
TECHNICIAN
TRAINING
DORMAN
Training Seminar Series
Presents:
Commercial Motor Vehicles
Battery, Starting and Charging
"Everything you need to know"

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Your Instructor For This Webinar

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What will be covered

- **Overview and description of the major components.**
- **Maintaining the system and component integrity.**
- **Testing and diagnosing.**
- **Live demo with components.**

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Impact Slide

Typical Loads On A Vehicle

Load	Watts (power)	Amps (current)
Starter	**1000 – 5000**	**200 – 1000**
Headlamps	100 – 200	4 – 10
Directionals	50	4 - 6
Blower motor		6 – 15
Windshield Wipers	100	4 – 8
Windshield Washers	20	2
Power Windows	100 – 200	10 – 30
Power Seats	100 – 200	10 – 30
Instruments	20 – 30	2
Engine Controls	15 – 60	1 – 10

Note: This is just a partial list. You can keep on adding to it.
Which require minimum voltages (preferably battery voltage)?
What about V-Ref ? What are normal operating values?
What about emissions?
What about Fuel injection?
Where does all this power come from?

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Batteries

Overview:

- The vehicles Battery(s) provide all the electrical energy when the engine is not running.
- **When the engine is running, the alternator is responsible for powering the electrical system.**
- The battery provides the energy to crank and start the engine.

Very Important: While the battery is supplying the required current for cranking (starting) the available voltage at the battery cannot be allowed to fall below a specified point.

WHY?

- **If voltage falls below these limits, the operation of the starter motor and electrical circuits required for starting such as fuel injection and ignition (type of engine specific) will be altered or may fail to operate. Not to mention other electrical circuits.**

Simplified: The Battery stores electrical energy generated by the alternator (generator) to be used by all the electrical components in a vehicle.

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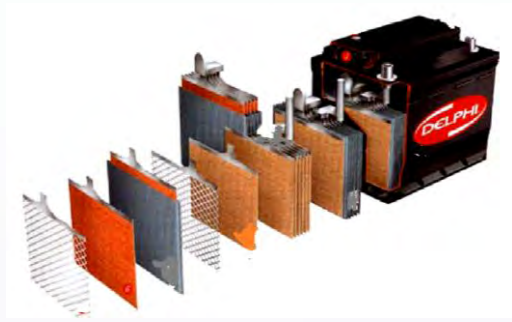
What's inside a typical battery?

- Each cell has alternating positive and negative plates. The plates are separated and insulated from each other, preventing a short circuit.
- The cells are immersed in an electrolyte solution (a mixture of sulfuric acid and water).
- The cells are connected in series, each one with a voltage of 2.1 volts. Six 2.1volt cells times six in series will provide an open circuit voltage of 12.6 volts in a fully charge battery.
- The plates in each cell are connected in parallel to increase battery capacity (amps).

Note: this is the same concept in using multiple batteries in trucks. Hooking two to four batteries in parallel will still provide 12 volts, but higher amperage (power) to crank a high compression diesel engine over.



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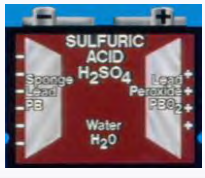
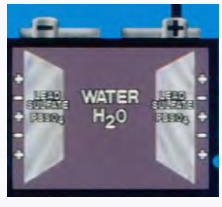
Battery Operation

- The battery develops its power through an electro-chemical reaction between a series of plates and an electrolyte solution (a mixture of sulfuric acid and water).
- Two dissimilar metals are placed in this electrolytic solution.
  - One type of lead (Pb) with O_2 additives forms the negative plate and the positive plate is formed by sponge lead (Pb).
- As a battery discharges, the negative plate loses its O_2 additive to the electrolyte, increasing the water content. The sulfate (SO_4) separates from the electrolyte and combines with both the positive and negative plates made of lead (Pb) to form a lead sulfate ($PbSO_4$).
- When this occurs, we no longer have two dissimilar metals, lowering the amount of electricity a battery can produce.

Two dissimilar metals. →





← *Two similar metals*

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Battery Operation

Simplified:

As a battery discharges, the water content increases.

The opposite occurs as a cell charges, returning the electrolyte to its original level.

