

Training Manual

Electrical System
Preventive Maintenance and
Diagnostic Procedures

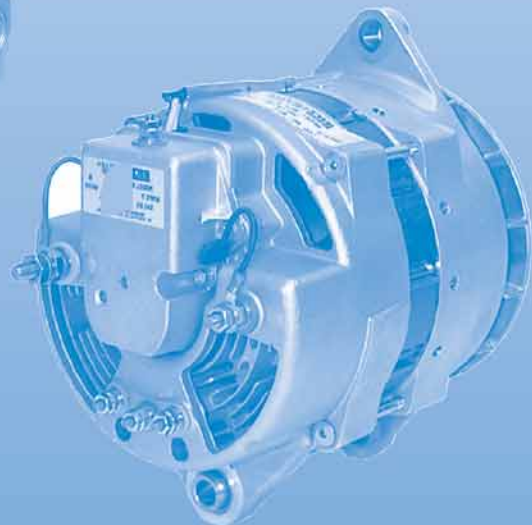
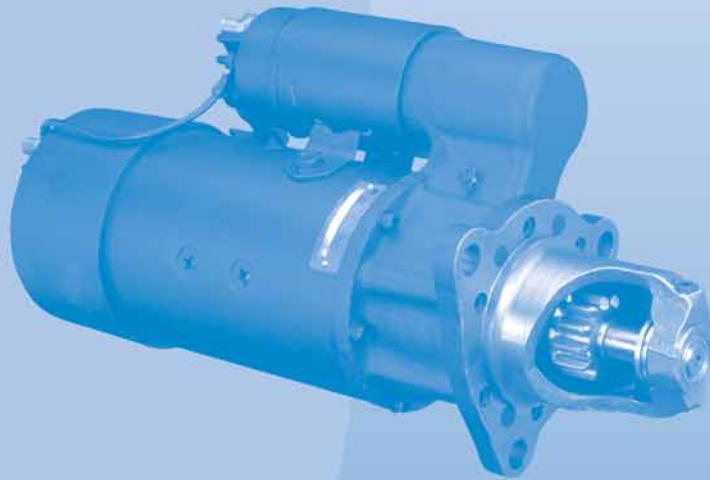


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SECTION 1: INTRODUCTION

1.1 Leece-Neville's Training Manual for Preventive Maintenance and Diagnostic Procedures on Heavy-Duty

The objective of this training manual is to provide the customer with a step by step, easy to understand outline of the procedures for maintaining and diagnosing a heavy-duty vehicle's electrical system.

As a service technician, you should consider yourself as the "doctor" who cares for your company's heavy-duty vehicles. It's your responsibility to make sure the vehicles are well-maintained. And it's your job to accurately diagnose and repair equipment problems if they occur.

Unfortunately, problems with the vehicle's electrical system are often misdiagnosed. What happens as a result? Well, most industry studies indicate that approximately 55% of alternators and starters returned under warranty to manufacturers, and noted as "defective", are later discovered to be in fine working order.

Now it's certainly true that electrical components can become damaged due to excessive heat and vibration, voltage spikes, careless handling and misapplication. Components can also become damaged by excessive heat, whenever they are forced to operate at continuously high levels of electrical output. (For instance, the addition of even a few accessories - such as mobile telephones, CB radios, portable CD players, coolers, microwaves, satellite tracking, bunk heaters, inverters, etc. - can overburden the amperage capacity of the originally installed alternator.)

Generally speaking, however, electrical components - such as alternators and starters - are designed to perform trouble-free for many thousands of miles.

So with knowledge and training, you'll be able to properly maintain your company's vehicles. And if problems occur in the electrical system, you'll be able to accurately diagnose and correct them, instead of immediately assuming that an electrical component itself is faulty.

That indeed is the goal of this training manual.

1.2 The Heavy-Duty Vehicle's Electrical System

If a technician does not have a clear understanding of how a vehicle's electrical system works, it's nearly impossible to accurately diagnose a problem.

A vehicle's electrical system is comprised of three elements: the battery system, the charging system, and the starting system. All three systems work together as a team.

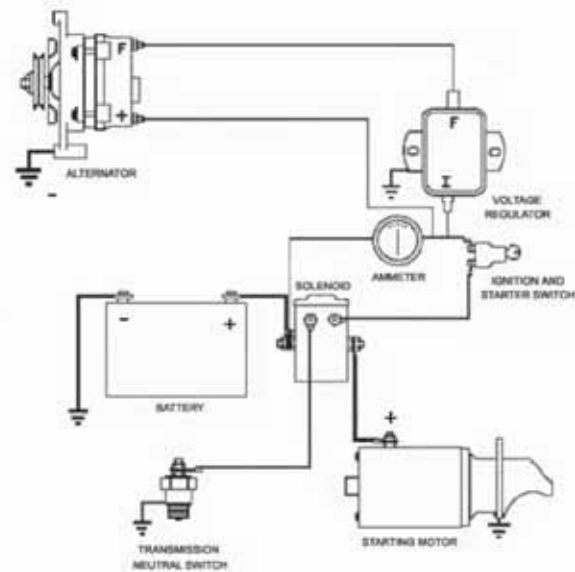


Figure 1: Vehicle electrical system

As with any team, each member has a specific and important job to perform. When diagnosing an electrical problem, it's necessary to consider each team member as potentially contributing to the problem.

That's why we've organized this training manual to cover the battery system first, followed by the charging system and finally the starting system.

You'll find that each of these three sections starts with an overview of how the system works, then moves on to cover various preventive maintenance and diagnostic (i.e. troubleshooting) procedures.

1.3 The Importance of Using Proper Preventive Maintenance Procedures

Throughout this manual, we'll underscore the importance of preventive maintenance, and show you the steps to become very proficient at it. Equally important, we'll show you how to perform preventive maintenance safely.

The advantages of performing preventive maintenance can be summarized in two ways. First, it enhances the lifespan of electrical components; and second, it improves the likelihood of trouble-free operation, thereby minimizing vehicle downtime.

1.4 The Importance of Using Proper Diagnostic Procedures

There's absolutely no question that diagnosing a problem in a vehicle's electrical system can be tedious and time consuming. However, spending the upfront time required is much more efficient than having the vehicle's driver come back to you with an uncorrected problem. Simply put, it's important to take enough time to properly diagnose and correct the real problem.

To accurately diagnose an electrical problem, you need to equip yourself with two things: the proper tools and the proper techniques.

We'll provide diagrams to show how to connect the testing devices to the vehicle's electrical components. We'll provide charts to reveal what are acceptable readings on the various devices. And as in the preventive maintenance section, we'll show you how to safely perform diagnostic procedures.

1.5 The Importance of Selecting the Proper Electrical Components

In the event that your diagnostic procedures point to a faulty electrical component, you'll need to carefully select the correct replacement component.

It's not enough to simply replace an alternator or starter, for example, with an identical version of the faulty part being replaced. There are two primary reasons why this is so. First, there's a chance the faulty part's specifications never actually met the vehicle's amperage demands. Second, the vehicle's amperage needs might have increased over time.

In any case, a new component needs to support the vehicle's electrical load requirements. This is especially true with newer vehicles' highly sophisticated computer systems, which need to be closely integrated with electrical systems components.



Figure 2: Diagnostic testing equipment.

1.6 The Importance of Following Safety Precautions

We want your vehicle to operate trouble-free. But we also want you to follow safety precautions when performing preventive maintenance and diagnostic procedures.

Whether you're working on the battery system, charging system, or starting system, make sure the vehicle's wheels are securely chocked and the vehicle is out of gear. When working on any of these three systems, always wear safety goggles or a face shield, never smoke, and do not wear jewelry or loose fitting clothing.

In the battery system section, we've listed several precautions to follow when recharging batteries. Here are some additional precautions to adhere to:

- A.** Always follow the battery manufacturer's instructions when equipment such as a battery charger or tester is used.
- B.** Never lean over a battery during charging, testing, or "jump starting" operations.
- C.** Don't break "live" circuits at the battery's terminals, because a spark invariably occurs where a "live" circuit is broken.
- D.** Keep batteries protected from sparks and open flames; never smoke near a battery. Batteries emit colorless hydrogen gas, which is extremely flammable; they can explode if they come in contact with sparks, flames, or ashes.
- E.** Be certain that battery charger cable clamps or booster leads are clean and making good connections. A poor connection can cause an electrical arc, which in turn can ignite the battery's gases and cause an explosion. Sparks can occur as a result of loose cable connections, metal tools making contact between the battery terminals, and metal tools making contact between the ungrounded battery terminal and adjacent metal parts that are grounded. Don't use the top of the battery as a tool rest.
- F.** Do not charge a battery unless you are thoroughly familiar with the step-by-step procedure for using the battery charger.
- G.** The room in which you're charging a battery must be well-ventilated.
- H.** Loose clothing shouldn't be worn around moving parts.
- I.** Keep in mind radiator cooling fans can be thermostatically controlled and could turn on at any time.

