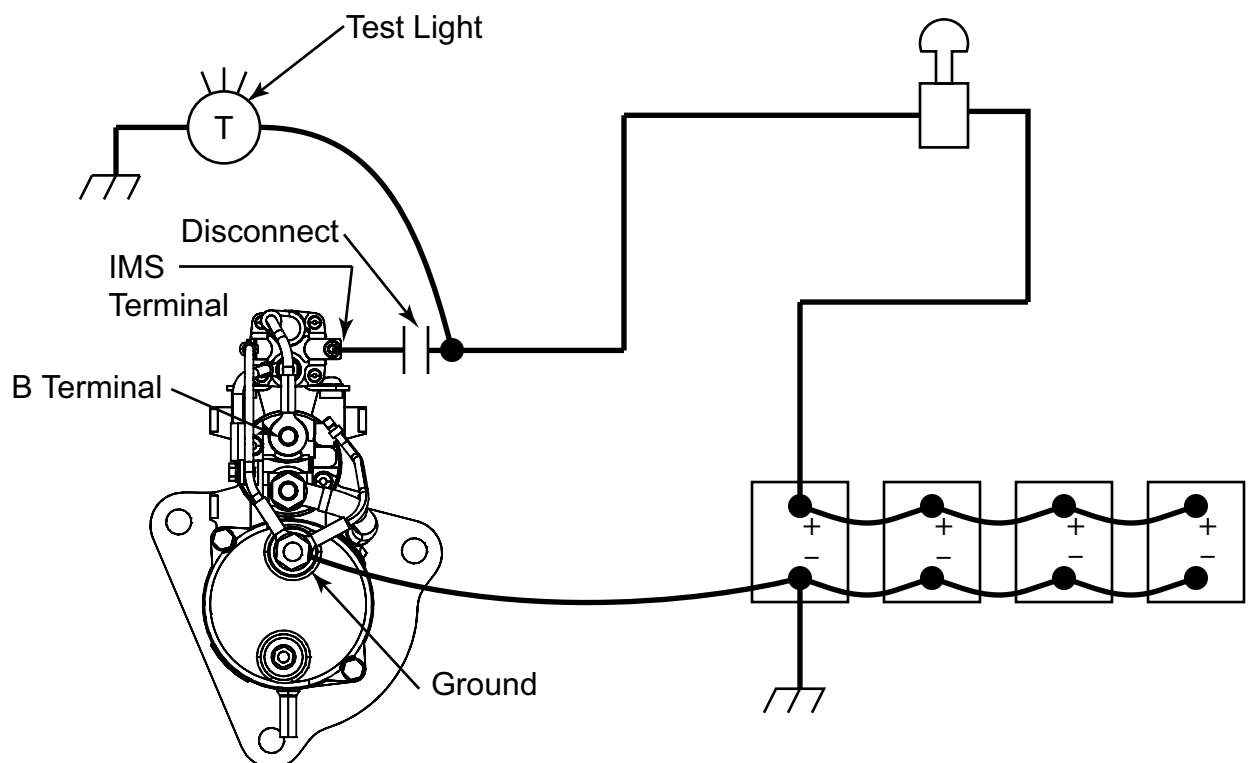


Figure 14: Step 4A – Key Switch Circuit w/o Remote Mounted Relay

### Step 4B: Starter without Integrated Magnetic Switch

- 1) Remove cable from starter's Sw terminal only
- 2) Connect carbon pile load tester to starter's ground terminal and cable removed from starter's Sw terminal as shown in Figure 15
  - ▶ Maintain 80 amp load while performing step below
  - ▶ Turn key switch on while performing step below
    - ▶ Some vehicles require the clutch to be disengaged or the vehicle to be in park for control circuit operation.
- 3) Using the wiring configuration in Figure 15, obtain:
  - ▶ B-cable Drop
  - ▶ Sw-cable Drop
  - ▶ Starter Relay Drop
    - ▶ Collect at least 3 times
    - ▶ Some remote mounted relays contain a disc with more than one contact point
- 4) Use the formula shown below to calculate control circuit voltage drop
  - ▶ Voltage drop must not exceed 0.8 volt
  - ▶ If the voltage drop exceeds 0.8 volt, replace the cable or starter relay with the excessive voltage drop

Control Circ. Voltage Drop = B-cable Drop + Sw-cable Drop + Starter Relay Drop

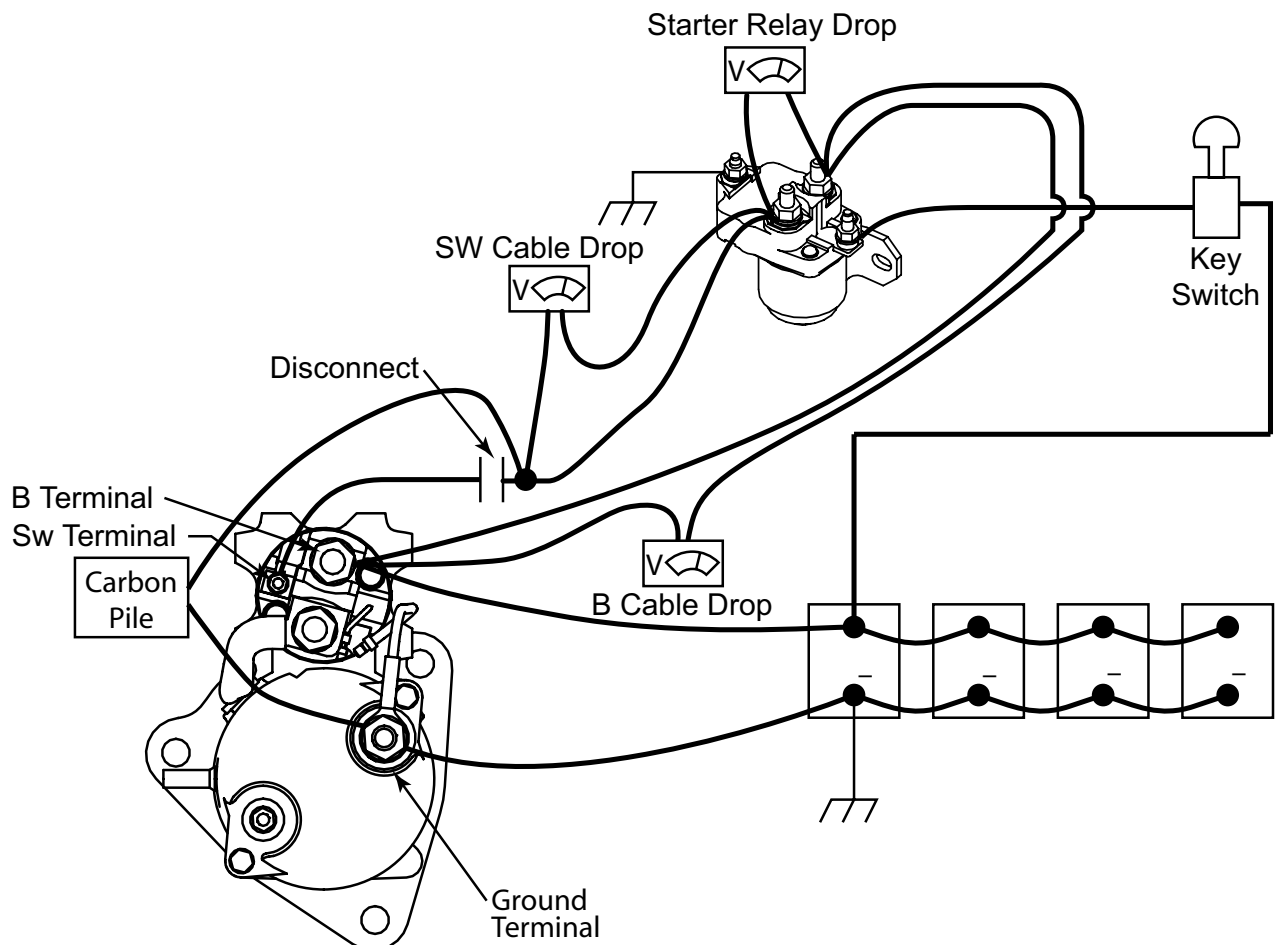


Figure 15: Step 4B – Starter w/o Integrated Magnetic Switch



**A starter relay that appears to work correctly during diagnosis does not mean it will always work correctly in the field.**

- ▶ Factors such as temperature, humidity and vibration can affect a relay's performance
- ▶ Replace the remotely mounted starter relay if found defective
- ▶ **Genuine Mitsubishi relays are available from your dealer**

### **Step 5: Retest Starting System**

Reconnect all starting circuits and double check for corrosion or loose connections. Attempt to start the vehicle.

