CRAFTSMAN®

Professional Shop Manual

Electric Module
28906,28980, 28981, 28984

NOTE: These materials are for use by trained technicians who are experienced in the service and repair of outdoor power equipment of the kind described in this publication, and are not intended for use by untrained or inexperienced individuals. These materials are intended to provide supplemental information to assist the trained technician. Untrained or inexperienced individuals should seek the assistance of an experienced and trained professional. Read, understand, and follow all instructions and use common sense when working on power equipment. This includes the contents of the product's Operators Manual, supplied with the equipment. No liability can be accepted for any inaccuracies or omission in this publication, although care has been taken to make it as complete and accurate as possible at the time of publication. However, due to the variety of outdoor power equipment and continuing product changes that occur over time, updates will be made to these instructions from time to time. Therefore, it may be necessary to obtain the latest materials before servicing or repairing a product. The company reserves the right to make changes at any time to this publication without prior notice and without incurring an obligation to make such changes to previously published versions. Instructions, photographs and illustrations used in this publication are for reference use only and may not depict actual model and component parts.

MTD Products Inc. - Product Training and Education Department

FORM NUMBER -769-06468

09/2010

Table of Contents

INTRODUCTION

INTRODUCTION

This module is divided into four sections:

- **Section 1:** About this module and precautions
- **Section 2:** Components
  This section will describe the location and operation of the electrical components on the tractor. Where appropriate, some disassembly or component removal instructions will be included.
- **Section 3:** Diagnostic Techniques
  This section will cover basic tools, techniques, and methodology for diagnosing electrical issues on the tractor. A lot of the information in this section can be applied to other equipment.
- **Section 4:** Schematics

Professional Shop manual intent

This **Manual** is intended to provide service dealers with an introduction to the mechanical aspects of the new 900 series tractor.

- Detailed service information about the engine will be provided by the engine manufacturer, in most cases.

Disclaimer: This manual was written using first generation tractors. The information contained in this shop manual is correct at the time of writing. Both the product and the information about the product are subject to change without notice.

About the text format:

> **NOTE:** is used to point-out information that is relevant to the procedure, but does not fit as a step in the procedure.
>
> **CAUTION:** Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.
>
> **DANGER:** Indicates an imminently hazardous situation that, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
>
> **WARNING:** Indicates a potentially hazardous situation that, if not avoided, could result in death of serious injury.

- **Bullet points**: indicate sub-steps or points.

Disclaimer: This Professional Shop Manual is intended for use by trained, professional technicians.

- Common sense in operation and safety is assumed.
- In no event shall MTD be liable for poor text interpretation, or poor execution of the procedures described in the text.
- If the person using this manual is uncomfortable with any procedures they encounter, they should seek the help of a qualified technician.

Fasteners

- Most of the fasteners used on the tractor are sized in fractional inches. Some are metric. For this reason, wrench sizes are frequently identified in the text, and measurements are given in U.S. and metric scales.
- If a fastener has a locking feature that has worn, replace the fastener or apply a small amount of releasable threadlocking compound such as Loctite® 242 (blue).
- Some fasteners like cotter pins are single-use items that are not to be reused. Other fasteners such as lock washers, retaining rings, and internal cotter pins (hairpin clips) may be reused if they do not show signs of wear or damage. This manual leaves that decision to the judgement of the technician.

Assembly

Torque specifications may be noted in the part of the text that covers assembly, they may also be summarized in tables along with special instructions regarding locking or lubrication. Whichever method is more appropriate will be used. In many cases, both will be used so that the manual is handy as a quick-reference guide as well as a step-by-step procedure guide that does not require the user to hunt for information.

The level of assembly instructions provided will be determined by the complexity and of reassembly, and by the potential for unsafe conditions to arise from mistakes made in assembly.

Some instructions may refer to other parts of the manual for subsidiary procedures. This avoids repeating the same procedure two or three times in the manual.

Description of the GT series

This tractor platform introduced in the 2010 season. . See Figure 1.1.

Figure 1.1

- New stronger frame
- New hood and grill designs
- Bumper
- A new 2 blade 46" deck
- Tighter turning radius

Model and Serial Numbers

The model and serial number tag can be found under the seat. See Figure 1.2.

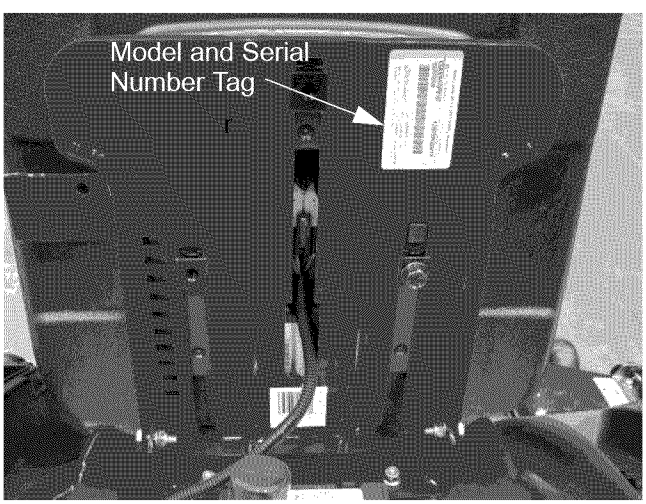


Figure 1.2

The serial number is located to the right of the model number as shown above. See Figure 1.2.

The model number is 13AR91PP099 The break down of what the number mean is as follows:

13.........................lawn tractor

...A.......................sales level

......R.....................engine code

........9...................tractor series

..........1................drive system

............P..............hood style

...............P...........deck

...................099....customer number

The serial number is 1J050H30003. The serial number reads as follows:

1...........................engineering level

..J.........................month of production (J = October)

.....05....................day of the month

.........0..................last digit of the year

...........H................plant it was built in

..............3.............assembly line number

.................0003.....number of unit built

Precautions

CAUTION: Before disconnecting any electrical component, take precautions to prevent the component or the wires attached to it from shorting out. The most effective means of doing this is to disconnect the battery ground cable from the negative battery terminal.

CAUTION: Unless performing tests that require the electrical system to be in operation, disconnect the negative cable from the battery before doing any work to the electrical system of the tractor.

ELECTRICAL SYSTEM

COMPONENTS

RMC Module

The RMC module contains electronic logic circuits. When diagnosing anything that is connected to the RMC module, a high impedance test light or a high impedance digital multi-meter (DMM) must be used. The amperage draw of a standard incandescent test light may over-burden some internal electronic circuits, burning-out the module.

- It is typical when industries shift from electro-mechanical to electronic controls that diagnosis shifts from tracing through a number of independent circuits to checking the in-puts to and out-puts from a central processor. This is similar to, but much less complex than the transition that the auto industry made with the conversion to fuel injection in the 1980s.

  NOTE: The starter safety circuit has no connection to the RMC module.