- **A fully charged cell has an electrolyte solution with a specific gravity of 1.265 @ 80°F.**
- **A completely discharged cell has a specific gravity of 1.120 @ 80°F.**

That was the reason for using a "Battery Hydrometer" to measure specific gravity. Specific gravity is a indicator of a cells state of charge.

Note: 1.00 value represents the weight or density of water at 68° F. Sulfuric acid added to water (electrolytic solution) made the solution thicker (denser).

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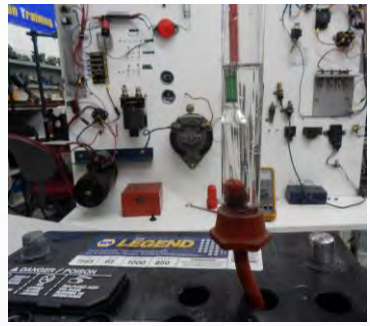
Specific Gravity Testing

State of Charge	Specific Gravity @ 80ºF
100%	1.265
75%	1.225
50%	1.190
25%	1.155
Discharged	1.120



Temperature of acid below 80° subtract from specific gravity reading

Temperature of acid above 80° F add to specific gravity reading.

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Old Technology

Battery Ratings

CCA (Cold Cranking Amps)

- Rates the battery's ability to deliver a specific amperage for 30 seconds at 0° F while maintaining a post voltage of 7.2 volts.

Note: This seems to be the standard used for most of the testing and purchasing of batteries.

RC (Reserve Capacity)

- Measures the battery's ability to provide a sustained current draw. It is the time in minutes required for a steady 25 amp draw to pull battery voltage below 10.5 volts at 80° F.

CA (Cranking Amps)

- A measurement of the battery's ability to deliver cranking power. It is a rating in amps that a battery can deliver for 30 seconds at 32° F while maintaining a minimum voltage of 7.2 volts.

Note: This is a less strenuous measurement.

Battery Ratings

Amp/Hours

- The amount of current which can be drawn from a battery before the voltage drops below 10.5 volts.

AGM – Absorbed Glass Mat

- Absorbed glass mats are used as separators between the plates.
- The electrolyte is absorbed and held between the plates by the glass mats, eliminating the need for immersing the plates in large amounts of electrolyte.
- Compressing the glass mats between tightly held plates and the absence of excess electrolyte increases the life of the battery.
- These batteries are ideal for being used inside the passenger compartment.

NOTE: 100% state of charge on a typical AGM battery is 12.8Volts.

This is the real world.

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Tools

Would you need all these tools just for Batteries?

Answer: Yes and No.

- **No for Battery**
- **Yes, for diagnosing electrical systems that depend on the batteries energy to perform their tasks.**

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Tools

Mix of old and new

- Conductance type Battery, Starting, Charging system analyzer.
- Battery Hydrometer
- Refractometer

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Open Circuit Voltage Test

- Open circuit voltage test allows a battery's state of charge to be determined using a DVOM.
- **Remove surface charge first to obtain an accurate test result.**

As an example, turn all accessories (headlights et.) on for 60 seconds.

- A good reading would be 12.6 volts.
- **This is a steady state or no-load battery voltage reading used to determine the state of charge.**

12.6 volts
Fully charged at 70° F

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Open Circuit Voltage Guide To Determine Testing Requirements.

12.8 Volts or Higher	Surface Charge
12.6V – 12.7V	100%
12.4V – 12.5V	75%
12.2V – 12.3V	50%
12.0V – 12.1V	25%
11.8V – 11.9V	Discharged

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Battery Load Tester

Battery Load Testing

- **This test measures a battery's capacity to deliver a large amount of current (amps) for short periods. Do not perform this test unless you have a minimum state of charge of 75%. Higher is better.**
- **To calculate use CCA. Most load tester use 1/2 of the battery's CCA as the test load. For example, if the battery CCA 800 amps, the test load will be 400 amps.**
- **Remove surface charge if present.**
- **Apply the test load for 15 seconds.**
  - **If no temperature correction is needed and the recorded voltage is 9.6 volts or higher, the battery is good.**

NOTE: If surface charge is above 12.6 volts or above, apply a 300-amp load for 15 seconds to remove the surface charge first.