- ▶ Starter motor does not need to be replaced if vehicle starts correctly
- ▶ Continue to Section 5.6 if vehicle does not start
- ▶ Replacement IMS and Solenoid kits are available from your dealer

## **5.6 Starter Motor Replacement**

Diagnostic steps for determining if the starter motor is at fault are completed. Result: Replace the starter motor.

### **Step 1: Starter Removal**

- 1) Disconnect vehicle's batteries
- 2) Remove cables connected to starter's ground and B terminal
  - ▶ Note cable location for reinstallation
- 3) Remove the cable connected to the IMS terminal or Sw terminal
  - ▶ Terminal depends on starter model
- 4) Remove three mounting bolts connecting starter to engine

### **Step 2: Ring Gear Wear Check**

- 1) Check the engine's ring gear for excessive wear before installing a new starter
  - ▶ Due to six cylinder diesel engine design characteristics, the ring gear will always come to rest in one of three possible positions
  - ▶ Check all three ring gear positions for wear
    - ▶ Commonly called "barring over" the engine
    - ▶ See Appendix A for wear examples

### **Step 3: Starter Motor Reinstallation**

- 1) Install new starter by reversing steps used for removal
  - ▶ Protect starter motor's pinion from impacts during installation
  - ▶ Roughness on pinion surfaces can lead to ring gear engagement errors
  - ▶ See Appendix B for recommended torque values

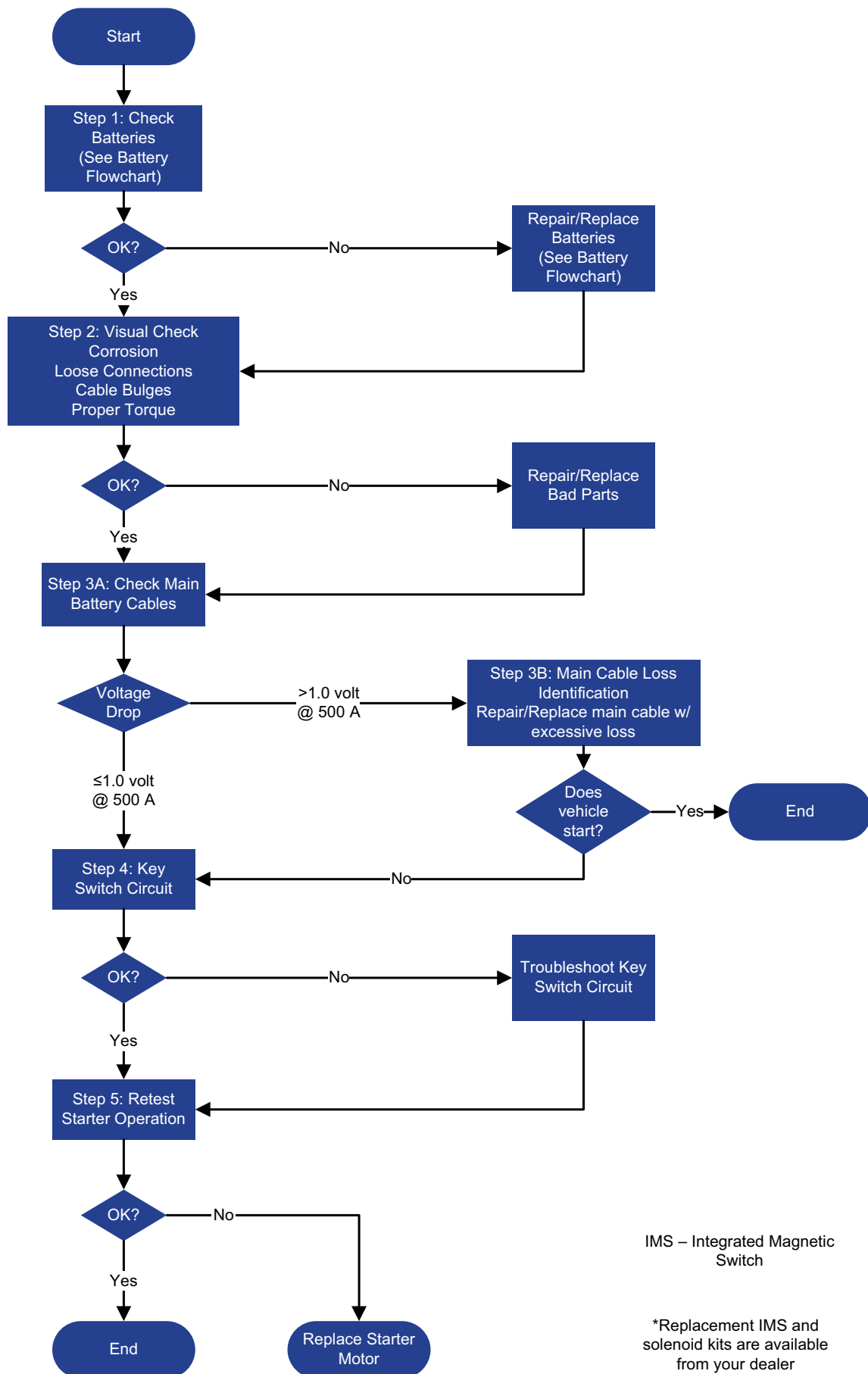
#### **Step 4: Final Visual Check**

- 1) Visually inspect starting system's electrical connections
- 2) There should be no gaps between the starter flange and the flywheel housing
  - ▶ Improper mounting can lead to:
    - ▶ Damaged pinion and ring gear
    - ▶ Engagement errors
    - ▶ Stuck pinion
    - ▶ Premature starter failure

Congratulations! You have now successfully completed troubleshooting your vehicle's starting system.

## Starting System Diagnosis Flowchart

- Refer to Section 5.5: Starting System Diagnosis for detailed instructions



## Section 6: Charging System

### 6.1 Safety



Be sure to follow proper safety techniques as outlined by your shop or employer. This includes wearing safety glasses and gloves at all times, and disconnecting the vehicle's batteries during any repair of the charging system. Make sure the vehicle is out of gear, parking brake is set and the wheels are chocked. Also, avoid wearing jewelry or loose fitting clothing.

The components tested in this section may continue to have power supplied to them even when the ignition switch is off. Use extreme caution at all times.

### 6.2 Tool Requirements

Three basic tools are needed for charging system diagnosis:

- ▶ Ammeter
- ▶ Multimeter capable of measuring voltage
- ▶ Carbon pile load tester (load tester)

### 6.3 Overview of Mitsubishi Electric BLA-II Alternators

Mitsubishi Electric BLA-II alternator uses a brushless design to maximize life and contains five main components: a stator, rotor, field coil, rectifier and regulator.