- The only one switch in the safety circuit that is capable of turning-off the engine works through the RMC module.
- It is still important to be familiar with the workings of the individual components of the electrical system, but some of them can now be checked from a central point on the tractor. This makes life easier on the technician, frequently making it unnecessary to connect to difficult to reach switches in the preliminary stages of trouble-shooting.
- The function of individual safety switches can be seen as providing information "inputs" to the RMC module.
- The next part of this section gives a detailed description of the electrical components on this tractor, their function in the system, and their physical location on the tractor. Armed with this information and the proper tools, a technician should be able to efficiently diagnose most electrical problems.

Key switch

The Key Switch is similar to those used in a variety of MTD applications since 1999. The difference in this case is that it is incorporated in the same housing as the RMC module; the two items are not available separately. See Figure 7.1.

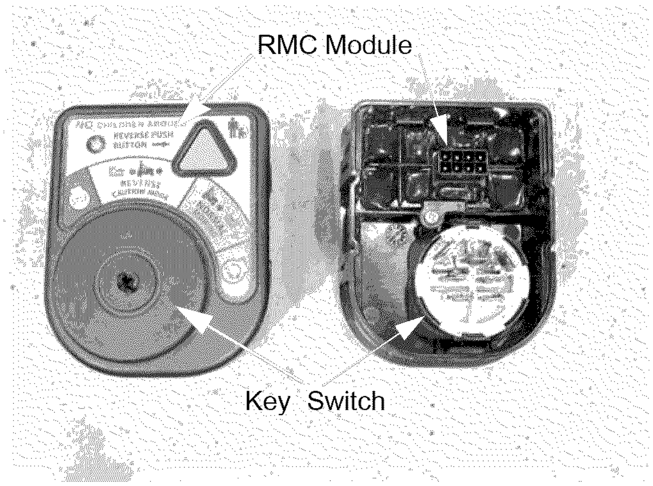


Figure 7.1

1. In the **OFF** position, continuity can be found between the M, G, and A1 terminals. See Figure 7.2.

Key Switch Schematic

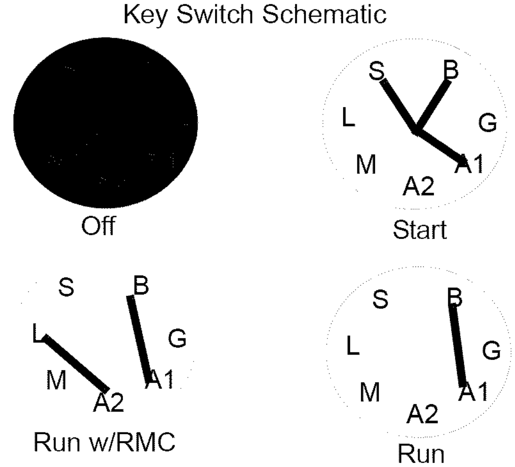


Figure 7.2

- M is connected to the magneto by a yellow wire, G is connected to ground by a green wire, and A1 is connected to the after fire solenoid.

  NOTE: In the **OFF** position, the magneto primary windings are grounded, disabling the ignition system. The altenator output is shorted to ground and the after fire solenoid looses its power from the B terminal. This turns-off the fuel supply.

- **Symptom**-engine runs with key in OFF position: The key switch is not completing the path to ground either because of an internal fault or a bad ground connection elsewhere in the harness. Check continuity between M, G, and A1 terminals with key switch in OFF position. Check green wire for continuity to ground.

- **Symptom**-loud "BANG" when key is turned to the OFF position: The after-fire solenoid is not closing, either because it is physically damaged or the power is not being turned off. Check for power at the solenoid. Check continuity between G and A1 terminals. Check for no continuity between A1 and the B terminals.

  NOTE: If the engine is at an idle when the key is turned off, fuel is drawn into the engine through the idle ports of the carburetor by-passing the fuel shut off solenoid. The raw fuel will travel through the engine and ignite in the muffler causing an after fire.

- **Symptom**-Engine runs 3-5 seconds after key is turned to OFF position: The after-fire solenoid is turning-off the fuel supply, but the ignition is continuing to operate. Check continuity between the M and G terminals in the OFF position. Check continuity from yellow wire connection all the way to the spade terminal on the magneto.

2. In the **START** position, continuity can be found between B, S, and A1 terminals.

- Battery power from the B terminal is directed to the start circuit through the S terminal and to the after fire solenoid through A1.

- **Symptom**-No crank and no starter solenoid click: Power is not getting to the trigger spade on the starter solenoid. Test for proper battery voltage. Then check for power where the fused red wire with white trace connects to the B terminal. Check for continuity between B and S terminals in START position. If power is getting to the S terminal in the START position, the problem lies down-stream in the starter circuit; Check continuity from the orange wire on the S terminal to the orange wire with white trace on the trigger spade on the starter solenoid. If it is broken, trace through the brake and PTO switches.

- **Symptom**-No crank, solenoid click: The problem lies in the heavy-gauge side of the starter circuit; battery cables, starter cable, solenoid, or ground issue.

- **Symptom**-Crank, spark, but not fuel: First test for power at the solenoid, if no power then check for continuity from B to A1 in the START position. If power is reaching the red wire that connects to the A1 terminal in the start position, the problem lies down-stream of the key switch. A handy quick-check is to apply power to the red wires where they connect to the S terminal (whole circuit) or directly to the after fire solenoid to listen for the audible "click" that it makes when functioning.

- **Symptom**-Crank, but no spark: This is a highly unlikely scenario. If it occurs after a key switch has been changed independently of the RMC module, this would arouse suspicion that the wrong key switch was installed. Otherwise, the problem lies elsewhere in the safety circuits or engine. Do not over-look the possibility of a bad magneto or chafed ground lead within the engine harness.

3. In the **NORMAL RUN** position (green zone), the B and A1 terminals should have continuity. Once the engine is running, the alternator produces current that tracks-back to charge the battery, via the red wire connected to the B terminal.

- **Symptom**-Battery does not charge: Follow the engine manufacturer's recommendations for testing alternator output. If alternator output is getting to and through the key switch, but not reaching the battery, the fuse may have blown after start-up. A blown fuse will disable the starter circuit. A simple quick-test for the presence of alternator output at the battery is to check across the battery posts for DC voltage.

- **Symptom**-After fire solenoid does not work: engine starts and dies: The after fire solenoid is powered directly by the red wire from the B terminal of the key switch, and should operate independently of anything else on the tractor once the engine is running. If the alternator fails *and* battery power is not reaching the after fire solenoid through the key switch, it will not work. This is an unusual set of circumstances.

4. In the **REVERSE CAUTION MODE** (yellow zone), the same characteristics are true as for the normal run position, but in addition the L terminal will have continuity with the A2 terminal. The A2 terminal is connected to the RMC module by a purple wire (electric PTO) or a white wire (manual PTO). The L terminal (formerly used for the lighting circuit) connects directly to the ground circuit of green wires. When the key is in the REVERSE CAUTION MODE position, the purple wire carries a ground signal to the RMC module. When the parking brake is not set, this ground signal arms (enables), *but does not turn-on* the RMC module.