SECTION 2: THE BATTERY SYSTEM

2.1 An Overview of the Battery System

To begin the topic of the battery system, we've provided you with some basic information on how the battery system functions.

Each cell of a battery consists of positive plates, negative plates, and an electrolyte solution. Batteries produce electricity because of a chemical reaction between these three elements.

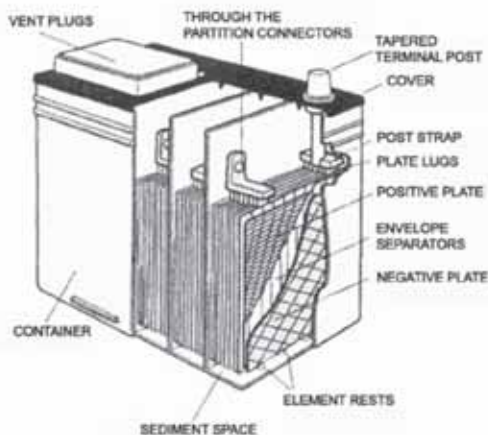


Figure 3: Battery components

In a fully-charged battery, the positive plate consists of lead peroxide (the symbol PbO_2), which is also called lead dioxide. Each molecule of PbO_2 consists of one lead atom and two oxygen atoms. The negative plate is sponge lead (the symbol Pb), which may be composed of an alloy of antimony or calcium. The electrolyte solution is sulfuric acid (the symbol H_2SO_4) diluted with water (H_2O).

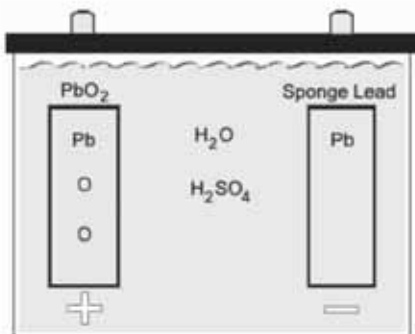


Figure 4: Fully charged battery

When an electrical load is placed on a battery, a chemical reaction takes place. The sulfate molecules in the electrolyte break off and attach themselves to the negative and positive plates. At the same time, the oxygen atoms from the lead peroxide positive plates go into the electrolyte solution to join with the hydrogen atoms, forming H_2O or water. The sulfate molecules moving to the plates and the oxygen atoms moving to the solution release energy. This is called the discharge cycle.

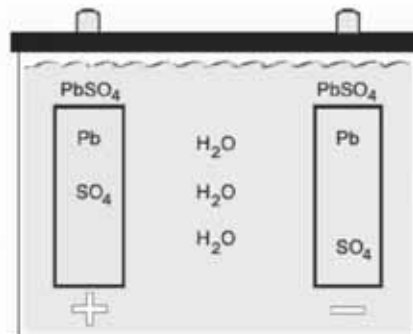


Figure 5: Fully discharged battery

When the battery is fully discharged, both plates are lead sulfate (the symbol PbSO_4), and the solution is water. In the charging cycle, the sulfate molecules return to the solution, and the oxygen molecules in the water return to the positive plates.

Fully charged and fully discharged states are the extremes. Normally, a battery is partially charged or partially discharged. For example, a battery may be 25% discharged, meaning that 25% of the chemical reaction has taken place and 75% of the battery is in its original chemical condition.

2.2 The Primary Causes of Battery System Malfunction

Before dealing with preventive maintenance and diagnostic procedures for the battery system, we're going to cover certain environmental and usage handling factors that can cause the system to malfunction.

Excessive heat. When batteries are subjected to high temperatures, positive plates corrode quickly and battery cells dry out.

Cold weather. Because engine oil thickens in cold temperatures, it makes engines harder to crank. This places a heavier and longer-lasting drain on the battery.

Vibration. If a battery is not securely fastened to the vehicle's frame, the resulting vibration can shed the active material from the battery's plate grids.

Fast charging. Using a high charging rate to quickly charge batteries can be damaging, if the battery becomes overheated and begins gassing.

Deep cycling. Repeated deep cycling will eventually cause a battery to lose its ability to accept a charge. If battery cycling occurs use high cycle batteries.

2.3 Preventive Maintenance Procedure

There are six preventive maintenance procedures that can help preserve battery life. These six procedures are also the first steps you should take when diagnosing (i.e. troubleshooting) a problem in the vehicle's electrical system. The six preventive maintenance procedures are as follows:

1. Check cleanliness. If the battery rack is dirty, remove the battery cables first, then remove the battery from the vehicle. Wash the battery rack with a water and baking soda solution. Flush the case with water, and dry with a towel. If necessary, clean the battery post and cable terminal with a wire brush or a special terminal cleaning tool. Wash batteries with baking soda and water.



Figure 6: Battery hold-down brackets.

2. Check hold-down brackets. Make sure the brackets holding the battery to the vehicle's frame are secure. If the brackets are loose, tighten to manufacturer specifications.

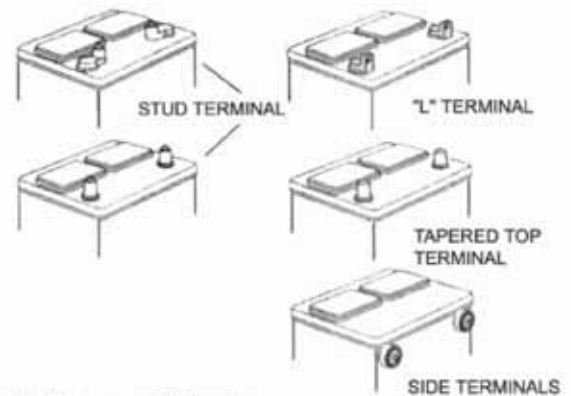


Figure 7: Battery terminal locations.

3. Check battery cables. Battery cable connections to terminal should be checked for corrosion and proper tightness, and cleaned and /or tightened as necessary. The cables themselves should be checked for swelling, cracking, or brittleness, cables should be replaced as necessary.

4. Check battery ground cables. The battery ground cables must be securely fastened to the alternator ground. Also be sure that the points where the cables are connected to the vehicle's frame or engine block are clean and secure.

5. Check battery case. The condition of the battery case often indicates whether internal component damage or loss has occurred. Telltale signs are swelling and cracking of the case.

6. Check fluid levels (only on non-maintenance-free types of batteries). If liquid in the battery is low, add clean soft water or distilled water only. Adding a pre-mixed electrolyte solution will make the sulfuric acid too strong and cause the plates, separators, and case to deteriorate prematurely.

2.4 Diagnostic / Troubleshooting Procedures

When trying to find the cause of a problem in a vehicle's electrical system, you should always begin with the battery. **In performing any diagnostic procedure, refer to the safety information section in the Introduction section 1.6.**

It's critically important for each individual battery to be properly tested and fully charged. It's only then that you can move on to diagnosing problems with the charging or starting systems. A battery not fully charged will cause all other electrical systems tests to be inaccurate.

Remember to always disconnect all battery ground cables, at the batteries, before replacing or servicing any electrical equipment. After removing battery ground cables verify no voltage is present at alternator output terminals.

Beyond the visual inspection procedures mentioned earlier, there are three simple steps to testing a battery: removal of the surface charge, determination of the state of charge, and load testing.

Remove the battery's surface charge. Electrical charges on the surface of the battery's positive plates cause a falsely high voltmeter reading. Removal of this so-called "surface charge" is required on batteries that have been charged by an alternator or a battery charger within 48 hours. Batteries on trucks that have not been run or charged on a charger within 48 hours will not have significant surface charge.

To remove the surface charge, you'll need to slightly discharge the batteries. This can be done by using a carbon pile load tester to load each battery to one-quarter of its cold cranking amps rating for 15 seconds, see Figure 8. Fifteen seconds is long enough to dissipate the surface charge from the plates.

The surface charge can be removed by simply turning on the vehicle's lights - without starting the engine - for two to three minutes per battery.



Figure 8: Carbon pile load tester

Test the battery's state of charge. The second step in battery testing involves testing each individual battery's state of charge. Connect a voltmeter across each battery and record the readings. Compare the readings to the Figure 9 chart to determine the percentage of charge. If the battery is at 75% or higher, you can proceed to the third step - the load test. If the battery is below 75%, recharge it. (See charging instructions at the end of this section). Remove the surface charge, and then test it again to determine the state of charge. If after recharging the battery, it is still below 75% charged, the battery may require further charging or it may be defective.