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Load test guide with temperature compensation

Minimum Volatge Under Load	Battery Temperature
9.6V	70ºF (21ºC)
9.5V	60ºF (16ºC)
9.4V	50ºF (10ºC)
9.3V	40ºF (4ºC)
9.1V	30ºF (-1ºC)
8.9V	20ºF (-7ºC)
8.7V	10ºF (-12ºC)
8.5V	0ºF (-18ºC)

Conductance Testing

- **Conductance describes the ability of a circuit to conduct current.**
- **Conductance is utilized to indicate how much plate surface is available for chemical reaction.**
- **Conductance is proportionally related to battery capability.**
- **This makes it an effective means of checking the batteries state of health and identify cells and batteries that might require attention or replacement.**
- **The tester contains a library of various CCA's ratings of various batteries as a baseline.**
- **A series of loads have been applied to various good, weak and bad batteries and recorded and graphed.**
- **The recorded information is recalled upon hookup to a battery to be tested.**
- **The test loads are automatically applied, with the results showing up on the screen.**

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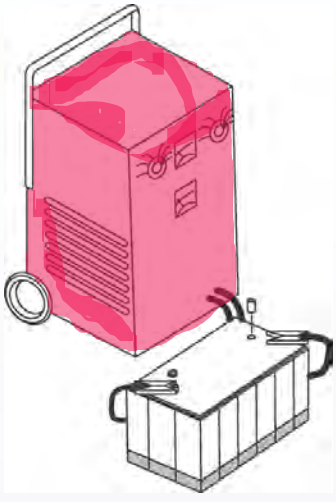

Charging

Important Concept:

- ***The charger produces voltage, and current flows as a result of that voltage.***
- ***The amount of charging current that flows is dependent on high the charger's voltage is and the internal resistance of the battery.***
  - ***When the charger voltage is high and the battery resistance is low, a larger charge current will occur.***
  - ***When the battery resistance is high, and the charger voltage is low, the result will be a smaller charge current.***
- ***The amp rating of a charger is based on its voltage capability under given conditions.***
- ***However, the actual current flow may vary.***

Note: the current flow can be measured with an ammeter while the battery is charging.

Important: The time it takes to properly charge is very important and the most neglected aspect of charging.

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Charging Amps	Open Circuit Voltage	Charging Time (Hours) at 70ºF (21ºC)
5 amps	12.00 to 12.24	6
5 amps	11.95 to 12.09	8
5 amps	10.00 to 11.95	12
5 amps	10.00 to 0	14
10 amps	12.00 to 12.24	3
10 amps	11.95 to 12.09	4
10 amps	10.00 to 11.95	6
10 amps	10.00 to 0	7
20 amps	12.00 to 12.24	1.5
20 amps	11.95 to 12.09	2
20 amps	10.00 to 11.95	3
20 amps	10.00 to 0	3.5

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Charger Voltage	Hours
16.0 volts or more	Up to 4 hours
14.0 - 15.9 volts	Up to 8 hours
13.9 volts or less	Up to 16 hours

** Charging times are listed for a battery temperature of 80ºF (27ºC)*

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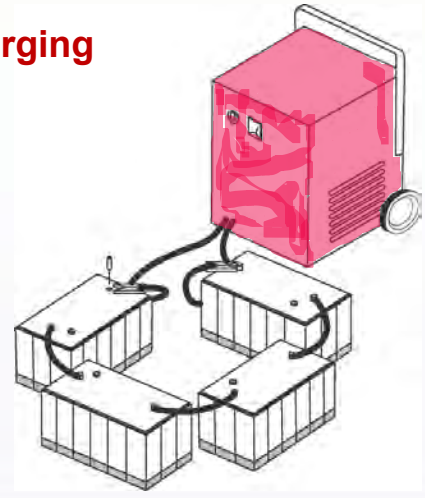
Series Charging



When series charging is used, all the batteries in the circuit will receive the same amount of charging current. The charging current is limited by the battery with the highest internal resistance.