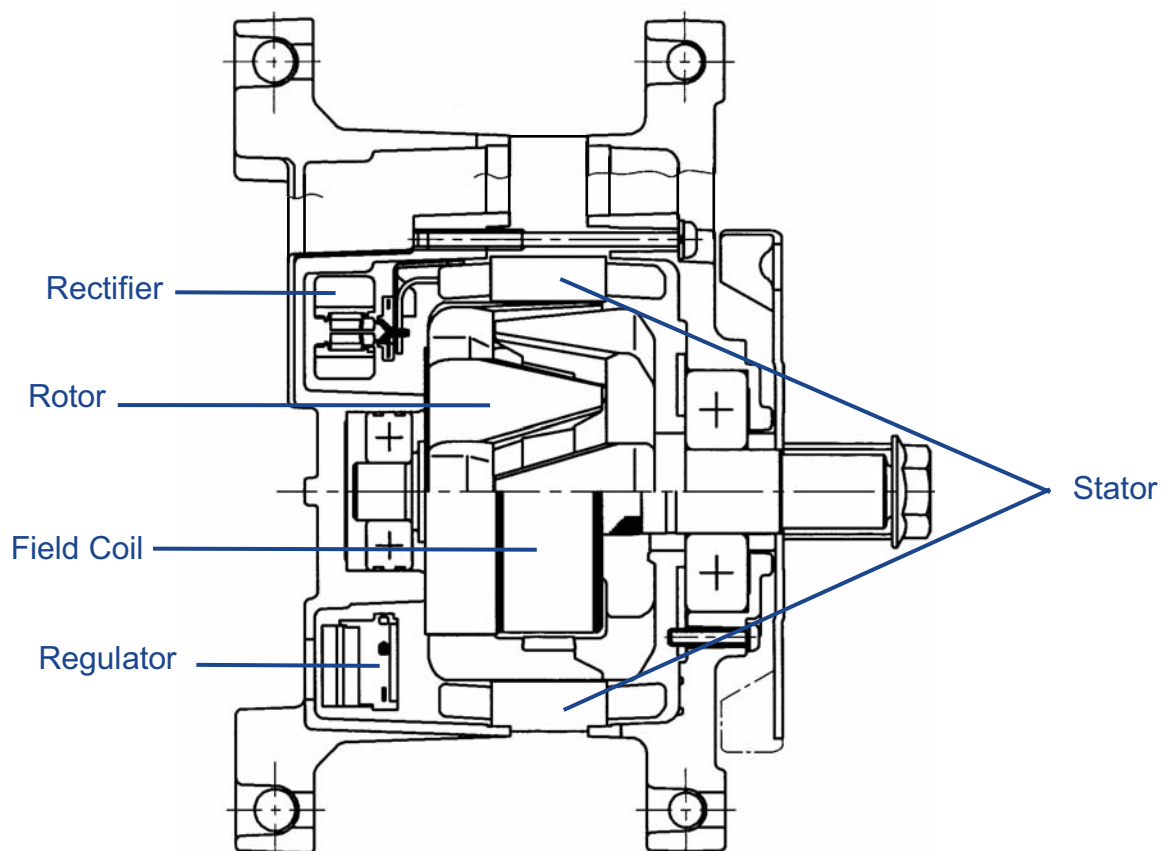


Figure 16: Alternator Main Components

### **Rotor**

Rotor is rotated by a shaft connected to the alternator pulley. It is responsible for inducing voltage in the stator. The rotor's poles create a change in magnetic flux in the stator.

### **Stator**

Stator produces the current supplied by the alternator to the vehicle. The change in magnetic flux produced by the spinning rotor induces a voltage in the stator.

### **Field Coil**

Field coil induces a magnetic field in the rotor. This is accomplished by supplying power to the field coil.

### **Rectifier**

Rectifier converts the 3-phase AC current produced by the stator into the DC current used by a vehicle's electrical system.

### **Regulator**

Regulator controls the alternator's output voltage by varying the current supplied to the field coil. Mitsubishi Electric alternators have temperature compensated regulators, which increase output voltage as ambient temperature decreases. This increases the alternator's ability to charge the batteries during cold weather.

## **6.4 Charging System Diagnosis**

### **Step 1: Battery Check**

Check the vehicle's batteries as outlined in Section 4

- ▶ Charged batteries are needed to perform voltage drop tests detailed later in this section
- ▶ Removes a variable in charging system diagnosis and ultimately saves time

### **Step 2: Visual Check**

Inspect all cables and connections in the charging system for corrosion, loose connections and frayed cables

- ▶ Proper charging system operation depends on good connections between electrical components
  - ▶ Use a wire brush to clean all corroded connections to bare metal
  - ▶ Retighten connections
- ▶ Bulges in cable insulation are an indicator of corrosion inside of cables
- ▶ Check all connections for proper torque
  - ▶ See Appendix B for alternator torque specifications
  - ▶ Check with the vehicle manufacturer for other torque specifications

Check the alternator's pulley nut for correct torque

- ▶ See Appendix B for torque specifications
- ▶ Use an 8 mm hex wrench and a 24 mm torque wrench for pulley nut tightening
- ▶ Do not use a screwdriver or other device to hold the cooling fins of the alternator when tightening the pulley nut



Check the vehicle's accessory belt for proper tension and damage such as cracking, fraying, glazing, etc. Improper tension or poor belt condition can lead to belt slippage, which can result in reduced alternator output. This ultimately results in improper system diagnosis.

### Step 3: Charging Circuit Cable Check

Charging circuit cables transmit power from the alternator to the batteries. These cables need to be capable of transmitting the alternator's rated output to the batteries with a maximum of 0.5 volt drop between the alternator and batteries.



**Ensure the vehicle's batteries all have a minimum 75% state of charge before continuing. Test results will be inaccurate otherwise.**

#### Step 3A: Main Cable Check

Begin by testing the main cables' current carrying capability

- 1) With engine off, connect carbon pile load tester to alternator's B+ and B- terminals as shown in Figure 17
- 2) Increase load on load tester to alternator's rated amperage while performing the step below
  - ▶ Rated amperages for each alternator model can be found in Appendix B
- 3) Using the wiring configuration in Figure 17, obtain:
  - ▶ Battery Voltage
  - ▶ Alternator Voltage
- 4) Use the formula shown below to calculate the voltage drop
  - ▶ Go to Step 3B if voltage drop exceeds 0.5 volt
    - ▶ Indicates problem with cables
  - ▶ Go to Step 4 if voltage drop is below 0.5 volt
    - ▶ Main cables are OK

Voltage drop = battery voltage – alternator voltage

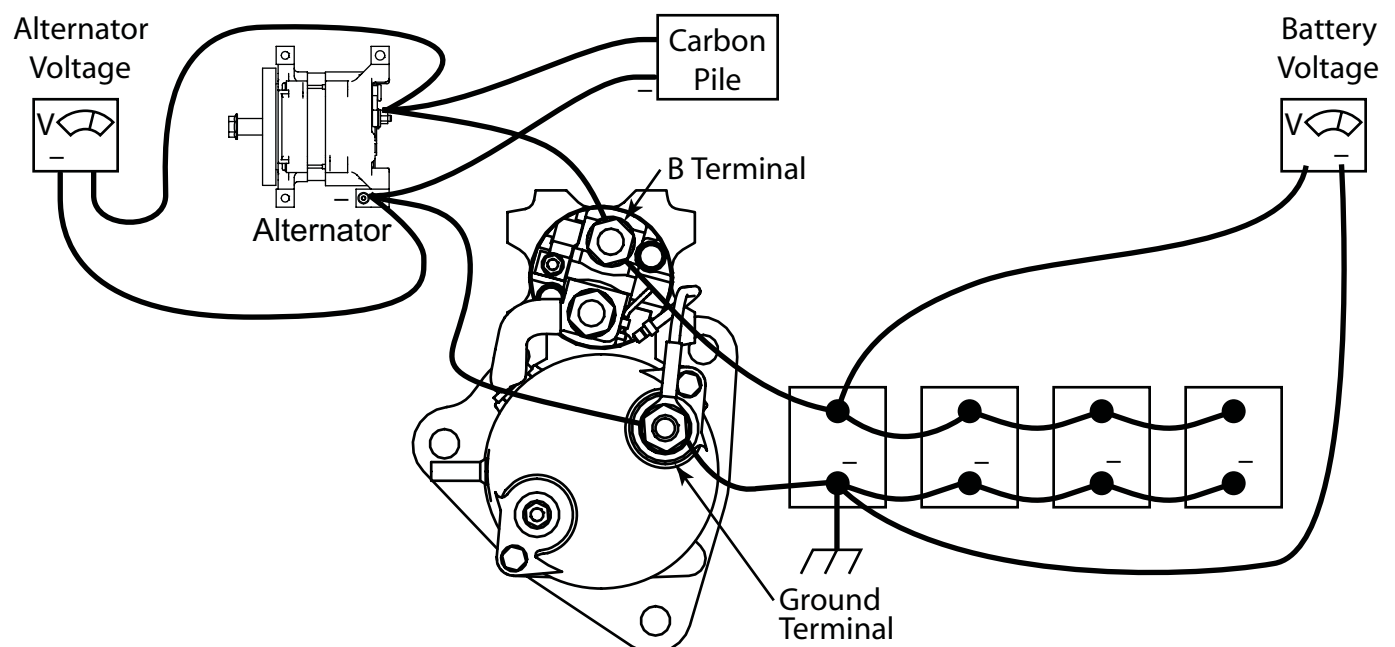


Figure 17: Step 3A – Main Cable Check

### Step 3B: Individual Cable Check

This check identifies whether the positive or negative cable from the alternator to the battery is causing an excessive voltage drop.