Percentage of Charge	
12.60 V	100%
12.45 V	75%
12.30 V	50%
12.15 V	25%

Figure 9

Carbon pile load testing. The third step in battery testing is to load test the battery. Follow the carbon pile-load tester manufacturer's instructions when connecting the tester and ammeter across the battery. Determine the battery's cold cranking amp rating, or CCA. Divide the CCA rating by two to determine the load. Load the battery for 15 seconds, adjusting the carbon pile to maintain the proper load. Do not load the battery any longer than 15 seconds, as this may cause damage to the carbon pile. At the end of the 15-second load, read the voltmeter and turn off the carbon pile.

The table in Figure 10 below is used as a guideline for the minimum acceptable load test results. Notice that as the electrolyte temperature declines, so does the minimum voltage. This is due to the effect of temperature on most chemical reactions. The battery reaction is slower as the electrolyte becomes colder.

Minimum Acceptable Results (when a load is applied of 1/2 the CCA rating of the battery)	
Electrolyte Temp (F)	Voltage
70° or above	9.6
60°	9.5
50°	9.4
40°	9.3
30°	9.1
20°	8.9
10°	8.7
0°	8.5

Figure 10

Batteries that pass the load test may be put back into service. Fully charged batteries that fail the load test have lost capacity or the ability to provide electrical current for cranking.

2.5 Battery Charging

When recharging batteries, please follow these important safety precautions:

- 1) Leave the battery charger unplugged until its cables are connected to the battery.
- 2) Charge each battery separately.
- 3) Use the proper charger.
- 4) Charge batteries in a well ventilated area.
- 5) Never smoke while charging batteries.
- 6) Use protective eye wear.
- 7) Do not wear watches or other jewelry.

2.6 Battery Replacement

If you perform regular preventive maintenance on batteries, and always properly charge and test batteries, you can avoid or reduce the need for costly replacements.

However, if your diagnostic procedures point to a faulty battery, you'll need to carefully select a new battery. The new battery's "cold cranking amp" rating must support the vehicle's intended application, or load and duty cycle.

SECTION 3: THE CHARGING SYSTEM

3.1 An Overview of the Charging System

The Charging system is an important part of the electrical system. It provides electrical current for the lights, the radio, the heater, the engine's electrical systems, and other electrical accessories. It also maintains the batteries in a charged state, recharging them as necessary.

In order to properly service the charging system, you need to understand how it operates. The charging system has three main components: the alternator, the voltage regulator, and the batteries.

The alternator generates electrical power to run accessories and to recharge the batteries. It is normally driven by a belt located off the crankshaft. Mechanical energy from the crankshaft is converted by the alternator into electrical energy for the batteries and accessories.

The voltage regulator acts as an electrical "traffic cop" to control alternator output. It senses when the batteries need recharging, or when the vehicle's electrical needs increase, and adjusts the alternator's output accordingly.

The batteries are a reservoir of chemical electrical power. Their primary purpose is to crank the engine. They also supply power to vehicle accessories when the electrical load is too great for the alternator alone.

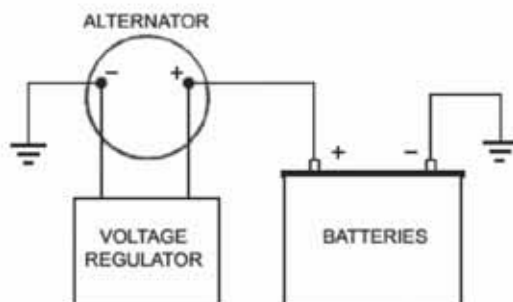


Figure 11: Wiring diagram

3.2 The Primary Causes of Charging System Malfunction

Before discussing the preventive maintenance and diagnostic procedures for the charging system, we're going to cover certain environmental and product application factors that can cause the charging system to malfunction.

Excessive heat. An alternator can become damaged if it operates too long at excessive temperatures. Damaging heat levels are generated in two ways: when the alternator becomes dirty either externally or internally restricting its ability to dissipate heat from its external surface or not allowing air to pass through the unit, and when air ducts and heat shields are not replaced after the alternator has been serviced.

Dirt and dust. Charging system components operate less efficiently when buildup of dirt particles form around wire and cable connection points. Dirty connection points impair the flow of electrical current.

Vibration. If charging system components are poorly or loosely mounted to the vehicle's frame, the resulting vibration can damage sensitive internal components. A loosely mounted component will also diminish the performance of the important belt drives. This is very important on high powered engines.

3.3 Preventive Maintenance Procedures

The object of preventive maintenance is to identify and correct the potential problems before they occur.

There are three preventive maintenance procedures that can greatly enhance the efficiency of the charging system's functions. These three procedures also represent the initial steps you should take when fully diagnosing (i.e. troubleshooting) a problem in the vehicle's charging system. The three preventive maintenance procedures are as follows:

Clean alternator and connection points. Insure that all alternator surfaces are clean to the point that they do not have a buildup of dirt, grease or dust. Air flow passages must also be clear so that air can easily pass through the unit. All connection points must be clean and free from corrosion.

Component mounting brackets. As mentioned previously, you need to make sure that the charging system components are securely mounted to their applicable brackets; the brackets, in turn, need to be bolted securely to the engine. Again, if charging system components are poorly or loosely mounted, damaging vibration and diminished belt drive performance are the result.

Tension and condition of belts. You need to also check the belt for proper tension. **Caution: be sure the engine is turned off.** A loose belt will slip on the pulley and fail to turn the alternator's rotor. Check belt tension with cricket belt tension gauge. Refer to vehicle manufacturer's specifications for proper belt tension. Before you adjust it, however, tilt the belt and inspect it for glazing, cracks, or dryness. A worn or damaged belt should be replaced.

If the belt is in satisfactory condition, use a belt tension gauge and check the results, see Figure 12. Different belt systems use different gauges. Use proper tensioning gauge for your application, adjust the tension according to the manufacturer's specifications. If engine is equipped with an automatic belt tensioner and the leading edge of the belt is damaged or fraying, inspect the tensioner. It could be worn or damaged and has contributed to belt damage.



Figure 12: Belt tension gauge

If you replace a worn or damaged belt, the new belt should be checked for proper tension as well. A new belt loses 60% of its tension in the first few hours of operation. So it needs to be tested under heavy load, and then retensioned. After a new belt is installed, run the engine - with every accessory turned on - for 15 minutes (this puts a heavy load on the belt). Then check the belt tension again and adjust it if needed. Please note that belts on high amperage output alternators may need retensioning twice after installation. Further note that if the vehicle has a multi belt drive, the belts need to be matched. Finally, in most cases and on most vehicles, belt tension should be tested every 10,000 miles.

3.4 Diagnostic / Troubleshooting Procedures

Timely preventive maintenance of the charging system should keep it running smoothly. However, when a problem does occur, effective diagnostic (i.e. troubleshooting) procedures will help you locate and correct the problem quickly and economically. **In performing any diagnostic procedure, refer to the safety information section in the Introduction section 1.6.**

Any discussion about the electrical system must begin with the batteries. Before you begin analyzing the charging system, you must be sure the batteries have been properly tested and are at least 75% charged. Otherwise, any electrical tests you conduct on the charging system will be inaccurate. (Please refer to Section Two of this manual for procedures on testing and charging batteries).

We're now going to show you how to perform four different tests specifically related to the charging system.

Alternator Performance Test. Connect voltmeter to alternator terminals and ammeter to alternator's positive output cable, per Figure 13. Make sure ammeter is at least 6 inches (15 cm) away from alternator to eliminate the possibility of faulty readings. Make sure voltage is present at alternator's output terminals. Start engine and run it at 1500 rpm (operating rpm). Check that all vehicle loads are turned off and reading on ammeter is less than 20 amps. If ammeter reading is greater than 20 amps double check that all vehicle loads are turned off and that batteries are fully charged. Record voltage on voltmeter. Reading should be between 13.8 & 14.4 v for a 12 volt system, 27.8 & 28.4 v for 24 volt systems. If the voltage is not within these ranges then try adjusting the regulator if available. If the regulator can not be adjusted, alternator is defective.