"Think about ohms law"

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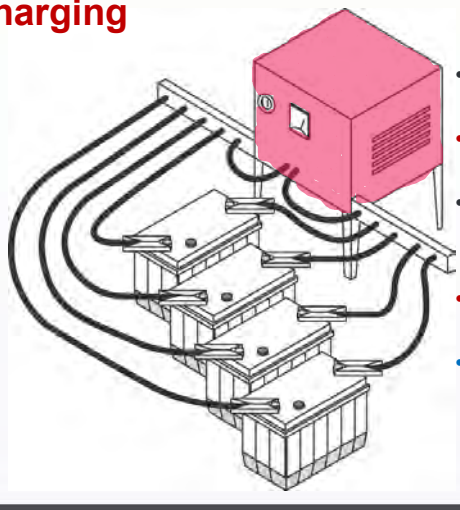
Parallel Charging



- **When charging batteries in parallel, all batteries in the circuit receive the same charging voltage influenced by the battery with the lowest internal resistance.**
- A charger with adjustable output is preferred for this type of charging.
- **Voltage should be adjusted as high as possible without exceeding 16 volts.**
- When it reaches 16 volts, monitor the current flow into each battery every 30 minutes.
- **The current flow will decrease as the battery nears full charge.**
- **Each battery falling below 5 amps at 16 volts will be at 95% state of charge or more and charging of that battery should be stopped.**

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Visual Inspection

- Look for corrosion at terminals/posts/cables/connections.
- Check electrolyte level if accessible.
- Check hold downs for proper type and tightness.
- Check for proper size and length of cable.
  - Length and size affects resistance.

Note: Emergency cable ends should not be used as permanent cable ends.

Clean battery (especially the top) can prevent voltage drain.

Common sense and good maintenance practices must prevail.
This is all a part of a good PM program.
It's the little things that prevent big issues.

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The Starting System

- The starting motor converts electrical energy into mechanical energy.
- It is used to initiate the combustion process.
- Electromagnetism is the means to convert electrical energy into mechanical energy.

The starting system is used to crank the engine until the engine can operate under its own power.
The starter provides the torque to overcome resistance resulting from compression and any internal friction.
Once the starter has provided the necessary torque to overcome the resistance, it must also turn the engine fast enough to provide heat for combustion.

It's a relationship

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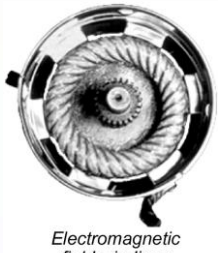
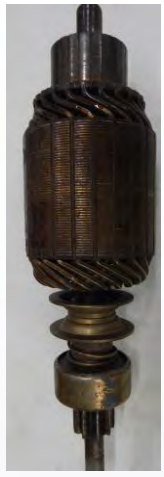
Starter Operation



Electromagnetic field windings

- An electric motor consists of two basic units, the field (electromagnet with its coils) and the armature, the structure that supports the conductors which cut the magnetic field and carry the exciting current in a motor.
- When current is passed through the armature of a DC motor, a torque is generated by the magnetic reaction and the armature revolves.
- However, the revolution of the armature within the magnetic field induces a voltage in the armature windings.
- This induced voltage is opposite in direction (opposite polarity) to the outside voltage applied to the armature and is termed as counter electromotive force (CEMF).
- The CEMF voltage rises as the speed of the motor increases until it is almost equal to the applied voltage.
- Current flow is now low, and the speed of the motor will remain constant as long as the motor is not under load and is performing no mechanical work except what is required to turn the armature.



Armature

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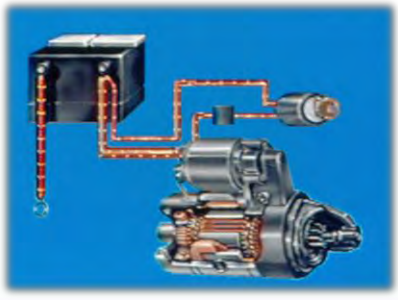
Starter Operation Continued

- Under load the armature speed is reduced.
- This reduces the amount of CEMF produced allowing a larger current to flow through the armature.
- Reduced armature speed increases current flow.
- This increases the strength of the electromagnetic field surrounding the armature that increases the amount of available torque.

Can we measure this and see it ????



Concept simply put: Varying the field current acting on the armature can control the speed of a DC motor and varying the field strength of the armature can modify available torque. This applies to all DC motors.