- **Symptom**-RMC module will not turn-on: Check for continuity between A2 and L terminals on the key switch when it is in the REVERSE CAUTION MODE position. Confirm that the green wire has continuity to ground. If the switch is capable of establishing a ground signal to the RMC module, the problem is likely to lie elsewhere in the system.

- **Symptom**-RMC module will not turn-on: confirm that the ground path (continuity to ground) to the purple or white wire is broken when the key switch is in any position other than REVERSE CAUTION MODE. The RMC module is disarmed (disabled) when the parking brake is set. To re-arm the module, the key is moved to another position, breaking the ground signal, then returned to the REVERSE CAUTION MODE, re-establishing the ground signal. It works something like a latched relay. If it is not possible to break the ground-path, it is not possible to freshly establish it either, and the RMC module will not be armable. Causes for such a condition might include a shorted or incorrect key switch, or a chafed purple wire shorting to ground between the key switch and the RMC module.

RMC module

The RMC Module is in the same housing as the key switch, and is not available separately. For the purpose of diagnosis it is treated separately. Diagnosis of the module with the key switch introduces too many overlapping variables. See Figure 7.3.

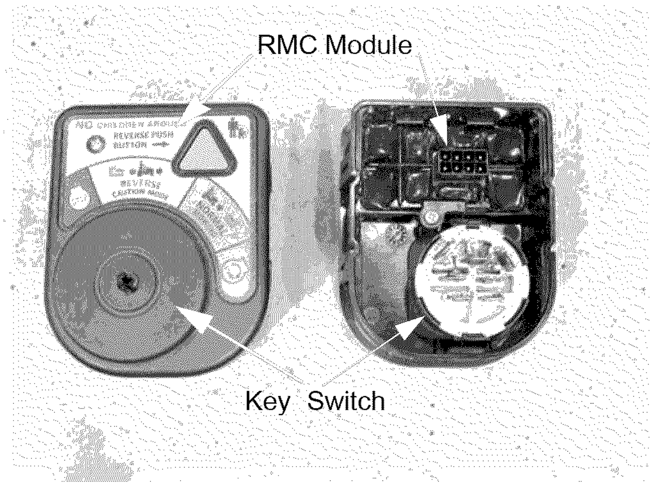


Figure 7.3

- **Principle**: To diagnose the module, the simplest approach is to check all of the inputs (safety circuits) that are connected to it. If the inputs work properly, but the RMC module does not work properly (outputs), then the module can be determined to be faulty. A specific procedure is covered, following the description of the correct operation of the RMC module.
- **Working properly**: The module cannot be diagnosed if it's function is not understood. It is designed to work as follows: See Figure 7.4.
- When the **RMC module is disarmed**, the tractor will operate as MTD tractors have historical operated:

If reverse is engaged when the electric PTO is ON, the PTO clutch will turn-off. On tractors with a manual PTO the engine will turn off.

If the operator leaves the seat with the engine running, the engine will turn off.

If the operator leaves the seat with the PTO in the OFF position, the engine will turn-off unless the brake is applied.

When the RMC module is armed, the tractor will operate identically to when the module is disarmed.

- When the **RMC module is armed and turned-on**: The tractor will operate identically to when the module is disarmed, except that the operator will be able to put the transmission in reverse with the PTO engaged and the cutting deck will continue to run The operator may put the tractor into and out of reverse as many times as they wish without having to re-arm or turn-on the module again.

1. **To arm the RMC module**: the operator must turn the key switch to the REVERSE CAUTION MODE (yellow zone), with the parking brake released. See Figure 7.4.

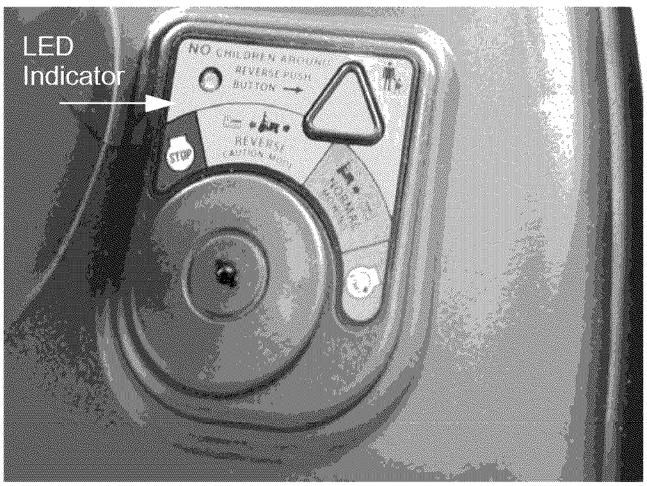


Figure 7.4

- **To turn the RMC module ON**: The module must first be armed, then the orange triangular button is depressed, illuminating the red LED indicator to indicate that it is ON. It is important that the operator must take two actions to turn the RMC module ON so that they do not do so inadvertently. See Figure 7.4.
- **The RMC module will turn-OFF and disarm if**:
    - The operator moves the key to any position other than REVERSE CAUTION MODE.
    - The operator sets the parking brake.
    - If the operator leaves the seat without setting the parking brake, the engine will turn-off. The key movement necessary to re-start the engine will make it necessary to re-arm and turn-on the RMC module if the operator wishes to continue with the ability put the tractor in reverse while the PTO is running.

2. **To re-arm and turn the module ON**:
If the key is in REVERSE CAUTION MODE position, it must be turned to another position (Normal Run), then returned to REVERSE CAUTION MODE. Once re-armed, the module can be turned-on by pressing orange triangular button. It will be confirmed that the module is ON by the illumination of the red LED on the module.

3. **To identify a faulty RMC module**: If the RMC module does not function as described, the **RMC plug test** should be the first step in diagnosis.

- If the RMC plug test confirms that the safety circuits (inputs) work as designed, yet the RMC module does not work properly, the RMC module is faulty.
- The RMC plug test will give an indication of what the problem is if it is not a faulty RMC module. If the problem is identified in a particular circuit, check the safety switch that is associated with that circuit. If the switch is good, then the problem lies within the wiring harness.

NOTE: Like the electronic components found on most cars, the RMC module requires a fully charged battery to work properly. If the system voltage falls below 12 V. an accurate diagnosis of the RMC module is impossible because the module will be temporarily disabled by low voltage.

RMC module plug test (electric PTO)

1. Disconnect the molded 8-pin plug from the RMC module. See Figure 7.5.

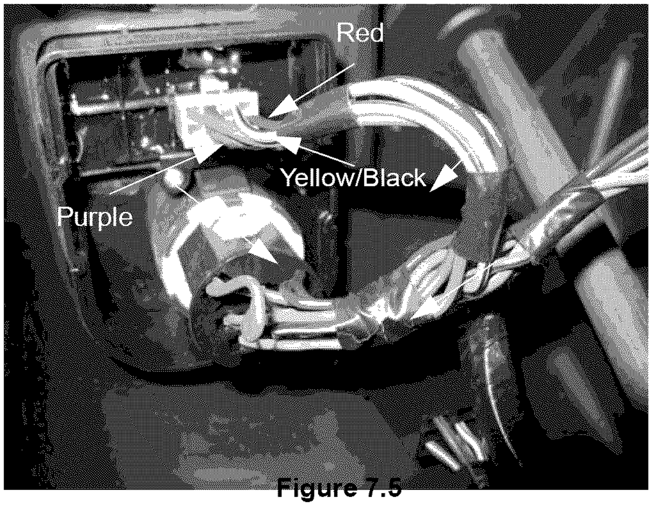


Figure 7.5

2. Looking at the plug head-on, it will be configured as shown in the diagram: There will be 8 female pin terminals. When probed they should yield the results described in the following sections. See Figure 7.6.