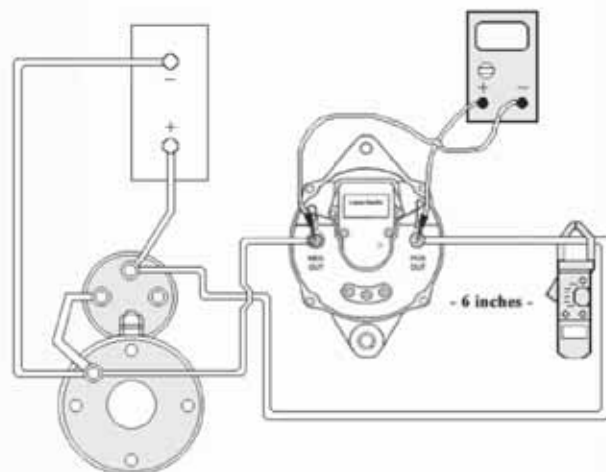


Figure 13: Alternator performance test under load

Alternator Performance Test Under Load. Keep engine running at 1500 RPM (operating RPM) and meters are connected per Figure 13. Turn on vehicle loads until 75% of the alternator's rated output is achieved on ammeter display. Record voltage on voltmeter. Compare reading to that taking during the Alternator Performance Test. If alternator voltage drops more than .5 volts for a 12 V system and .7 volts for a 24 V system then alternator is defective. An alternative method of putting load on an alternator is with a carbon pile tester. Connect carbon pile tester across batteries. Adjust carbon pile until desired reading is obtained on ammeter. Record voltage on voltmeter and shut off vehicle.

Alternator Cable Test. To test the positive cable connect the ammeter to the positive cable from the alternator. Make sure the ammeter is at least 6 inches (15 cm) away from the alternator to eliminate the possibility of faulty readings. Connect the voltmeter's negative lead to the positive terminal of the alternator and the positive lead to the positive terminal on the battery, see Figure 14. Start engine and set engine RPM to 1500 RPMs (operating speed). Turn on vehicle loads until 75% of alternator's rated output is achieved on ammeter display. If necessary use a carbon pile tester to apply load on alternator. Record voltage on voltmeter. If reading is greater than .25 volts in a 12 volt circuit or .50 volts in a 24 volt circuit check all wire connections and cable conditions. If reading is less than .25 volts in a 12 volt circuit and .50 volts in a 24 volt circuit cables are good. Turn off vehicle loads and shut off engine. To test the negative cable move voltmeter's negative lead to the negative terminal of the battery and the positive lead to the negative terminal of the alternator, see Figure 15. Run test again. Use Figure 16 for recommended wire sizes for any cable repairs.

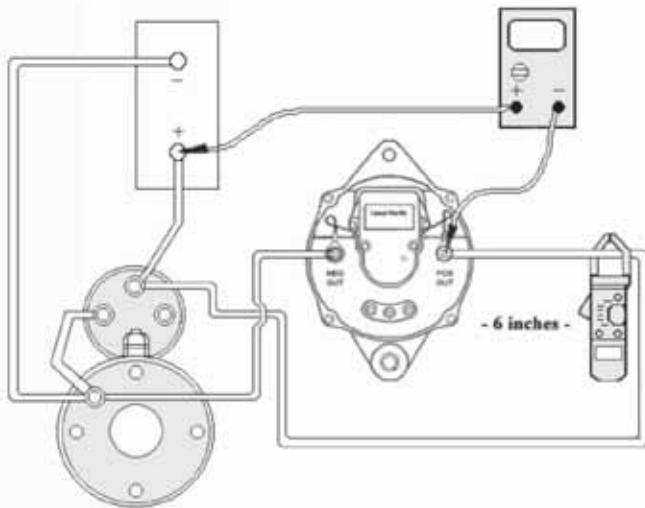


Figure 14: Positive cable test

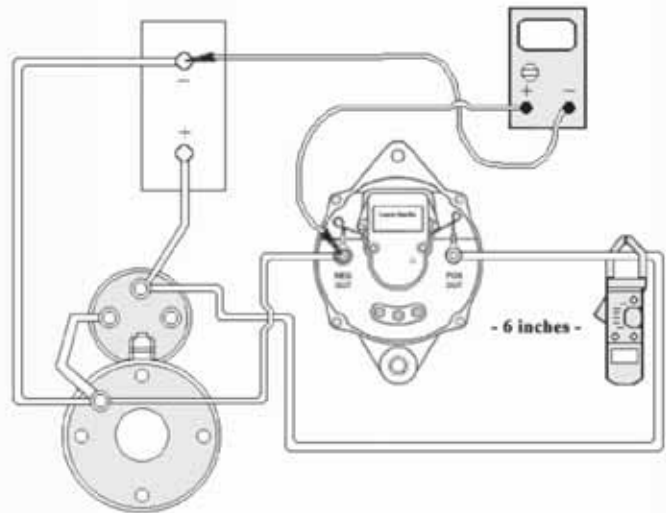


Figure 15: Negative cable test

Maximum Available Current	Total Circuit Length	Recommended Wire Size
60-75 amps	15 feet or less	#6
	16-25 feet	#4
	26-40 feet	#2
80-125 amps	15 feet or less	#4
	16-25 feet	#2
	26-40 feet	#0
130-250 amps	15 feet or less	#0
	16-25 feet	#0
	26-40 feet	#00
250-325 amps	12 feet or less	#00
	12-20 feet	#0000

Figure 16: Recommended wire size chart

3.5 Alternator Replacement

In the event that all of the diagnostic / troubleshooting procedures point to a faulty alternator, you'll need to select a new alternator. Its "amperage capacity" rating must support the vehicle's intended application, or load and duty cycle.

If the vehicle has had a history of charging problems and you've eliminated failure in the system, you may want to reevaluate the capacity of the alternator.

When installing a new alternator and retensioning belts, be sure to carefully follow the instructions noted earlier in this section under "preventive maintenance".

See Appendix A, B, and C at the end of this manual for the Alternator Sizing Worksheet, Trouble Shooting Flowchart, and Alternator Test Procedure Flowchart.

SECTION 4: THE STARTING SYSTEM

4.1 An Overview of the Starting System

The starting system converts electrical energy from the batteries into mechanical energy to turn the engine over. A malfunction within the starting system will make it difficult to get the engine started.

In order to properly service the starting system, you need to understand how it operates. The starting system has five main components: the ignition switch or start button, a neutral safety switch (an option on some vehicles), the starter solenoid, the starter motor, and the batteries.

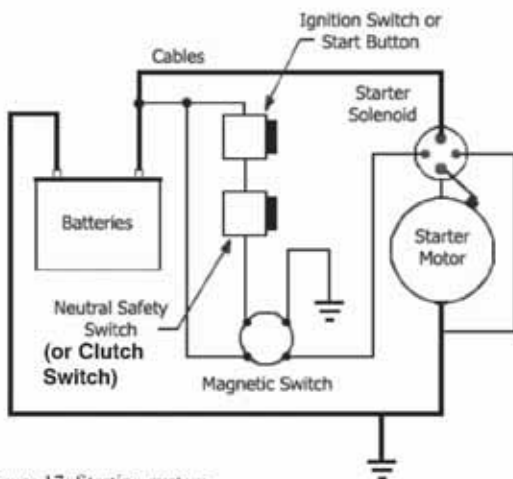


Figure 17: Starting system

When the key is turned in the ignition switch to the start position, or the start button is pushed, electricity flows from the batteries to the starter solenoid.

Some vehicles are equipped with a neutral safety switch and/or a clutch switch. If the vehicle is in gear when the key is turned, the neutral safety switch blocks the signal to the batteries, so the engine doesn't start cranking. Otherwise, the vehicle could jump forward or backward when the key is turned.

The starter solenoid is an electromagnetic switch mounted on the starter motor. When coils inside the solenoid are energized by electricity, they create a magnetic field which attracts and pulls a plunger. Attached to one end of this plunger is a shift lever. The lever is connected to the drive pinion and clutch assembly of the starter motor.

The starter motor is a small but powerful electric motor that delivers a high degree of power for a short period of time. When the starter motor is energized it engages the flywheel ring gear and produces torque, which turns the flywheel and cranks the engine.

When the driver releases the ignition switch from the start position to the run position, the solenoid is deactivated. Its internal return springs cause the drive pinion to be pulled out of mesh with the flywheel, and the starter motor stops.

4.2 The Primary Causes of Starting System Malfunction

Before discussing the preventive maintenance and diagnostic procedures for the starting system, we're going to cover certain environmental and product application factors that can cause the starting system to malfunction.

- 1. Battery charge.** A battery having a low / poor state of charge will place abnormal stresses on the starting system. When measuring battery voltage, make sure voltage is 12.4 V or greater.
- 2. Excessive heat.** A starter motor can become damaged if it operates too long at high temperatures. Excessive heat is generally due to continuous engagement of the starter. Damage to starting system components can occur when the starter motor is cranked for long periods (often due to cold weather starts). Starter should operate for 30 seconds maximum then let to cool down for 2 minutes.
- 3. Excessive vibration.** If starting system components are poorly or loosely mounted to the vehicle's engine, the resulting vibration can damage sensitive internal components.
- 4. Corrosion, dirt, and dust.** Starting system components operate less efficiently when corrosion forms or dirt particles build up around wire and cable connection points. Corroded and dirty connection points impair the flow of electrical current.
- 5. Defective solenoid.** If the starter fails to engage or fails to stay engaged, the pull-in or hold-in coil may be defective, or the wiring to the solenoid is bad. You need to check the wiring to the solenoid. If the wiring is ok then the coil is defective and you will have to replace the solenoid.