- 1) With engine off, connect load tester and voltmeter as shown in Figure 18
- 2) Increase load tester to alternator's rated output while performing the step below
- 3) Using the wiring configuration in Figure 18, obtain:
  - ▶ Positive Cable Voltage (PCV)
  - ▶ Negative Cable Voltage (NCV)
- 4) If PCV or NCV are excessively high, repair or replace the cable causing problem
  - ▶ PCV + NCV below 0.5 volt is necessary for proper system operation
  - ▶ Adding PCV and NCV together is same as performing voltage drop test in Step 3A

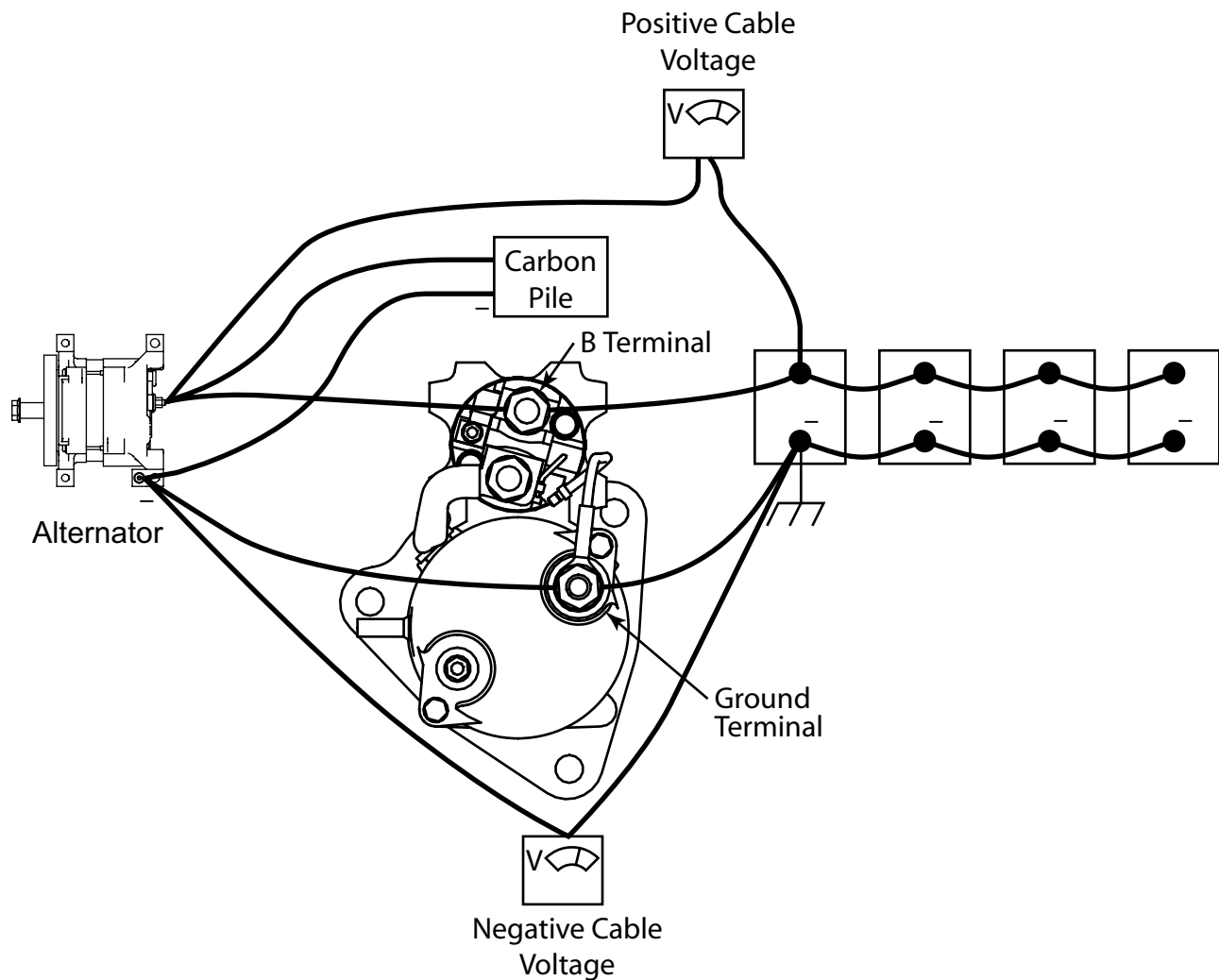


Figure 18: Step 3B – Individual Cable Check

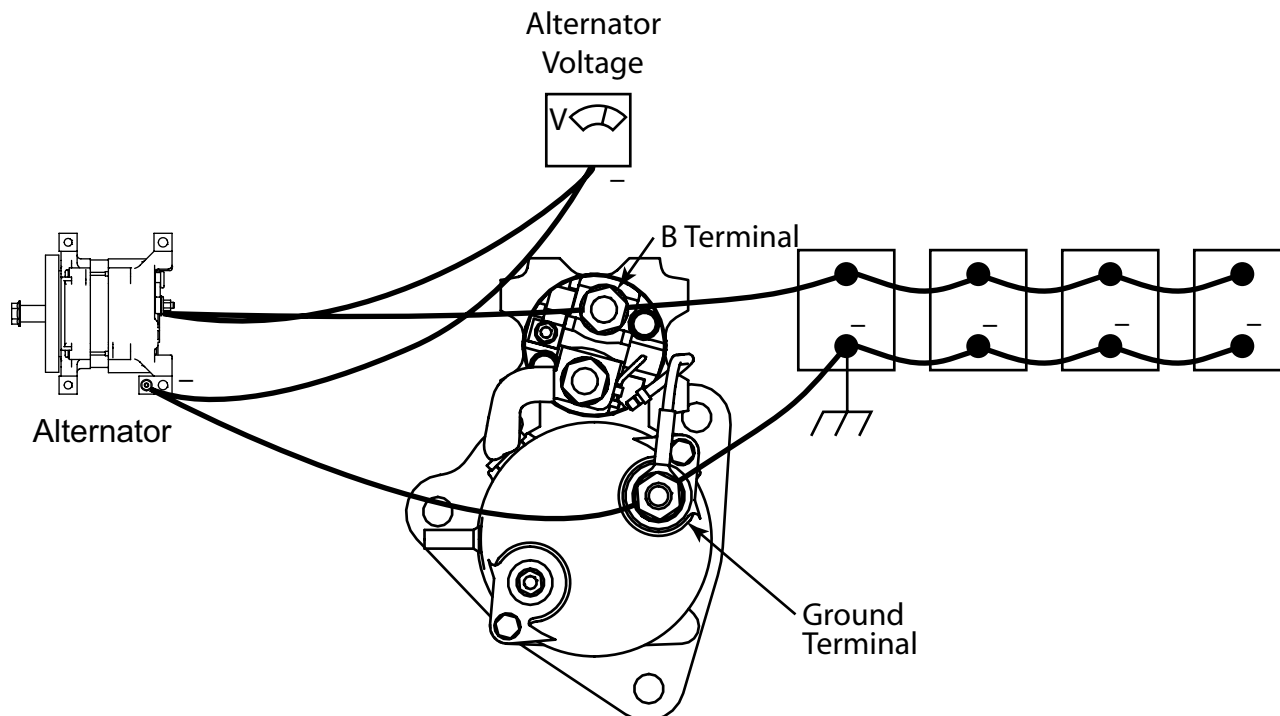
### Step 4: Alternator Regulator Check

Check the alternator's regulator after checking charging circuit cables. The regulator controls the voltage output of the alternator.