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The Starting System

Diagnosis

- **Typical Symptoms**
  - No crank
  - Slow crank condition
- **A starter that fails to engage the engine is diagnosed differently than a starter that engages but fails to crank and a slow-cranking condition.**
  - In this situation the current consumption will typically be higher.
  - Think about the back voltage (CEMF) in the previous slide.
  - When the starter is first engaged the armature is stopped, therefore there is no back-voltage. At this moment in time the starter consumes the largest amount of current (only for a short period). As soon as the motor begin to spin, it produces back-voltage, causing current flow to drop.
- **Best way to understand this is to watch your Amp readings.**
  - Higher than normal initial current readings can be due to either electrical shorts in either the starter field or armature windings.
  - How about a bad power supply (Battery) and the related supply cables.

The Starting System

Diagnosis Continued

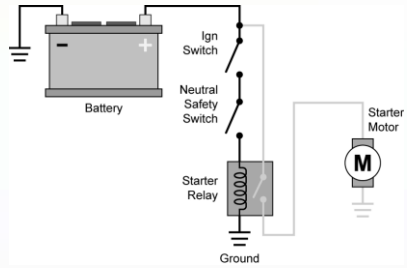
- **Usually, it all boils down to resistance.**
  - Unwanted resistance due to connection issues, cable size and length.
  - Lower voltage caused by resistance, will result in lower than normal initial current consumption (draw).
  - Because the starter is unable to develop the required torque, the motor spins slower than normal.
  - This slower than normal speed produces less than normal “back-voltage”, resulting in a higher-than-normal current flow during this period.
  - The decrease of available torque because of low voltage increases the average current consumption in a starter circuit
- **That’s why an average current flow is used to directly or indirectly to validate a starters performance**

Reminder. “This is our real world”

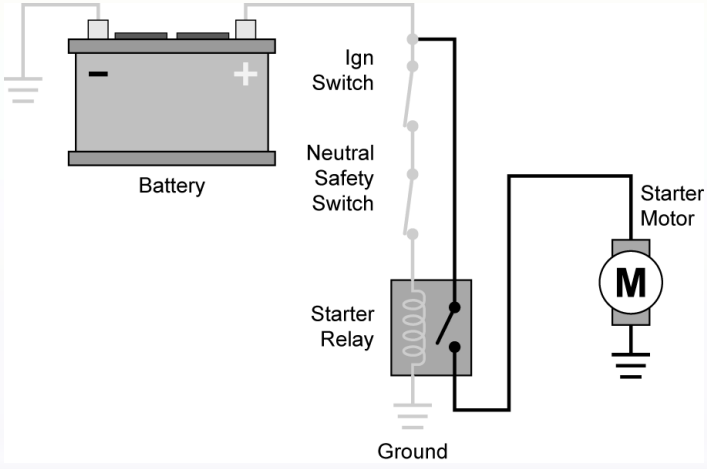
It’s 15° F outside. The truck was towed in for a no - crank and I want to get it into shop fast. No air to release brakes. It’s been sitting out there over night . I have no qualms in trying to tap the starter/solenoid with whatever will reach in there. If that doesn’t do it, I will do a little jumping at the solenoid to hopefully start it and get into the warm shop. I will make the same attempt on a no-start/no crank issue service call.

Low amperage side of a Starting System

- Typical “control” circuit.
  - Battery
  - Relay/ solenoid
  - Ignition switch
  - Clutch switch
  - Neutral safety switch and
  - Related wiring



High Amperage side



- Battery
- Relay/Solenoid
- Battery cables

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Let's put it all together

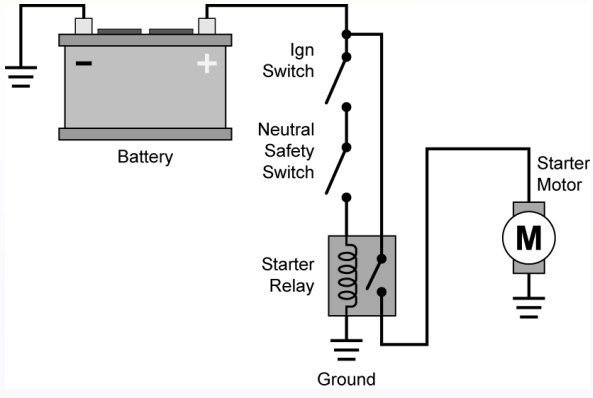
- Current flowing in the low amperage side energizes the relay or solenoid.
- This allows high current to flow from the battery through the cables to the starter.