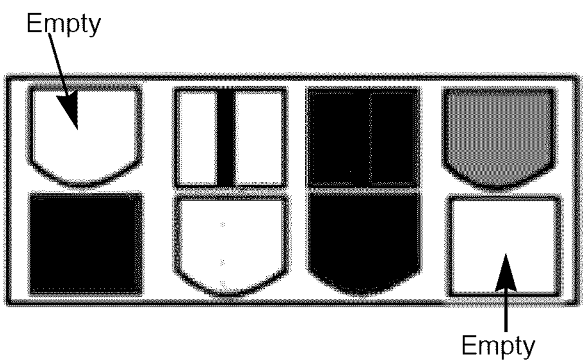


Figure 7.6

3. Top left middle square-shape: Yellow wire with Black trace:

- **Behavior**: Should show DC power with the key on.
- **Circuitry**: The yellow wire with black leads to the PTO switch and the PTO relay. It allow the RMC module to apply a ground to the coil of the PTO relay, which energizes the relay, severing the ground to the PTO clutch. When the PTO relay energizes it also applies a ground to the PTO switch. This ground loops back to the PTO relay's coil, latching it in the energized position.
- **Interpretation**: If behavior is correct, the N.C. side of the PTO switch /circuit is functioning properly

If there is continuity to ground, then there is a short to ground either between the PTO relay and the RMC module or in the PTO switch circuit.

4. Bottom left middle rounded-shape: Yellow wire

- **Behavior**: When the terminal is probed (yellow wire), there should be continuity to ground *only* when the seat is empty.
- **Circuitry**: The yellow wire leads to the seat safety switch, where it finds a path to ground when the seat is empty.
- **Interpretation**: If behavior is correct, the seat safety circuit is good. If there is continuity to ground when the seat is occupied, the switch may be inoperative, or there may be a short to ground in the wire leading to it. If there is not continuity to ground when the seat is empty, the switch may be inoperative or there may be an open condition in the wire leading to it.

5. Top right middle square-shape: There is a red wire with black trace between yellow wire with a black trace and the green wire. This wire provides the module with input from the **reverse switch.**

- **Behavior**: When the tractor is in reverse, this terminal should have continuity to ground.
- **Circuitry**: This wire runs directly to the reverse safety switch.
- **Interpretation**: Continuity to ground when the tractor is not in reverse would indicate a short to ground. This could take the form of a chafed wire contacting ground or a shorted reverse safety switch.

Lack of continuity to ground would indicate:

- A broken or disconnected wire leading to the reverse safety switch
- A switch that is not closing because of physical damage or corrosion.
- Loss of ground to the reverse switch.

6. Top right rounded-shape: is a green wire.

- **Behavior**: The green wire should always have continuity to **ground**.
- **Circuitry**: The green wire leads to ground.
- **Interpretation**: If this ground path is not good, there will probably be other ground-related issues with the tractor: slow starter motor, slow battery charge, dim lights. All ground connections should be mechanically secure and corrosion free.

7. Bottom left square-shape: The red wire on the OCR plug carries **battery voltage**.

- **Behavior**: With key switch in any of the run positions, D.C. battery voltage should show-up on a volt meter when the red probe is touched to this terminal and the black probe is grounded.
- **Circuitry**: This wire draws power from the A1 terminal on the key switch.
- **Interpretation**: If there is not battery voltage at this terminal, the tractor is probably not function at all. Look for a blown fuse or a bad key switch.

8. Bottom right middle rounded-shape: The purple wire provides a **ground signal** to the RMC module when the key switch is placed in the **REVERSE CAUTION MODE.**

- **Behavior**: There should be continuity to ground at this terminal when the key switch is in the REVERSE CAUTION MODE position.
- **Circuitry**: When the key switch is in the REVERSE CAUTION MODE position, a ground path is established by connecting terminal A2 to terminal L within the key switch. The purple wire from the RMC module connects to A2, and a green ground wire connects to L.
- **Interpretation**: If the purple wire fails to reach a ground path when the key switch is in the REVERSE CAUTION MODE position, the RMC module will not arm or operate. Check the key switch for continuity between A2 and L in the REVERSE CAUTION MODE position, confirm that the green wire connecting to the L terminal does have good continuity to ground, and check for any loss of continuity in the purple wire that extends from the key switch to the RMC module, including the molded connector between the two components.

9. If the RMC plug test indicates fault with any of the safety switches, the next step is to test the suspect switch. The operation of those switches is described in the following sections.

RMC module plug test (manual PTO)

1. Disconnect the molded 8-pin plug from the RMC module. See Figure 7.7.

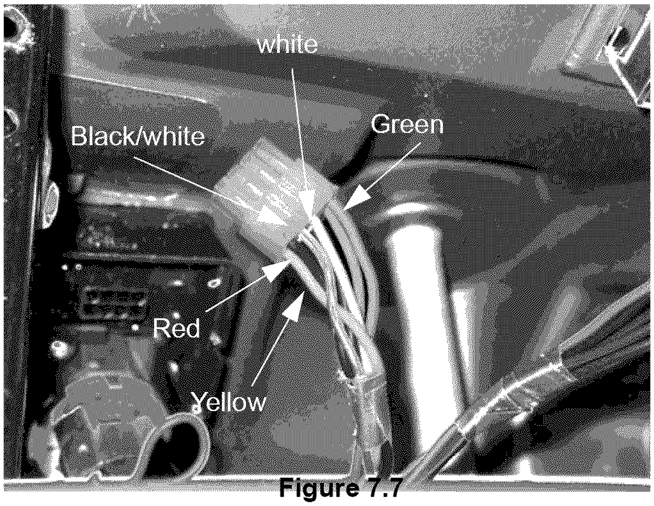


Figure 7.7

2. Looking at the plug head-on, it will be configured as shown in the diagram: There will be 8 female pin terminals. When probed they should yield the results described in the following sections.
See Figure 7.8.