4.3 Preventive Maintenance Procedures

The object of preventive maintenance is to identify and correct potential problems before they occur.

There are two preventive maintenance procedures that can greatly enhance the efficiency of the starting system's functions. These two procedures also represent the initial steps you should take when fully diagnosing (i.e. troubleshooting) a problem in the vehicle's starting system.

Engine operating condition. Keeping the engine in good running condition is essential to ensure efficient operation of the starting system. Simply put, an engine in poor condition is harder to start, and this shortens the life of the starter motor. An engine that starts easily results in fewer turns of the starter motor, and therefore, a longer life for the starter.

Wires and cables. For any type of vehicle electrical system, it's important to keep all connection points clean. Road dirt and grease create resistance that interferes with electrical current flow. In order to get the necessary power from a unit the size of a starter motor, there must be little or no resistance between the batteries and the starter motor. In the same vein, you need to make sure that wires and cables are clean, properly tightened, and of the proper size. Any loss of current due to poor connections will reduce power of the starter motor. Clean all connections on a periodic basis.

Employing the preventive maintenance steps we've outlined will be extremely beneficial to the starting system. There's also another way to save yourself a lot of time and wrench work: visually inspecting the starting system's components for signs of damage.

4.4 Diagnostic / Troubleshooting Procedures

Timely preventive maintenance of the starting system should keep it running smoothly. However, if the starter motor is cranking slowly, or not at all, it's time to diagnose (i.e. troubleshooting) the starting system. **In performing any diagnostic procedure, refer to the safety information section in the Introduction section 1.6.**

Any discussion about the electrical system must begin with the batteries. Before you begin analyzing the starting system, you must be sure the batteries have been properly tested and are at least 75% charged. Otherwise, any electrical tests you conduct on the starting system will be inaccurate. (Please refer to Section Two of this manual for procedures on testing and charging batteries.)

You must also be aware that if the batteries aren't being recharged, there may be a problem in the charging system, which will lead to starting system problems. (If that's the case, please refer to Section Three of this manual for procedures on testing and troubleshooting the charging system). Once you have verified that the batteries and charging system are working, you can begin testing the starting system.

When troubleshooting, you always want to strive for the most easily obtainable solution and progress toward the most difficult problems to address. **And remember, when replacing electrical equipment, always disconnect all battery ground cables at the batteries.**

Ignition / run switch test. You should begin by determining whether the problem is in the ignition switch, push button, mag switch and associated wiring or if it's in the solenoid and starter motor.

We'll begin with the ignition switch circuit. Connect a voltmeter between the ignition switch terminal of the starter solenoid and ground see Figure 18. Have someone attempt to crank the engine and record the voltage. You'll get either no voltage, low voltage, or normal voltage, with slow cranking or no cranking at all.

First, troubleshoot the switch circuit. You can test it by connecting a remote start switch between the battery positive and the switch terminal on the starter solenoid. When you close the switch, the starter should engage and start the engine. Again, record the voltage while cranking and compare it to your first reading. A difference of less than one volt is not enough to indicate a problem. If there is a difference of more than one volt, however, then there is a problem in the switch circuit.

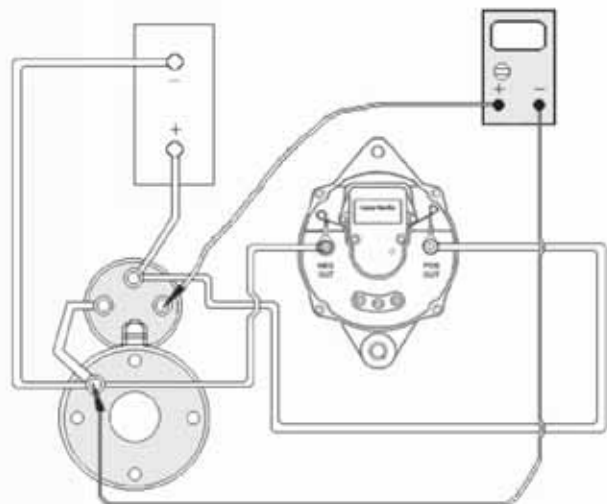


Figure 18: Ignition / run switch test

Use the voltmeter to check each connection, moving backward through the switch circuit. If your first test of the ignition switch had shown low voltage, that may indicate a shorted starter motor, which would have to be repaired or replaced.

If the voltage in your first test was normal, but there was slow cranking or no cranking at all, that would indicate a problem related to the batteries, battery cables, or a damaged starter.

Solenoid test. Although the reasons for low voltage or normal voltage with slow cranking are different, the procedures for locating the problem area are the same. If the solenoid clicks but the motor won't turn, it means current is flowing through the solenoid coils but not through the main contacts.

Connect the voltmeter to the motor terminal of the solenoid per Figure 19. If there's no voltage from the motor terminal to ground (when the solenoid is activated), that indicates the disc isn't making contact with the terminals, or there is a problem with the cable between the battery positive terminal and the solenoid. The solution is to repair or replace the solenoid or cable.

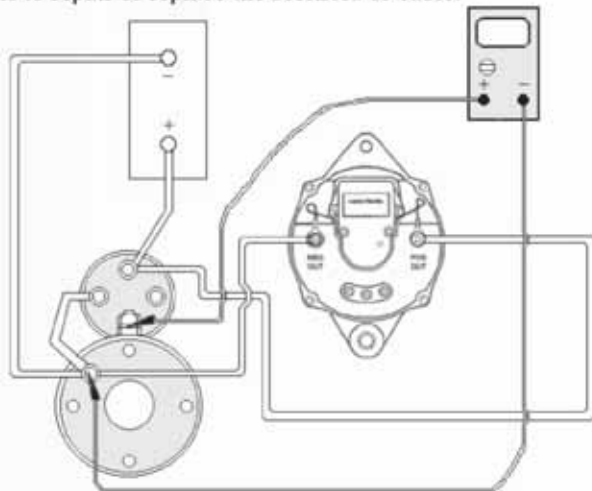


Figure 19: Solenoid test

Starter motor test. If voltage is present at the solenoid motor terminal, then the problem is the starter motor or its cabling. If your original test of the ignition (or run) switch indicated normal voltage, but slow or no cranking, your next step is to check the motor system and its connections.

If the drive pinion keeps shifting out of mesh with the flywheel, then check for a broken or a loose external ground wire on the solenoid. Replace a broken wire or reattach a loose one.

Measure the amp draw with ammeter in either the positive, see Figure 20, or ground cable, see Figure 21, of the starter motor while pressing the start switch. If the amp draw is excessive, according to the manufactures specifications, then the starter motor is faulty. Slow cranking or high current draw can also indicate that bushings are worn because of an off-center armature. Worn bushings and / or and off-center armature cause poling and throw off the alignment of the magnetic fields. But, before you replace the starter, check the condition of the engine to make sure it turns freely. An engine in poor condition could cause the starter to work harder or longer. In other words, the starter may not be the problem. It may be damaged by the engine's poor condition.

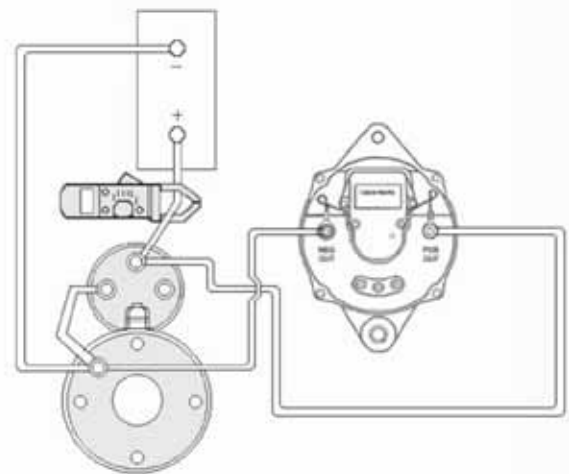


Figure 20: Starter motor test, positive cable

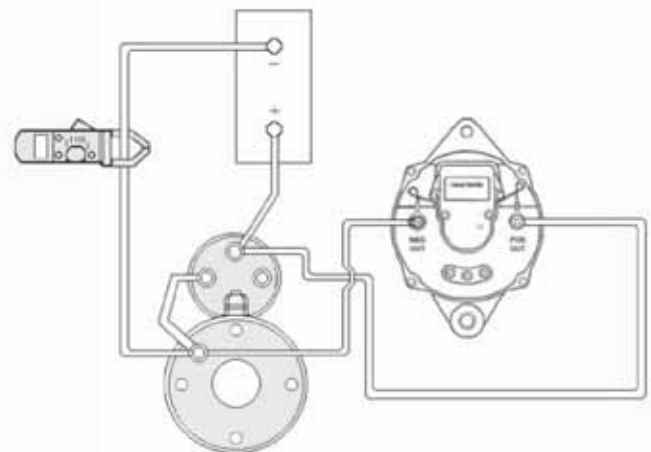


Figure 21: Starter motor test, ground (negative) cable

Voltage drop test. Sluggish cranking may be caused by a very small amount of extra resistance in the circuit. This may come from dirty connections or bad or broken cables. With the voltage drop test, you first must check the starter's positive terminals, then the negative terminals.