➢ **TESTING:**

- Test for voltage at the relay/solenoid when the key is turned on.
- If battery voltage is present, you know that the ignition switch, cutch/neutral switch and related wiring are good.

Note: Any unwanted resistance in the switches or related wiring will prevent the relay/solenoid from engaging.

➢ **The high amperage side is best tested with Ammeter.**



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Starter Circuit Test Guide

RPM	Amps	Volts	Problem Area
Low	High	Low	- High mechanical resistance - Wrong viscosity oil - Binding engine - Defective starter - Carbon buildup
Low	Low	High	- High electrical resistance - Loose or corroded connections - Increased resistance in wires, cables, relay or pump
Low	High	Normal	- Defective starter/cable short
Low	High	Low	- Weak or undersized battery
High	Normal Low	Normal	- Low compression / Timing belt or chain

Note: This chart is a guide with problem areas dependent on the type of engine.

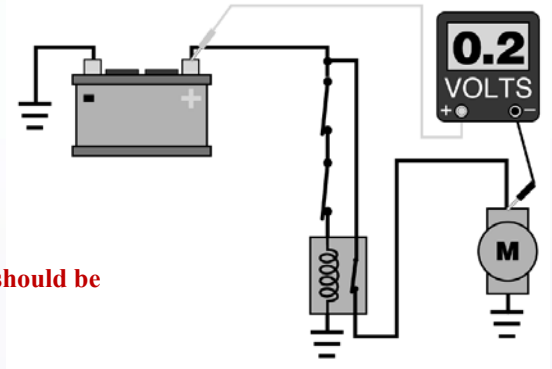
Amp testing

- Crank engine over for 15 seconds.
- Starter current should not exceed the maximum limit for the vehicle being tested.
- Cranking voltage should not go below 9.6 volts.
- Cranking speed should be normal.

Voltage Drop Test

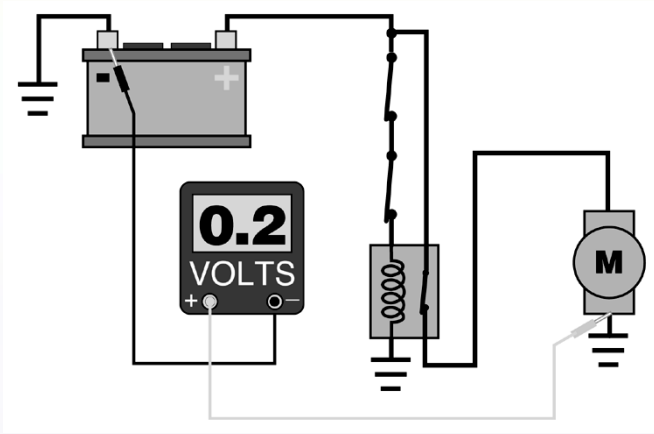
➢ Feed Side

- Check the entire feed side. A voltage drop of less than 0.5 volts shouldn't require any further testing on the feed side.
- More than 0.5 volts will require specific voltage drop tests on the positive side.
- Start at battery positive post and work your way down.



Note: These numbers are not cast in stone. But you should be close.

Don't forget the ground side



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The Charging System

- Charging systems came into existence to recharge the battery after being drained by the electric starter. Prior to that, a hand crank was used and an engine driven magneto.
- Each advancing technology such as light, wipers, heaters etc. increased the need for the charging System.
- Today's charging system is responsible for generating the electrical current needed for all the vehicles loads. Also perform its original function of recharging the battery.
- We have evolved trough two types of charging systems
  - DC generators and AC alternators
  - Purpose of both is to generate electrical current
  - The original DC generator was replaced by the AC alternator for better efficiency to generate electricity.
  - The term that still best describes the function is "Generator".