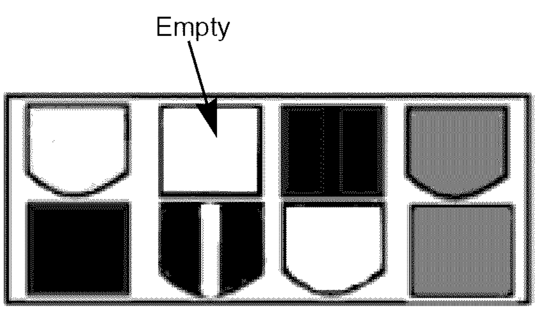


Figure 7.8

3. Top left rounded-shape: Yellow wire

- **Behavior**: When the terminal is probed (yellow wire), there should be continuity to ground when the seat is empty.
- **Circuitry**: The yellow wire leads to the seat safety switch, where it finds a path to ground when the seat is empty.

  NOTE: The yellow wire also branches off to the PTO switch. If the PTO is "on" and the key switch is turned to the "off" position, the yellow wire will get a ground through the key switch.
- **Interpretation**: If behavior is correct, the seat safety circuit is good. If there is continuity to ground when the seat is occupied, the switch may be inoperative, the PTO is on while the key switch is off or there may be a short to ground in the wire leading to it. If there is not continuity to ground when the seat is empty, the switch may be inoperative or there may be an open condition in the wire leading to it.

4. Top right middle square-shape: There is a red wire with black trace between yellow wire and the green wire. This wire provides the module with input from the **reverse switch.**

- **Behavior**: When the tractor is in reverse, this terminal should have continuity to ground.
- **Circuitry**: This wire runs directly to the reverse safety switch.
- **Interpretation**: Continuity to ground when the tractor is not in reverse would indicate a short to ground. This could take the form of a chafed wire contacting ground or a shorted reverse safety switch.

Lack of continuity to ground would indicate:

- A broken or disconnected wire leading to the reverse safety switch
- A switch that is not closing because of physical damage or corrosion.
- Loss of ground to the reverse switch.

5. Top right rounded-shape and the bottom right square shape: are green wires.

- **Behavior**: The green wires should always have continuity to **ground**.
- **Circuitry**: The green wires leads to ground.

- **Interpretation**: If this ground path is not good, there will probably be other ground-related issues with the tractor: slow starter motor, slow battery charge, dim lights. All ground connections should be mechanically secure and corrosion free.

6. Bottom left square-shape: The red wire on the OCR plug carries **battery voltage**.

- **Behavior**: With key switch in any of the run positions, D.C. battery voltage should show-up on a volt meter when the red probe is touched to this terminal and the black probe is grounded.
- **Circuitry**: This wire draws power from the A1 terminal on the key switch.
- **Interpretation**: If there is not battery voltage at this terminal, the tractor is probably not functional at all. Look for a blown fuse or a bad key switch.

7. Bottom left middle square-shape: There is a black wire with a white trace between the red wire and the white wire. This wire provides the module with input from the **park brake switch.**

- **Behavior**: When the brake pedal is depressed and the park brake is set, a ground path is established through the black wire with a white trace..
- **Circuitry**: This wire runs to the brake switch, then on to the park brake switch..
- **Interpretation**: Continuity to ground when the park brake is not set would indicate a short to ground. This could take the form of a chafed wire contacting ground or a shorted reverse safety switch.

Lack of continuity to ground would indicate:

- A broken or disconnected wire leading to the brake or park brake switches
- A switch that is not closing because of physical damage or corrosion.
- Loss of ground to the park brake switch.

8. Bottom right middle rounded-shape: The white wire provides a **ground signal** to the RMC module when the key switch is placed in the **REVERSE CAUTION MODE.**

- **Behavior**: There should be continuity to ground at this terminal when the key switch is in the REVERSE CAUTION MODE position.
- **Circuitry**: When the key switch is in the REVERSE CAUTION MODE position, a ground path is established by connecting terminal A2 to terminal L within the key switch. The white wire from the RMC module connects to A2, and a green ground wire connects to L.
- **Interpretation**: If the white wire fails to reach a ground path when the key switch is in the REVERSE CAUTION MODE position, the RMC module will not arm or operate. Check the key switch for continuity between A2 and L in the REVERSE CAUTION MODE position, confirm that the green wire connecting to the L terminal does have good continuity to ground, and check for any loss of continuity in the white wire that extends from the key switch to the RMC module, including the molded connector between the two components.

9. If the RMC plug test indicates fault with any of the safety switches, the next step is to test the suspect switch. The operation of those switches is described in the following sections.

Electric PTO switch

Understanding the electric PTO switch

- In A-Com, power is supplied to the PTO switch from the A1 terminal of the ignition switch through a red wire. when the PTO switch is turned on this completes the circuit to allow power to go to the PTO clutch. It is a normally opened (NO) set of contacts.
- B-COM is in the safety shut-down circuit. It is a normally opened (NO) set of contacts. A circuit is completed from the NO terminal on the PTO relay through the white wire with black trace to the E-PTO terminal on the RMC module and the PTO relay coil through the yellow wire with black trace when the contacts are closed. This gives the RMC module the ability to turn-off the PTO clutch.
- C-COM is in the starter inhibit circuit. It is a normally closed (NC) set of contacts. When the PTO is OFF, and the contacts are closed, power coming from the brake switch (key switch in START, brakes ON) through the orange wire with black trace is passed on to the trigger terminal on the starter solenoid through the orange wire with white trace.

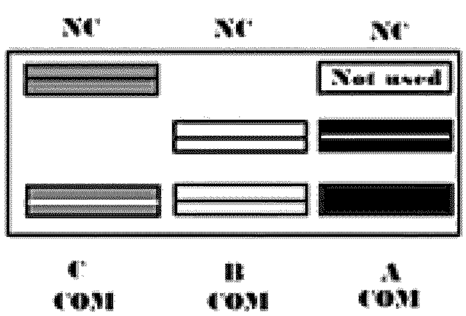


Figure 7.9

NOTE: The top terminals are showing normally closed at rest and the middle terminals are normally open at rest

NOTE: There are three contacts on the right side in the C-COM. For this application the normally opened (NO) contact is used.

PTO relay

The PTO relay is located on the main harness, underneath the electric PTO switch. See Figure 7.10.

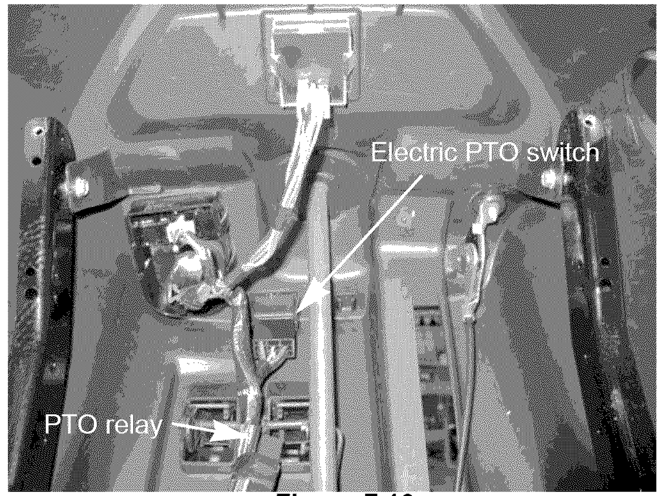


Figure 7.10

The PTO relay has 5 wire going to it:

- The red wire is battery power from the A1 terminal of the key switch. It is connected to the coil of the relay.
- The green wire is a ground wire. It is connected to the common terminal of the relay.
- The white wire connects the NC terminal of the relay to the ground side of the PTO clutch.
- The white wire with black trace connects the NO terminal of the relay to the "B" circuit terminals of the electric PTO switch.
- The yellow wire with black trace connects the coil of the relay to the "B" circuit terminals of the electric PTO switch.