### Step 4A:

Start vehicle and turn all electrical loads off

- ▶ Run engine at idle speed
- ▶ Wait at least 30 seconds before performing steps below
- ▶ Alternator voltage must stabilize



*Figure 19: Step 4A and 4B – Regulator Check*

Using the wiring configuration in Figure 19, obtain the alternator voltage. It will be between 13.8 and 14.8 volts if operating properly

- 1) If voltage is above 14.8 volts, regulator can cause an overcharging situation
  - ▶ Alternator will need to be replaced. Go to Section 6.5 or 6.6
  - ▶ Overcharging can damage vehicle's batteries
- 2) If voltage is below 13.8 volts, regulator can cause an undercharging situation
  - ▶ Alternator will need to be replaced. Go to Section 6.5 or 6.6
  - ▶ Undercharging can lead to discharged batteries
- 3) Continue to step 4B if voltage is between 13.8 and 14.8 volts

### Step 4B:

- 1) Increase engine rpm to governed speed
  - ▶ Allow voltage to stabilize while at governed speed
- 2) If idle speed and governed speed voltage outputs differ by more than 0.5 volt:
  - ▶ Regulator has failed
  - ▶ Alternator will need to be replaced. Go to Section 6.5 or 6.6
- 3) Continue to Step 5 if idle speed and governed speed voltage outputs differ by less than 0.5 volt

### Step 5: Output Check with Carbon Pile Load Tester

Connect load tester, voltmeter and ammeter as shown in Figure 20. Run engine at its governed rpm, and increase load through the load tester until the alternator voltage reads 13.5 volts. This causes the alternator to generate its maximum output.

- 1) If ammeter indicates an output of at least 90% of the alternator's rated output:
  - ▶ Alternator is functioning properly
  - ▶ Does not need to be replaced
- 2) If the ammeter indicates an output of less than 90% of the alternator's rated output:
  - ▶ Alternator has failed
  - ▶ Go to Section 6.5 or 6.6

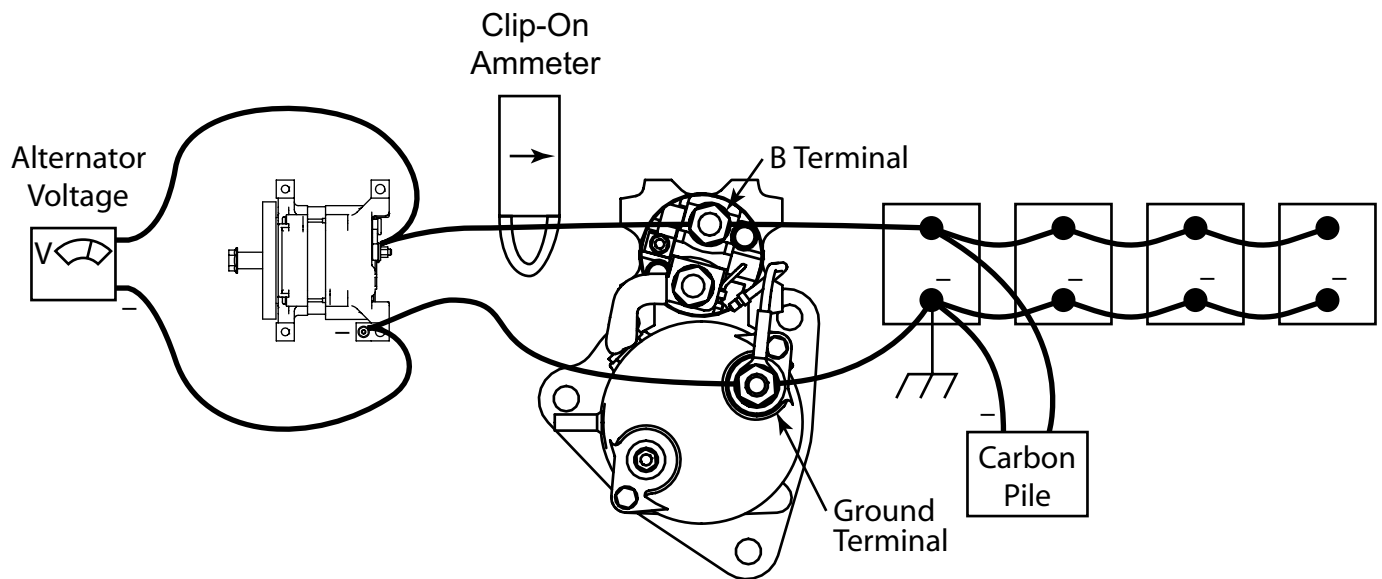


Figure 20: Step 5 – Output Check w/ Carbon Pile Load Tester

## 6.5 PAD Mount Alternator Replacement

By now sufficient steps have been taken to reasonably assume that the alternator is at fault. The alternator requires replacement.

### Step 1: Alternator Removal

- 1) Disconnect vehicle's batteries
- 2) Remove cables connected to alternator's B+ and B- terminals
  - ▶ Note cables' location for reinstallation
- 3) Disconnect accessory belt from alternator's pulley
  - ▶ Visually inspect belt for cracking and fraying
- 4) Remove four mounting bolts connecting alternator to engine
- 5) Remove pulley from alternator using an 8 mm hex wrench and a 24 mm wrench
  - ▶ It will be reinstalled on the replacement alternator
  - ▶ Replace pulley with a new one if damaged

### Step 2: Alternator Installation

- 1) Install pulley removed from alternator in Step 1 onto new alternator
  - ▶ Proper torque values are listed in Appendix B
- 2) Connect alternator to engine using four mounting bolts removed in Step 1
- 3) Connect accessory belt to the alternator's pulley

- 4) Connect positive and negative cables to alternator
- 5) Reconnect vehicle's batteries
- 6) Test alternator using the steps provided in Section 5.4: Charging System Diagnosis

Congratulations! You have now successfully completed troubleshooting your vehicle's charging system.

## **6.6 Hinge Mount Alternator Replacement**

By now sufficient steps have been taken to reasonably assume that the alternator is at fault. The alternator requires replacement.

### **Step 1: Alternator Removal**

- 1) Disconnect vehicle's batteries
- 2) Remove cables connected to alternator's B+ and B- terminals
  - ▶ Note location of these cables for reinstallation
- 3) Loosen the mounting bolts connecting the alternator to engine
- 4) Disconnect the accessory belt from alternator's pulley
  - ▶ Visually inspect belt for cracking and fraying
- 5) Remove mounting bolts connecting alternator to engine
- 6) Remove pulley from alternator using an 8 mm hex wrench and 24 mm wrench
  - ▶ It will be reinstalled on the replacement alternator
  - ▶ Replace pulley with a new one if it is damaged