Positive cable test. Connect voltmeter, ammeter, and carbon pile tester per Figure 22. Adjust a carbon pile load tester until ammeter reads 500 amps through to the meter. Note the voltage reading. On 12-volt system, voltage drop should not exceed .4 volts. On a 24 volt system, voltage drop should not exceed 1 volt. Turn off carbon pile tester when test is complete.

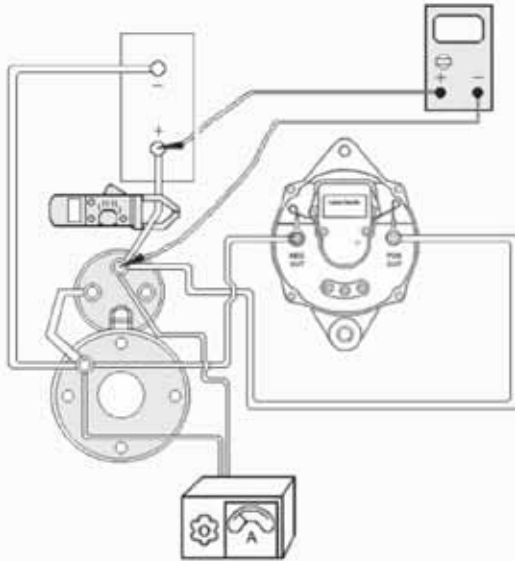


Figure 22: Positive cable test

Negative cable test. Connect voltmeter, ammeter, and carbon pile load tester per Figure 23. Adjust carbon pile load tester until ammeter reads 500 amps. Note the voltage reading. On 12-volt system, voltage drop should not exceed .4 volts. On a 24 volt system, voltage drop should not exceed 1 volt. Turn off carbon pile load tester when test is complete.

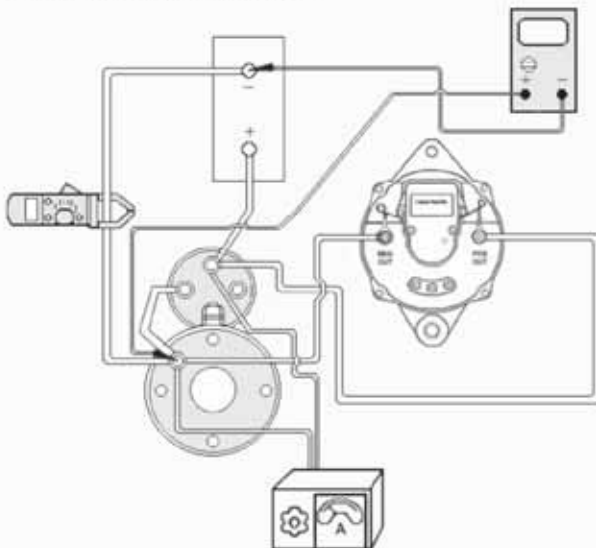


Figure 23: Negative cable test

Solenoid voltage drop test. The final check takes place at the solenoid terminal. And for this test, you must crank the engine. Disconnect the carbon pile load tester, voltmeter (if applicable), and ammeter so that none of the testing equipment will be damaged by the test procedure. An autoranging digital voltmeter is useful in this case, as full battery voltage appears across the solenoid terminals before they close. Connect voltmeter per Figure 24. Crank the engine and note the voltage reading. No more than two-tenths voltage drop should exist between the solenoid contacts.

The voltage readings from the three tests (Positive and Negative cable tests and Solenoid voltage drop test) must not add up to more than one volt for a 12 volt system or 2.5 volts maximum for a 24 volt system.

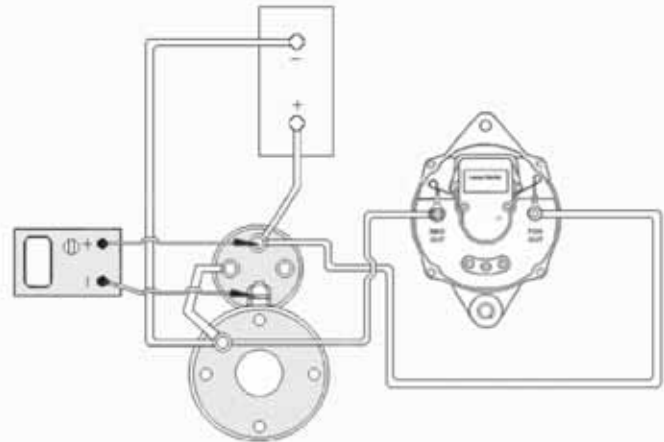


Figure 24: Solenoid voltage drop test

If the voltage drop is more than allowable, check the cables and connections.

One final note: There are many variations of grounding the starter circuit. Some vehicles have a ground cable for the battery and another ground cable for the starter motor. Both attach to the frame. When doing a voltage drop test, you must check all cables regardless of the circuit.

4.5 Starter Replacement

In the event that all of the diagnostic / troubleshooting procedures point to a faulty starter, you'll need to replace your unit with a new starter.

SECTION 5 : CONCLUSION

5.1 The Benefits of Using Proper Preventive Maintenance and Diagnostic Procedures

After having read this manual, we think you'll agree that service technicians who approach their craft as "diagnostic experts" exhibit a higher degree of professionalism than mere "parts changers".

The use of proper preventive maintenance and diagnostic procedures has many advantages. Electronic components inevitably last longer and vehicle downtime is greatly minimized. You will be able to take pride in a job well done. And your company will be pleased with the cost savings resulting from trouble free vehicle operation.

5.2 The Benefits of Selecting Proper Electrical Components

As we've also noted throughout this manual, careful selection and replacement of electrical components assures that your heavy-duty vehicle's entire electrical system will operate to its utmost efficiency.

We at Leece-Neville trust that you've found this manual to be helpful. Continue to use it as a reference guide, and refer to it as necessary. Always feel free to contact us with your comments or questions.

Leece-Neville is committed to providing you with reliable, durable, quality built electrical components. And we're committed to equipping you with the knowledge to perform your important job in the most professional manner possible.