To access the PTO relay, remove the fuel tank by following the step described in Chapter 2: Engine Related Parts.

NOTE: The PTO relay should be mounted so that the terminals face down. This helps to keep water out of the relay. The PTO relay connector can be filled with petroleum jelly before inserting the relay. This will also help to keep moisture out of the relay.

NOTE: Electrical tape that is wrapped tightly around the relay can prevent the relay from operating properly.

PTO switch (manual PTO)

- The manual PTO switch is mounted on the right side of the seat box section of the frame. See Figure 7.11.

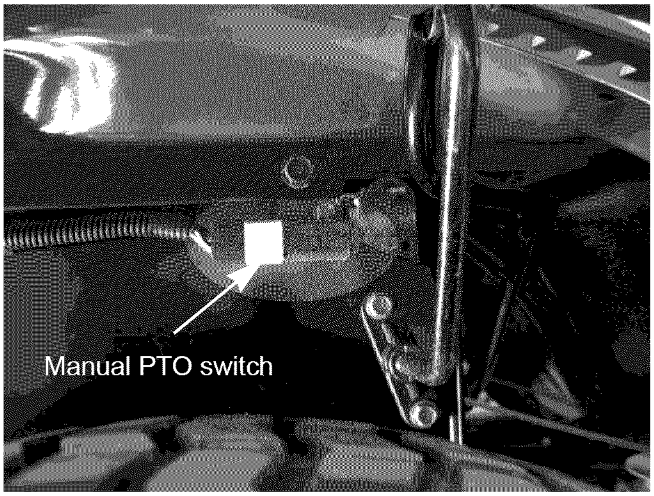


Figure 7.11

- The PTO switch plunger is depressed when the PTO lever is moved to the "off" position.
- The switch has two pair of contacts: one NO and one NC.
- The Orange wire with black trace connects to one of the NO terminals of the PTO switch. When the PTO is turned "off" the NO contacts close, completing a circuit from the brake switch to the starter solenoid through the orange wire with white trace.
- There are three yellow wires connected to the NC terminals.
  1. The yellow wire from the seat switch and the yellow wire from the RMC module are connected to the same terminal.
  2. The other yellow wire goes to the ignition module.
  3. If the seat is empty or an unsafe condition is sensed by the RMC module, a ground signal is sent to the PTO switch. If the PTO is "on" the ground signal will pass through the switch and go to the ignition module turning the engine off.

Brake switch (manual PTO)

- The brake switch is mounted on the top side of the frame, on the left side behind the dash.
- The brake switch used on manual PTO tractors is a triple pole single throw switch. It has one set of contacts that are normally closed (NC) and the other two sets are normally open (NO). See Figure 7.12.

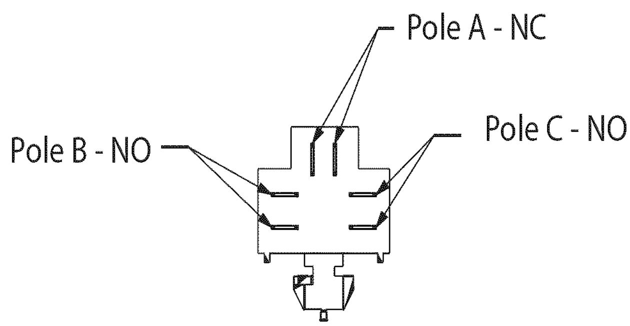


Figure 7.12

- The plunger on the switch is depressed when the clutch / brake pedal is pressed-down, de-clutching the drive belt and applying the brakes. The switch contains two sets of contacts.
- The normally closed (NC) set of contacts is in the safety shut-down circuit. If the seat is vacant the seat switch contacts will close connecting the yellow wire with white trace to ground. When the brake pedal is up, the contacts close connecting the ground signal in the yellow wire with white trace to the module through the yellow wire.
- A normally open (NO) set of contacts is in the starter inhibit circuit. When the clutch / brake pedal is depressed, the contacts are closed, power coming from the key switch (key switch in START) through the orange wire is passed on to the PTO switch through the orange wire with black trace.
- The other set of NO contacts receives the signal from the parking brake switch through the purple wire. When the brake pedal is down, the contacts close, sending that signal to the RMC module through the black wire with white trace.

To access the brake switch:

1. Remove the deck by following the steps described in Chapter 8: Cutting Decks and Lift Shaft.
2. Squeeze the tab on the underside of the brake switch with a pair of pliers, while pushing up on the brake switch. See Figure 7.13.

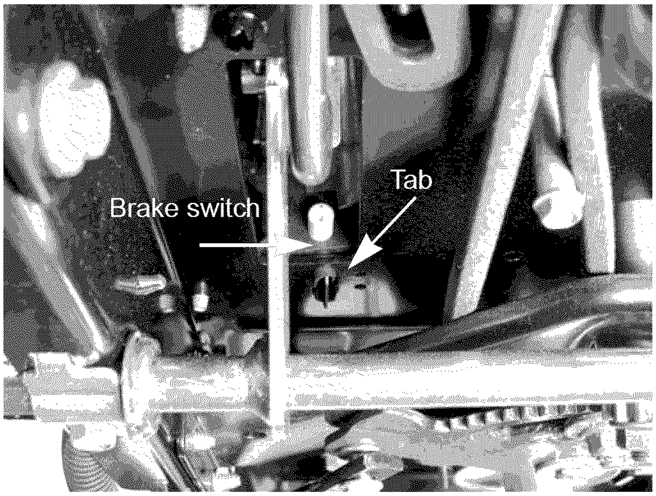


Figure 7.13

3. Reach in between the left side of the engine and the dash. Pull the switch and harness pigtail out as one piece. See Figure 7.14.

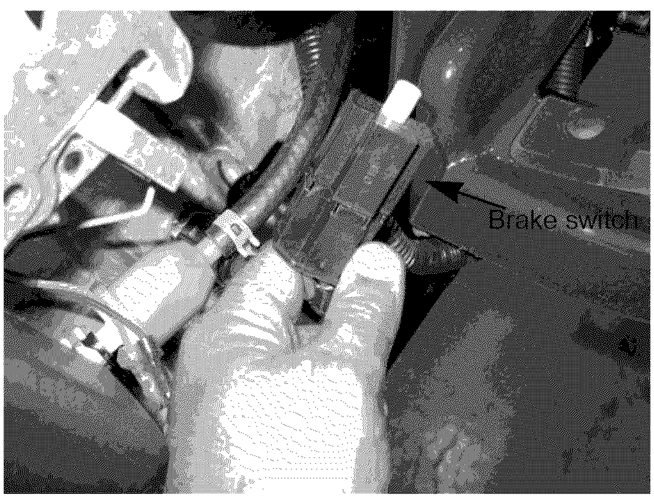


Figure 7.14

4. Install the brake switch by following the previous steps in reverse order.

Brake switch (electric PTO)

The brake switch is mounted on the top side of the frame, on the left side behind the dash.
See Figure 7.15.