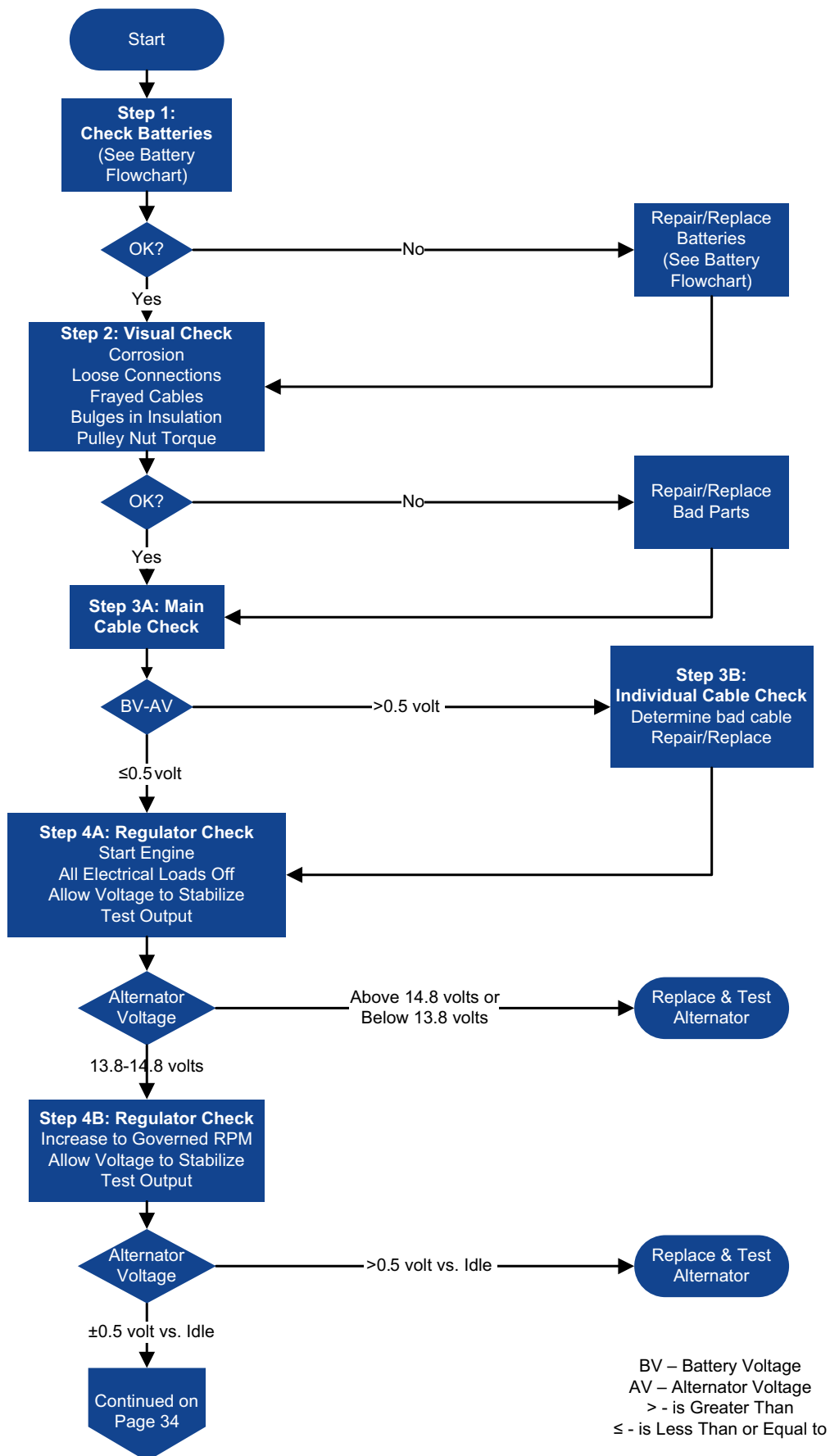
### **Step 2: Alternator Installation**

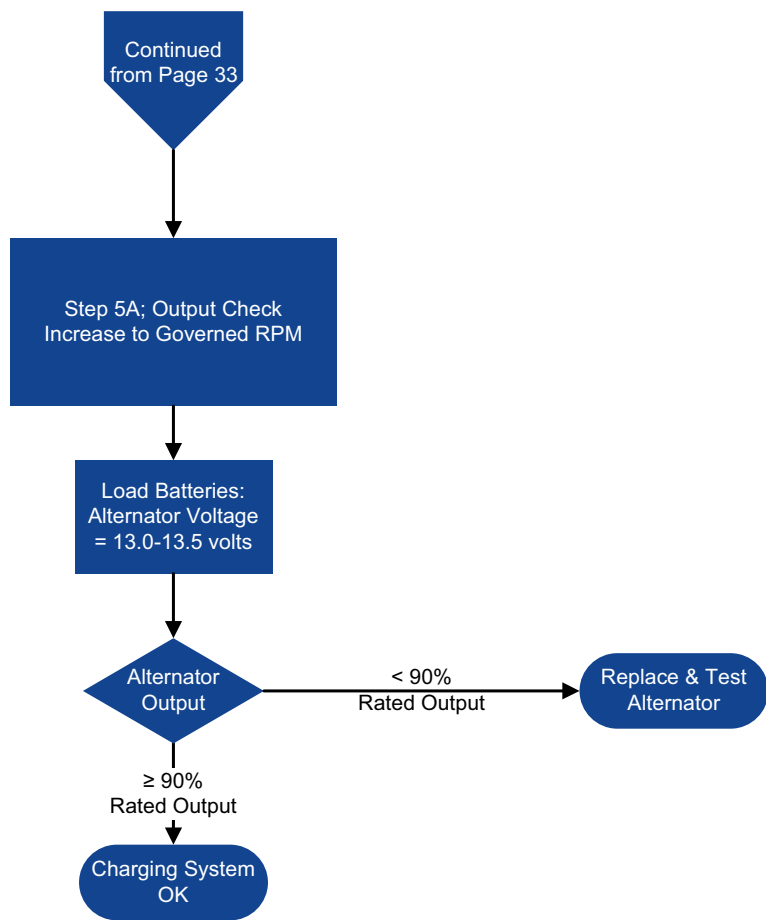
- 1) Install pulley removed from the alternator in Step 1 onto new alternator
  - ▶ Proper torque values are listed in Appendix B
- 2) Connect alternator to engine using mounting bolts removed in Step 1
- 3) Connect accessory belt to the alternator's pulley
- 4) Tighten accessory belt and alternator mounting bolts
- 5) Connect positive and negative cables to the alternator
- 6) Reconnect vehicle's batteries
- 7) Test alternator using steps provided in Section 5.4: Charging System Diagnosis

Congratulations! You have now successfully completed troubleshooting your vehicle's charging system.

## Charging System Diagnosis Flowchart

► Refer to Section 5.4: Battery System Diagnosis for detailed instructions





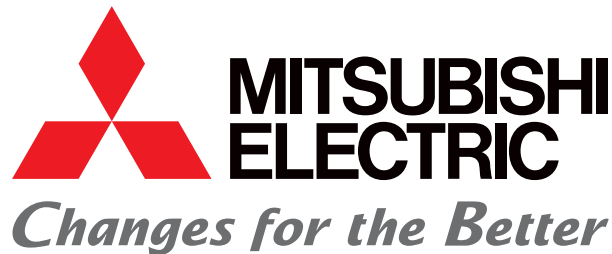


## Section 7: Conclusion

We at MEAA hope that our recommended troubleshooting procedures, when followed correctly, will assist you in maintaining a heavy-duty electrical system that performs at the high levels you and your company expect. Preventive maintenance and proper use will increase the longevity and performance of your vehicle's electronic components, resulting in less vehicle downtime. These procedures are not all inclusive and there are many situations that these procedures do not address. We rely on your experience and knowledge as a skilled maintenance technician to identify and act upon these issues.

If you require further assistance, please visit our website: [www.heavyduty.meaa-mea.com](http://www.heavyduty.meaa-mea.com)

MEAA proudly stands behind every product that we manufacture. We are committed to providing you with the most reliable and durable products on the market. You can be assured of our dedication to quality and performance in every electrical component that we manufacture. This is what sets us apart.



## Section 8: Glossary

**Alternating Current (AC)** - An electric current which reverses direction in a circuit at regular intervals

**Alternator** - An electric generator that produces alternating current (AC). Diodes within the alternator are then used to convert the AC output into DC output usable by a vehicle.

**Clip-on Ammeter** - Measures electric current through a cable by means of induction. Provides an output in amperes.

**Ampere** – Standard unit of current flow.

**Ampere- hour** – Measurement of the total energy passed through a cable during a specific time period.

**B Terminal (Starter)** – Located on the starter's solenoid. Connected to the positive battery cable.

**B+ Terminal (Alternator)** – Connected to the positive battery cable.

**B- Terminal (Alternator)** – Connected to the negative battery cable.

**Batteries** – Provide power for engine cranking and electrical loads when the alternator is not generating power. Also stabilizes voltage levels in the electrical system.

### Circuits

- ▶ **Closed Circuit** – Provides a continuous path for current flow.
- ▶ **Control Circuit** – Transmits power to the starter's solenoid. Includes the key switch, remotely mounted relay (if so equipped), and associated wiring.
- ▶ **Open Circuit** – Contains a disruption in current flow. This disruption is usually an air gap or an insulating material. Current is unable to flow in an open circuit condition.
- ▶ **Parallel Circuit** – Closed circuit in which current flows through multiple paths.
- ▶ **Series Circuit** – Closed circuit in which current flows through a single path.

**Carbon Pile Load Tester (Load Tester)** – An instrument which draws current from a battery using a variable resistance. In this manual it is used to perform voltage drop tests.

**Current** – Flow of electrons through a circuit.

**Direct Current (DC)** – An electric current flowing in one direction only.

**Electronic Tester** – Combines the features of a carbon pile load tester, voltmeter and ammeter in one unit.

**Field Coil** – Induces a magnetic field in the alternator's rotor

**Ground (Vehicle Application)** – Electrical connection to the negative terminal (typically) of the vehicle's batteries, usually through the vehicle's frame. Used to complete an electrical circuit.

**Hydrometer** – An instrument used to determine the specific gravity of a liquid.

**IMS Terminal** - Located on the starter motor's integrated magnetic switch, and is connected to the vehicle's control circuit.