Figure 25: Quality Leece-Neville Starter Motors



Figure 26: Quality Leece-Neville Alternators

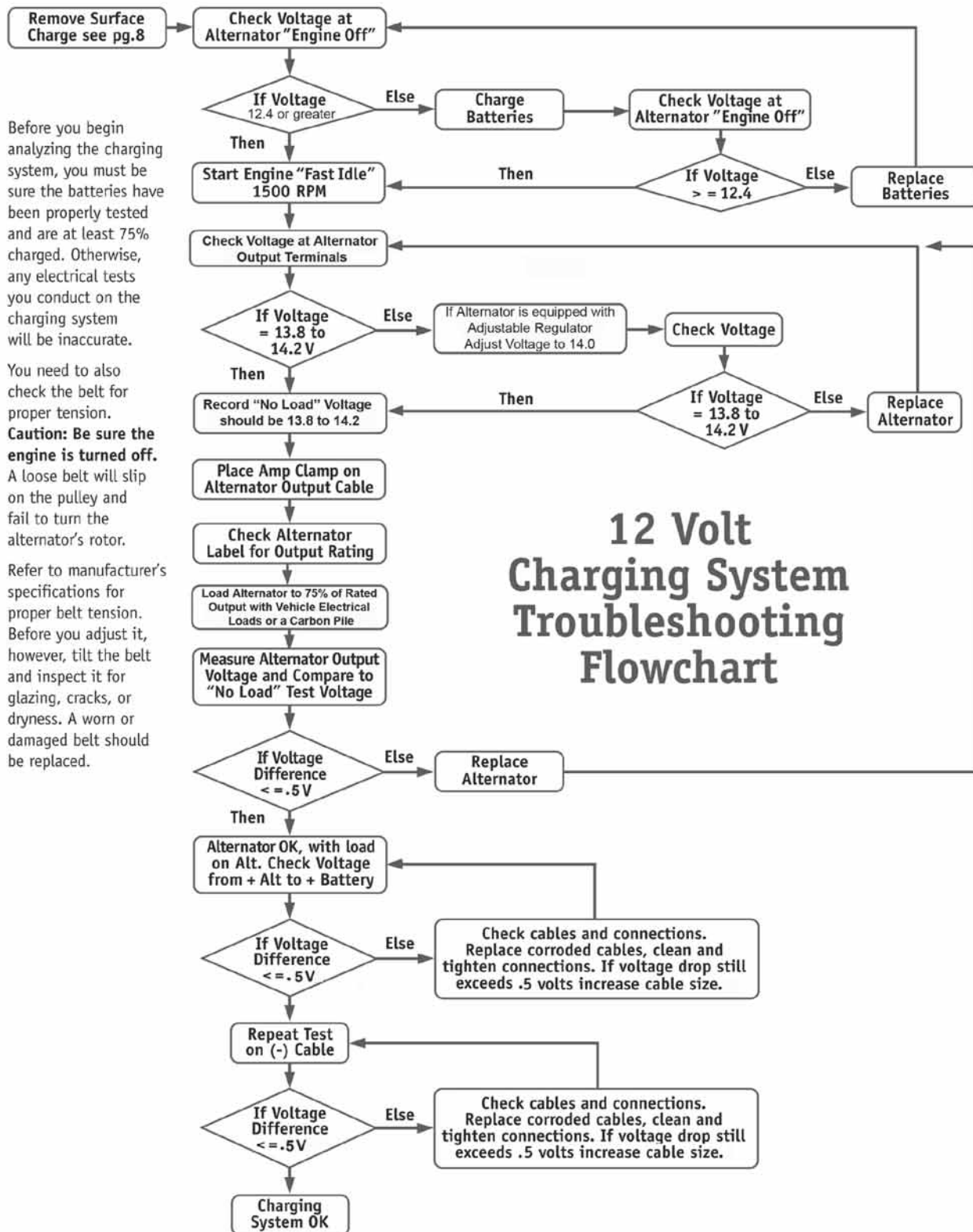
Appendix A: Alternator Sizing Worksheet

	Typical Current / Amp Rating	Qty	Total Current / Amp		Typical Current / Amp Rating	Qty	Total Current / Amp
CAB				LIGHTS ON TRACTOR			
Heater (Select only ONE)				Headlights (Select only ONE)			
Heater/AC Blower Motor - 4 (high)	24.00	x _____ = _____		4 - Hi Beam	14.00	x _____ = _____	
Heater/AC Blower Motor - 3	19.00	x _____ = _____		2 - Hi Beam	11.00	x _____ = _____	
Heater/AC Blower Motor - 2	18.00	x _____ = _____		Daytime Running Lights	5.00	x _____ = _____	
Heater/AC Blower Motor - 1 (low)	12.00	x _____ = _____		Clearance Marker Lights			
Key On All Loads Off (Default 1 Qty)	10.00	x <u>1</u> = <u>10.00</u>		LED Light (# of LIGHTS)	0.08	x _____ = _____	
A/C Compressor Clutch	4.40	x _____ = _____		Incandensent Light (# of BULBS)	0.30	x _____ = _____	
Interior Lights	2.00	x _____ = _____		Brake Lights			
Mirror Heater	9.00	x _____ = _____		LED Light (# of LIGHTS)	0.50	x _____ = _____	
Windshield Wiper (high)	10.00	x _____ = _____		Incandensent Light (# of LIGHTS)	2.20	x _____ = _____	
Windshield Wiper (low)	7.00	x _____ = _____		Turn Lights			
			Total _____	LED Light (# of LIGHTS)	0.75	x _____ = _____	
SLEEPER				Incandensent Light (# of LIGHTS)	2.20	x _____ = _____	
Bunk Fan (Select only ONE)				Fog/Driving Lamps	15.60	x _____ = _____	
High	15.00	x _____ = _____		Back-up Lamps	2.30	x _____ = _____	
Medium	10.00	x _____ = _____		Tail Lamps	1.00	x _____ = _____	
Low	8.00	x _____ = _____					Total _____
Bunk Heater	12.00	x _____ = _____		LIGHTS ON TRAILER			
Lights	2.00	x _____ = _____		Clearance Marker Lights			
			Total _____	LED Light (# of LIGHTS)	0.08	x _____ = _____	
RADIOS				Incandensent Light (# of BULBS)	0.30	x _____ = _____	
AM/FM Radio	1.00	x _____ = _____		Brake Lights			
CB	1.00	x _____ = _____		LED Light (# of LIGHTS)	0.50	x _____ = _____	
			Total _____	Incandensent Light (# of LIGHTS)	2.20	x _____ = _____	
ACCESORIES				Turn Lights			
Microwave Oven (Inverter Powered)	80.00	x _____ = _____		LED Light (# of LIGHTS)	0.75	x _____ = _____	
Electric Blanket	3.00	x _____ = _____		Incandensent Light (# of LIGHTS)	2.20	x _____ = _____	
Satellite	2.00	x _____ = _____		Fog/Driving Lamps	15.60	x _____ = _____	
Refrigerator (Cooler Style)	4.50	x _____ = _____		Back-up Lamps	2.30	x _____ = _____	
Television & VCR	3.00	x _____ = _____		Tail Lamps	1.00	x _____ = _____	
			Total _____				Total _____
BATTERIES				TOTALS			
Battery @ 8 amps each	8.00	x _____ = _____		CAB			= _____
			Total _____	SLEEPER			= _____
				RADIOS			= _____
				ACCESORIES			= _____
				BATTERIES			= _____
				LIGHTS ON TRACTOR			= _____
				LIGHTS ON TRAILER			= _____
							Grand Total _____

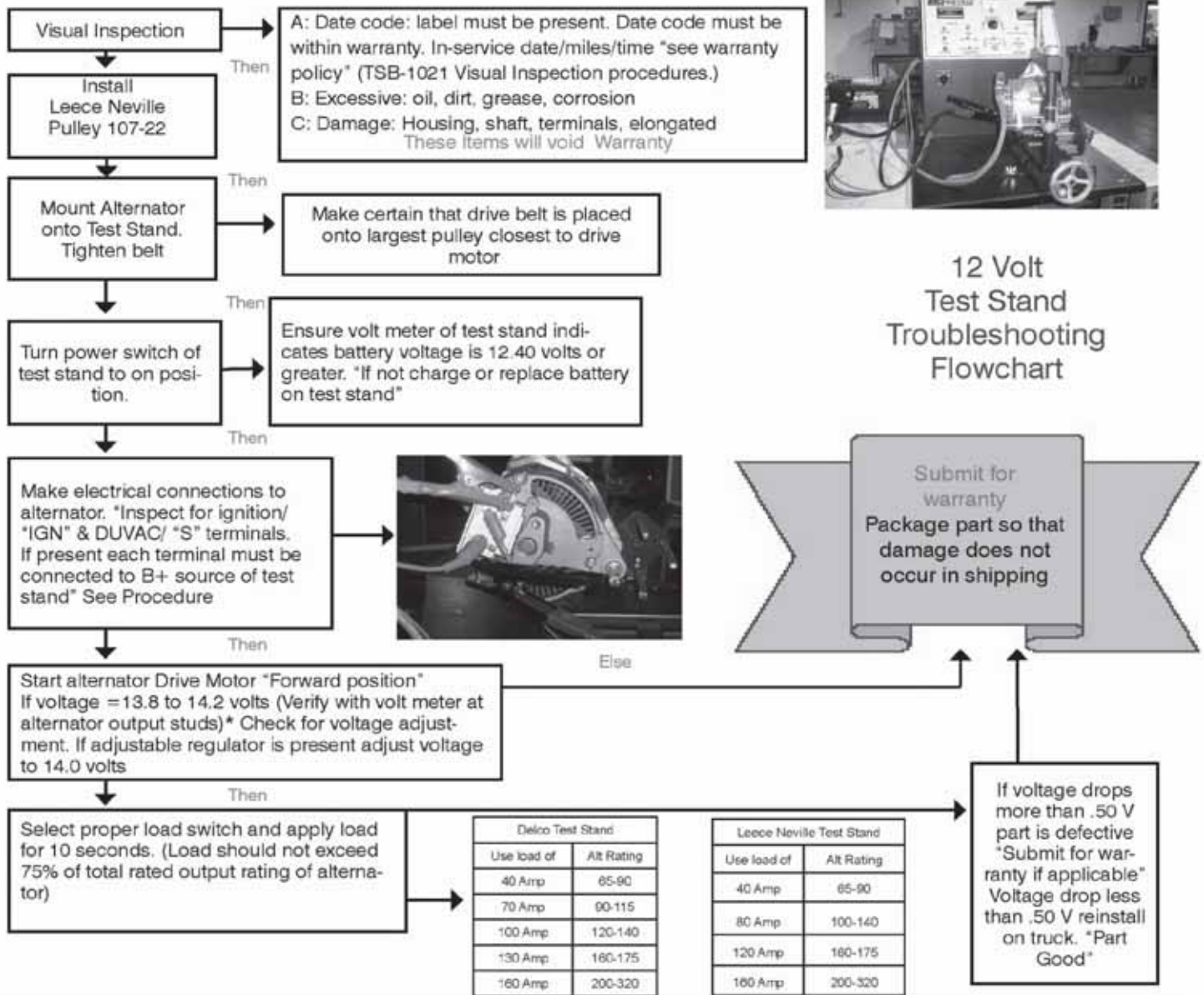
*Note - amps are all estimated values and should be used as a guideline only values may vary, depending on vehicle