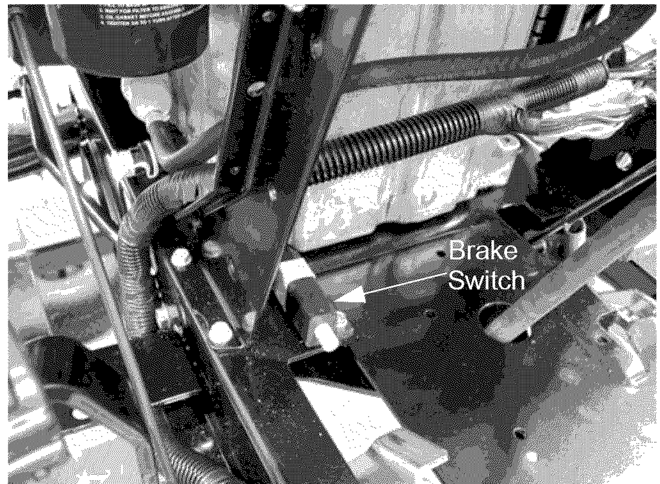


Figure 7.15

- The plunger on the switch is depressed when the clutch / brake pedal is pressed-down, de-clutching the drive belt and applying the brakes. The switch contains two sets of contacts.
- The brake switch is accessed by removing the fender and dash. The fender and dash can be removed by following the steps described in Chapter 4: Body/Chassis.
- A normally open (NO) set of contacts is in the starter inhibit circuit. When the clutch / brake pedal is depressed, the contacts are closed, power coming from the key switch (key switch in START) through the orange wire is passed on to the PTO switch through the orange wire with black trace.
- A normally closed (NC) set of contacts is in the safety shut-down circuit. A circuit is completed from the ignition module's primary windings to ground. The ground comes from the seat switch (if the seat is empty) through the yellow wire with black trace. If the brake pedal is up, that ground signal will pass through the brake switch to the ignition through the yellow wire.

Park brake switch

The park brake switch is only used on tractors that are equipped with a manual PTO. The park brake switch is a simple NO single pole single throw (SPST) switch.

The park brake switch is located on the frame, behind the dash on the right hand side. See Figure 7.16.

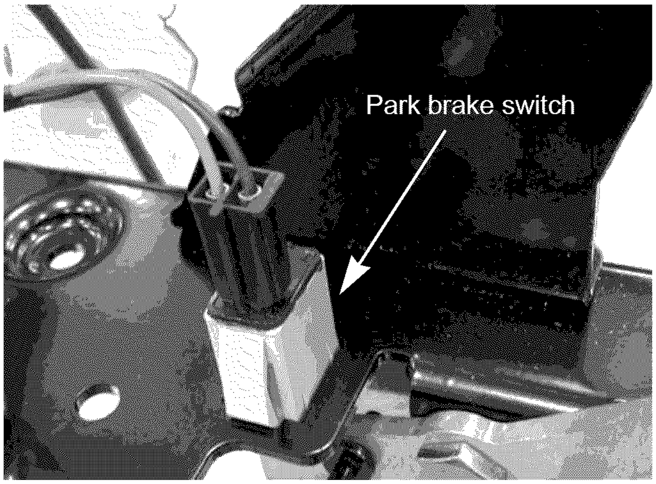


Figure 7.16

- The green wire is attached to ground.
- The purple wire is connected to the brake switch.
- If the brake pedal is depressed and the parking brake is set, a ground signal will pass from the park brake switch, through the brake switch to the RMC module.

Reverse Safety Switch

The Reverse Safety Switch is a simple metal contact tang switch.

CVT transmissions

Tractors that have the CVT transmissions have the reverse switch mounted on the left side of the frame, by the rear wheel. When the tractor is placed in reverse, the shift linkage will contact the switch providing a ground, See Figure 7.17. This switch has a red wire with black trace that goes directly to the RMC module. See Figure 7.17.

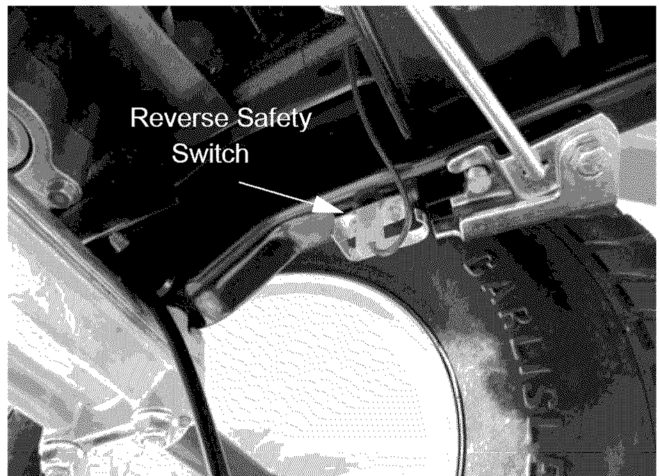


Figure 7.17

Hyrdostatic transmissions

Tractors equipped with a hydrostatic transmission have the reverse switch mounted on the transmission, next to the selector plate. See Figure 7.18.

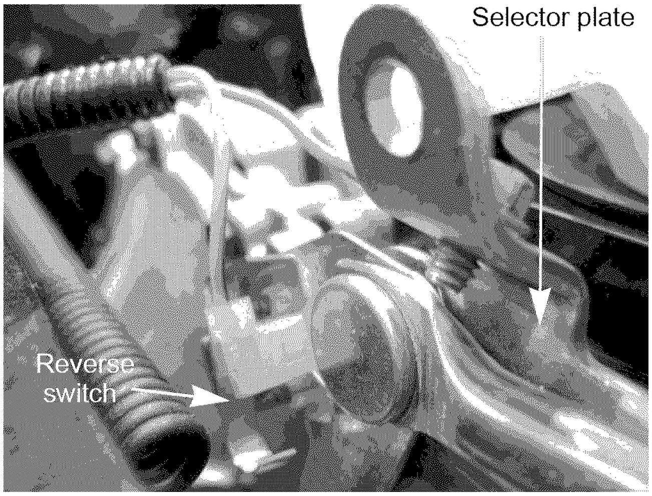


Figure 7.18

This switch has a yellow wire with black trace connected to it. The yellow wire with black trace plugs into the main harness by the starter solenoid and becomes the red wire with black trace that goes directly to the RMC module. See Figure 7.19.