**Integrated Magnetic Switch (IMS)** – Starter relay that is directly mounted on the starter motor.

**Magnetic Flux** – A measure of the strength of a magnetic field.

**Ohm** – Standard unit of resistance. A load with one ohm will have a voltage of 1 volt across its terminals when one ampere of current is passed through it.

**Ohm's Law** – States that Voltage, Current and Amperage are interrelated. This relationship is expressed through the equation  $V=I \times R$ . In this equation V=voltage, I=current flow and R=resistance. If two of the values are known, the equation can be manipulated to find the third value.

**Open Circuit Voltage** – The voltage of a battery when it is not supplying current.

**Pinion** – Gear connected to the output shaft of a starter motor. Engages the engine's ring gear during cranking.

**Planetary Gear Reduction** – Gear train which utilizes a "sun" and "planetary" gears. In a Mitsubishi Electric starter motor, this gear train is used to convert the low torque input of the armature to a high torque output at the pinion.

**Rectifier** – Converts the 3-phase AC current produced by the stator into the DC current used by a vehicle's electrical system.

**Regulator** – Controls the alternator's output voltage by varying the current supplied to the field coil. Mitsubishi Electric alternators have temperature compensated regulators, which increase output voltage as ambient temperature decreases. This increases the alternator's ability to charge the batteries during cold weather.

**Relay** – Device that closes a set of electrical contacts when a voltage is applied. This voltage is usually applied to a coil of wire, creating a magnetic field to close the electrical contacts.

**Remote Mounted Relay** – A relay in the control circuit of a vehicle. When this relay's contacts are closed, it transmits power to the starter motor's solenoid. This relay is generally mounted on a vehicle's firewall or battery box.

**Resistance** – The opposition to current flow.

**Ring Gear** – Connected to the motor's crankshaft by way of the flywheel. The starter motor's pinion rotates the ring gear during cranking.

**Rotor** – Is rotated by a shaft connected to the alternator pulley. It is responsible for inducing voltage in the stator. The rotor's poles create a change in magnetic flux in the stator.

**S Terminal** – Located on the starter motor's solenoid, and is connected to the vehicle's control circuit

**Soft-Start** - Allows the pinion to fully engage the ring gear before full current is applied to the starter and before the starter begins to crank the engine. A secondary circuit within the starter is utilized to slowly rotate the pinion as it is engaging the ring gear. This feature nearly eliminates pinion and ring gear wear and milling.

**Solenoid** – In a Mitsubishi Electric starter, this is a device that both functions as a relay and provides the mechanical force needed to extend the pinion. The relay function transmits current from the batteries to the motor portion of the starter.

**Specific Gravity (In reference to batteries)** – The density of a battery's electrolyte relative to the density of water. This measurement is made with a Hydrometer and will determine the sulfuric acid content of the electrolyte.

**Starter Motor** – An electric motor for starting an engine.

**State of Charge** – A measure of the amount of usable power remaining in a battery.

**Stator** – Produces the current supplied by the alternator to the vehicle. The change in magnetic flux produced by the spinning rotor induces a voltage in the stator.

**Temperature Compensated Regulator** – Alternator regulator which increases output voltage as ambient temperature decreases. This increases the alternator's ability to charge the batteries during cold weather.

**Troubleshoot** – To investigate, determine and settle or solve a problem.

**Voltage** – The difference in electrical "pressure" between two points.

**Voltage Drop** – A difference in voltage along a conductor through which current is flowing. Loss of voltage is due to high resistance and can be caused by bad ground connections, loose connections and corrosion, improper wire sizing, broken wires, etc.

**Voltmeter** – Measures differences in electrical potential in volts.

## Section 9: Legal Disclaimer

The safety of workers is the highest priority in all situations and should supersede all other considerations when you engage in troubleshooting operations.

Information in this manual is designed for use by persons with experience and training in the repair of commercial vehicle electrical systems. It is not intended to supersede or replace information contained in manufacturers' user manuals, technical manuals, handbooks or other publications. Mitsubishi Electric Automotive America, Inc. (MEAA) is not responsible for any damage – physical, electrical or otherwise – as a result of you following the information and directions in this manual. The manual is for informational purposes only and is not intended to cover every situation or problem which you may encounter with your Mitsubishi Heavy Duty Electrical System. Some steps or directions contained in this manual may not apply depending on your particular circumstances.

THIS INFORMATION CONTAINED IN THIS MANUAL IS PROVIDED “AS IS” AND WITHOUT WARRANTIES OF ANY KIND, EXPRESS OR IMPLIED. TO THE FULLEST EXTENT PERMITTED BY LAW, MEAA DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. MEAA MAKES NO REPRESENTATIONS OR WARRANTIES REGARDING THE USE OR THE RESULTS OF THE USE OF THESE MATERIALS OR THAT DEFECTS WILL BE CORRECTED. YOU ASSUME THE ENTIRE COST OF ALL NECESSARY SERVICE, REPAIR OR CORRECTION TO THE ELECTRICAL SYSTEM.

Users of this manual should report errors or omissions, recommendations or other comments to Mitsubishi Electric Automotive America, Inc. 15603 Centennial Drive, Northville, Michigan 48168, Attention: Heavy Duty Applications Phone: (734) 453-6200; Fax: (734) 453-6212.

## Section 10: Information Acknowledgements

Mitsubishi Electric Automotive America, Inc. would like to thank the following companies and organizations for their contributions to this manual:

- ▶ Auto Meter Products Inc.
- ▶ Exide Technologies
  - ▶ Fred Feres
- ▶ Fluke Corporation
- ▶ Purkey's Electrical Consulting, Inc.
- ▶ Tawas ICMS
  - ▶ Robert Galyen
  - ▶ Tom Julian

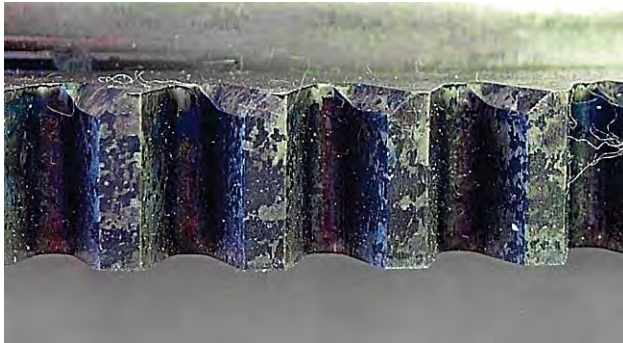
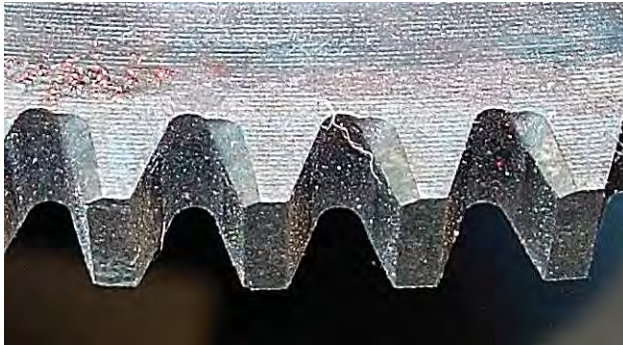


## Appendix A: Ring Gear Wear Examples

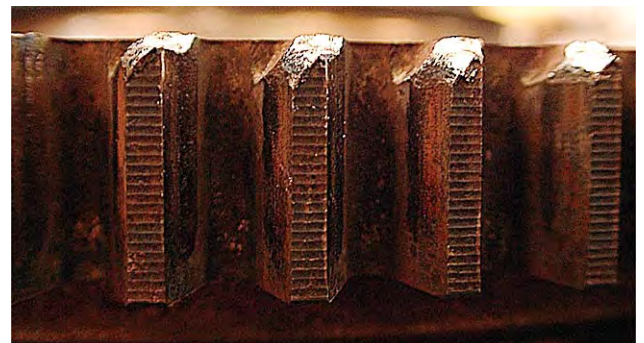
The photos below show two different ring gears. Left: This ring gear's teeth have not experienced excessive wear, and will provide a lowered occurrence of misengagement. Right: This ring gear's teeth have experienced excessive wear. This ring gear has a greater chance of misengagement, and should be replaced.

Two factors affect the probability of misengagement: wear depth and wear shape. The chance of misengagement increases as wear depth increases. Sharp, uneven tooth surfaces also increase the chance of misengagement.