Pad Mount Alternator →

J- Mount Alternator →

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Producing Electricity

Production of electricity is best described by the rule of "Electromagnetic Induction"

- **Whenever an electrical conductor passes through a DC magnetic field, a voltage is induced into that conductor.**
- **Passing current through an electrical conductor creates a DC electromagnetic field.**

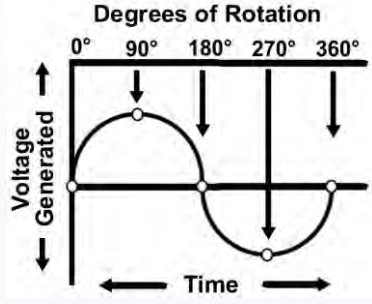
Note: The strength of the magnetic field can be increased with the addition of easily magnetized metals, increasing the windings in the field and the amount of current flowing through it.

Producing Electricity

- **In the alternator, the electromagnetic field is created by passing current through the rotating conductor (rotor).**
- **Stationary conductors (stator) have voltage induced into them as the rotor turns.**
- **Since the electromatic field is rotating, the voltage polarity reverses every 180°**

Rotor Stator

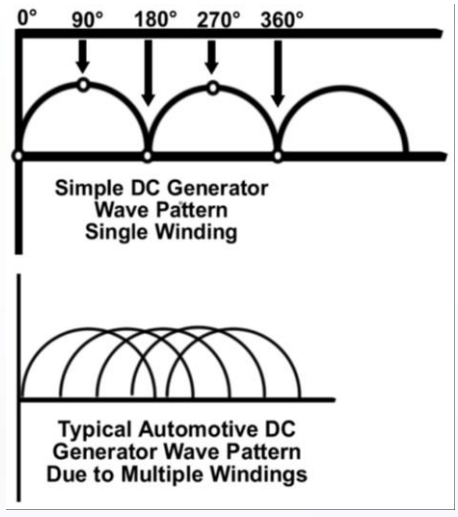
This AC voltage generated is not useful. The battery and loads require DC voltage.



Rectification

- Diodes are used to rectify (correct) the AC voltage produced.
- **Diodes are "one-way" current check valves.**
- They are connected to the stator in a manner as to form a bridge so current of incorrect polarity is blocked while still allowing it to cross over the circuit.
- Crossing results in correcting the polarity and let current pass.
- **Simply put, the negative portion of the AC produced is blocked and we now have DC current.**

Rectifier Bridge Heat sink

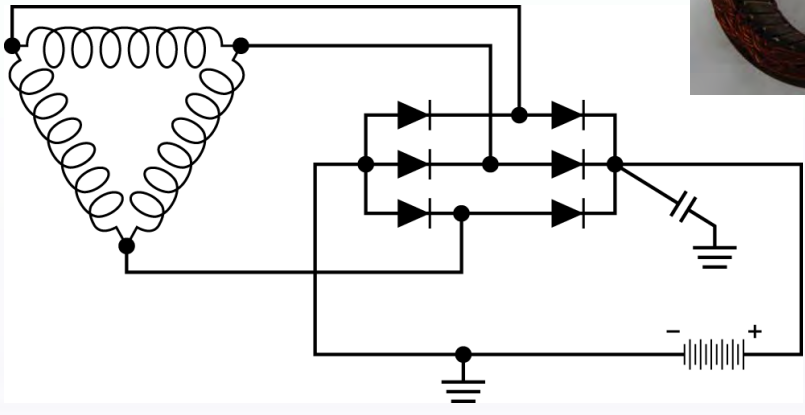


Three windings from Stator

Delta Winding

Current is generated in each coil individually.

Note: Another type used is WYE connection type.



Regulating Output

- When the charging system output exceeds the need of the electrical system, the voltage level increases.
- As the current requirements of the electrical system increases, the voltage level will fall.
- The voltage level can define the electrical system load (demand).
- That's why the voltage level is used as a reference to regulate the amount of current passing.

The voltage regulator is responsible for regulating current through the field control wire, modifying the strength of the rotating electromagnetic field (rotor), which translates into a modified current output.

Diagnostics

- Look for charging voltage level of approximately 13.8volts to 14.5 volts.
- Does the alternator designed output meet the requirement of all the loads.
- If the alternator is not capable of all the above. Where do you start?
- Absolutely start with the basics.
- A good visual inspection of cables, connectors, terminals (include the battery into this).
- Voltage drop on both feed and ground side.
- Don't forget a diode ripple test.
- How about AC running over DC. Note: maximum should be 500 mv.

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