Total Electrical Load = _____
Total Amperage @ Idle (80% of total elec load) = _____

Appendix B Charging System Troubleshooting Flowchart (12 Volt System)



Appendix C Alternator Test Procedure Flowchart (12 Volt System)

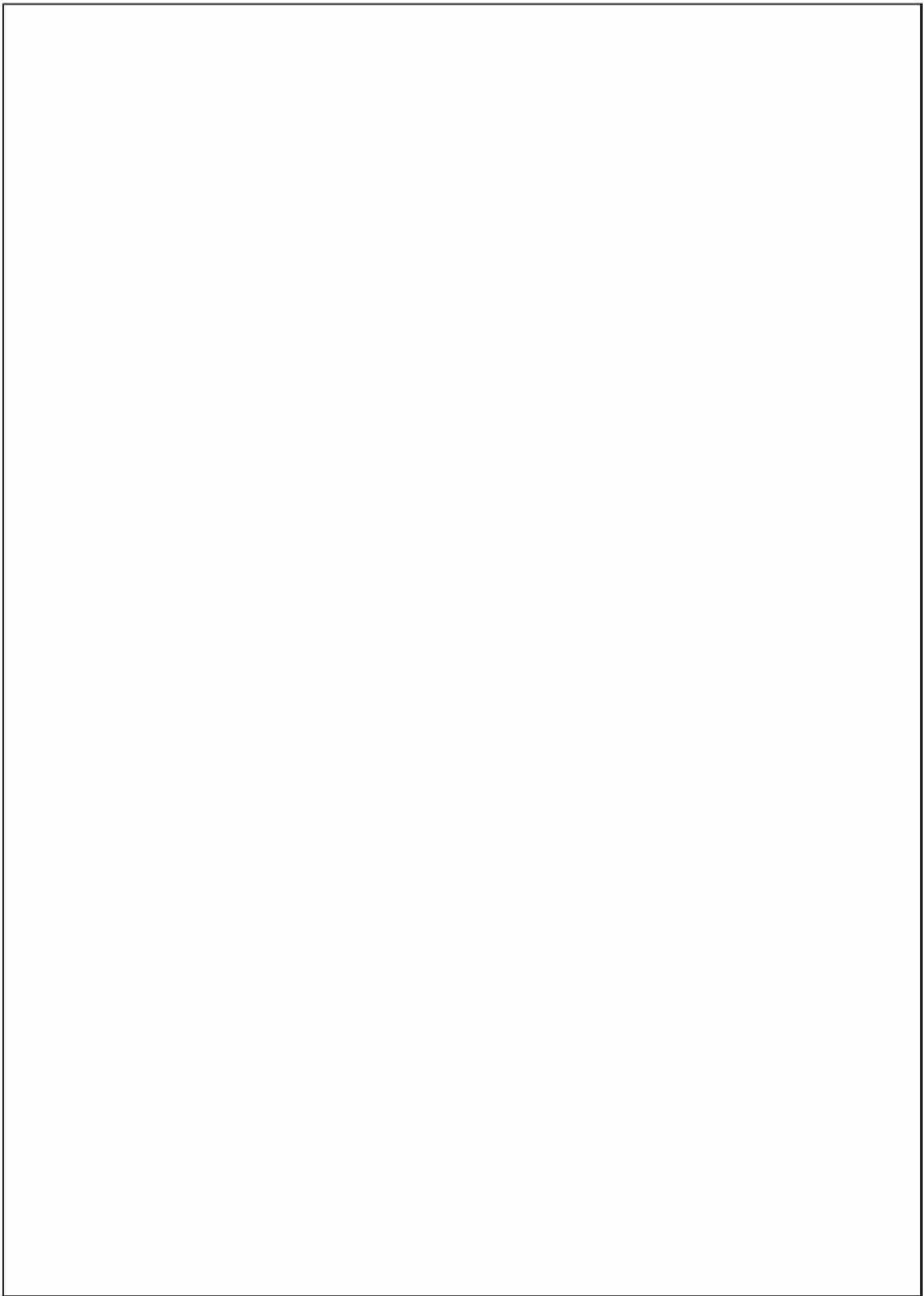


Note: Poor alligator clamp connections can cause voltage drop to be greater than .5 volts. Use external voltmeter on output terminals to correct this.

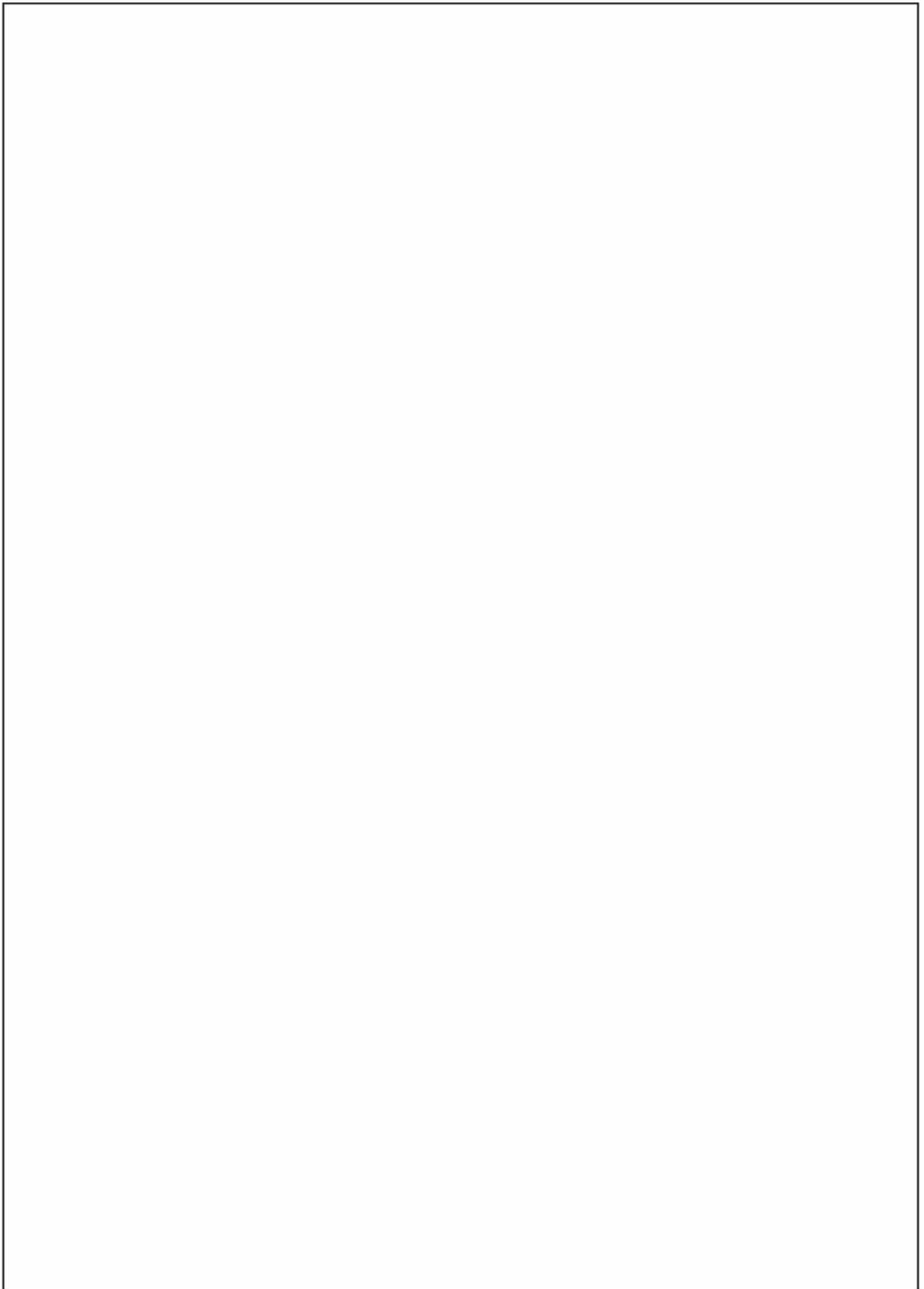
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