**Examples of new ring gear teeth.**

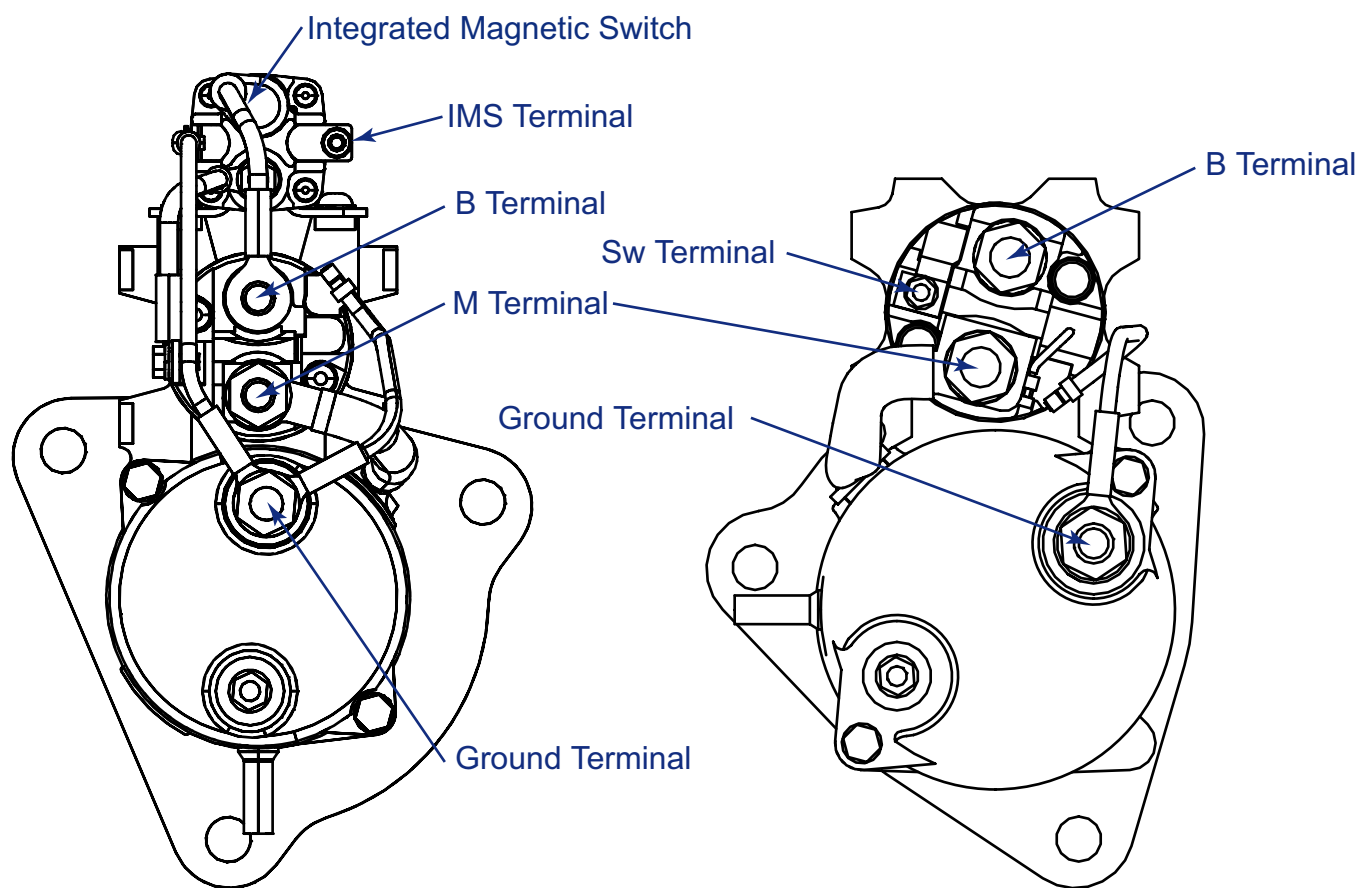


**Examples of worn ring gear teeth.**



## Appendix B: Torque Specifications

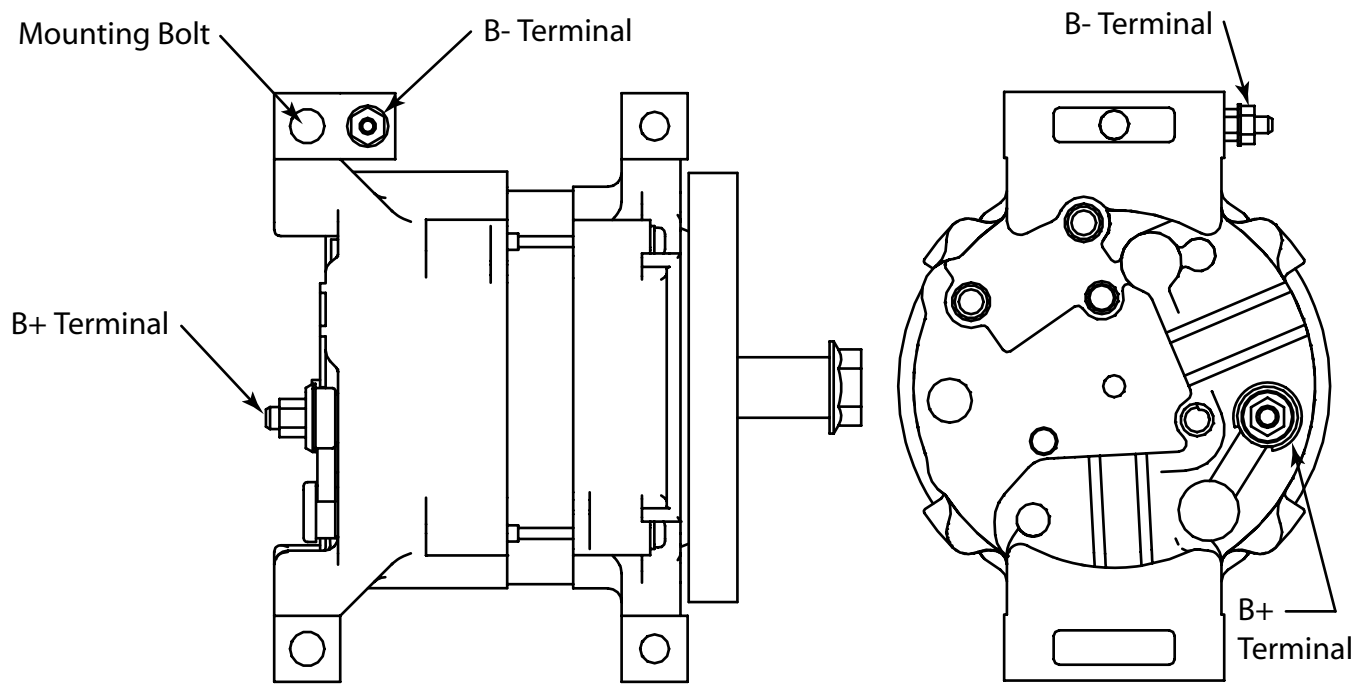
Starter Torque Specifications							
		B	Ground	IMS	SW	Mounting Bolts	
		180-264	180-264	18-22	18-22		lb.in
All Models		15-22	15-22	1.5-1.8	1.5-1.8	74-147	lb.ft
		20-30	20-30	2.0-2.5	2.0-2.5	100-200	N.m
		M12	M12	M5	M5		Size
Alternator Torque Specifications							
	Rated Output	B+	B-	Pulley Nut			
Pad Mount		70-96	31-60		lb.in		
	145 A	5.8-8.0	2.6-5.0	72-101	lb.ft		
		7.8-10.8	3.5-6.8	98-137	N.m		
		M8	M6	8mm/ 24mm	Size		



**Starter with IMS**

**Starter without IMS**





## Notes

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

## Notes

[illegible]

## Notes

This image shows a full page of blank, lined paper. It features approximately 28 horizontal grey lines spaced evenly apart, typical of notebook paper. The lines extend across the entire width of the page, leaving small margins at the top and bottom. There are no vertical lines or other markings present.

## Notes

[illegible]

## Notes

This image shows a full page of blank, lined paper. It features approximately 28 evenly spaced horizontal grey lines across its entire width, providing a template for writing or drawing. The margins are consistent on all sides.

## Notes

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

## Notes

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.