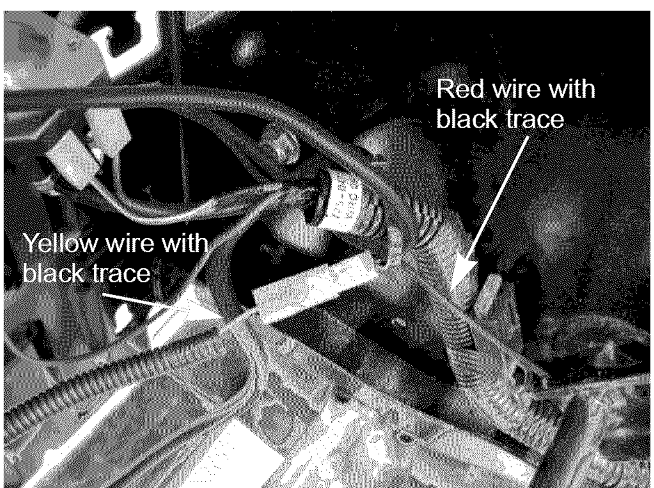


Figure 7.19

Seat Safety Switch

The Seat Safety Switch is a double pole single throw (DPST) switch. Both poles are normally closed and it is located inside the seat. See Figure 7.20.

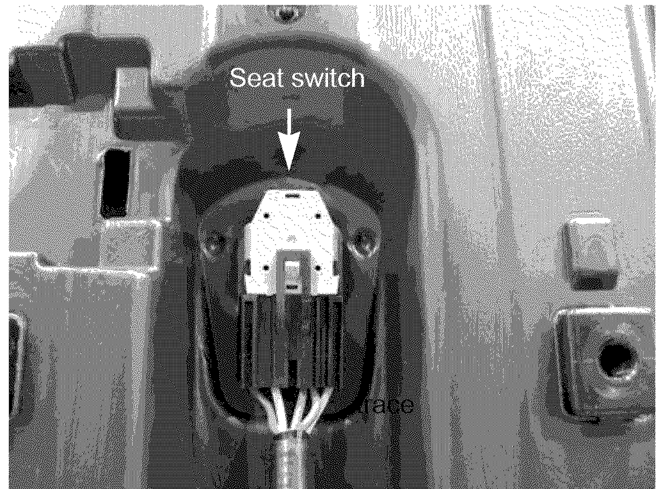


Figure 7.20

- The yellow wire with white trace is connected to the safety circuit. When the seat is vacant, the switch closes creating a ground path in series with the brake switch. If the brake is OFF and the seat is empty, the circuit is completed, shorting-out the primary windings of the ignition module, turning-off the engine.
- On tractors with an electric PTO, the yellow wire connected to the seat safety switch sends a ground signal to the RMC module when the seat is vacant.
- On tractors with a manual PTO, the yellow wire goes to the PTO switch. A yellow wire from the RMC module connects with the yellow wire from the seat switch at the PTO switch. The other side of the PTO switch is connected to the primary windings of the ignition module. If the seat is empty or the RMC module senses an unsafe condition while the PTO is on, a ground signal is sent to the ignition module, turning-off the engine.

Starter solenoid

The starter solenoid is mounted inside the seat box section of the frame. See Figure 7.21.

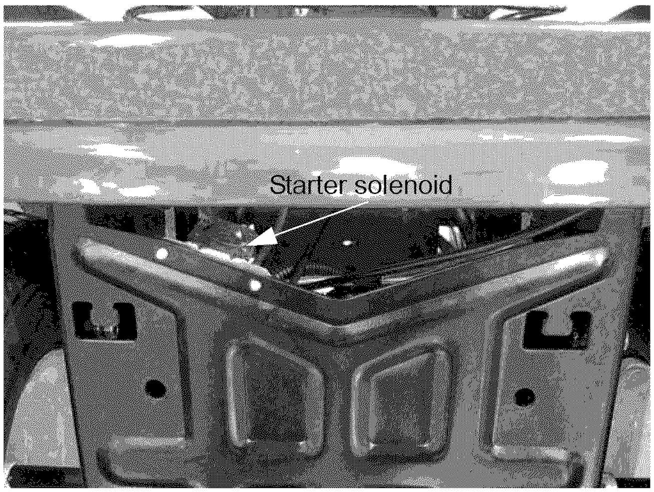


Figure 7.21

The starter solenoid can be accessed by removing the battery box and reaching through the opening.
See Figure 7.22.

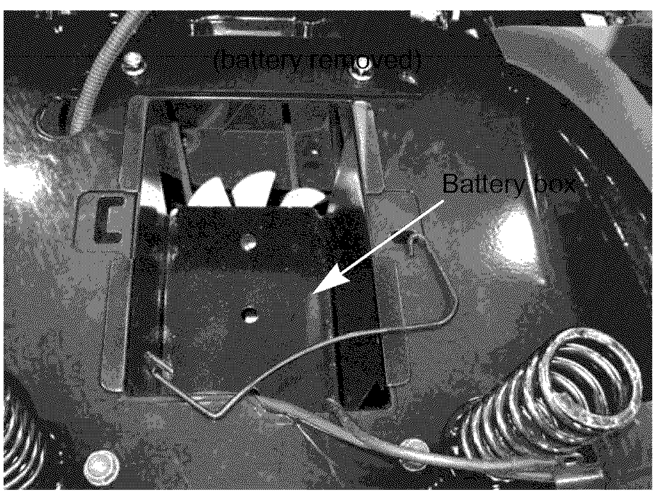


Figure 7.22

When the proper safety conditions are met, (brake applied, PTO OFF) the orange wire with white trace energizes the windings that magnetize an iron core, pulling the contacts closed between the two heavy posts, connecting battery power to the starter motor.

The green wire provide a ground for the coil inside the starter relay.

Lighting circuit

The lighting circuit is hot whenever the engine is running. It receives it's power from the A1 terminal of the key switch. See Figure 7.23.

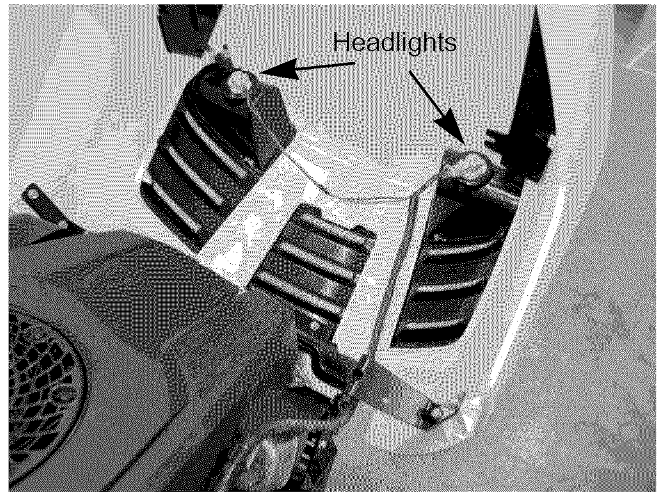


Figure 7.23

- The red wire carries battery power, the green wire is a ground.

Fuse

The 20A fuse is located inside the seat box section of the frame, on the left side near the deck lift shaft. See Figure 7.24.

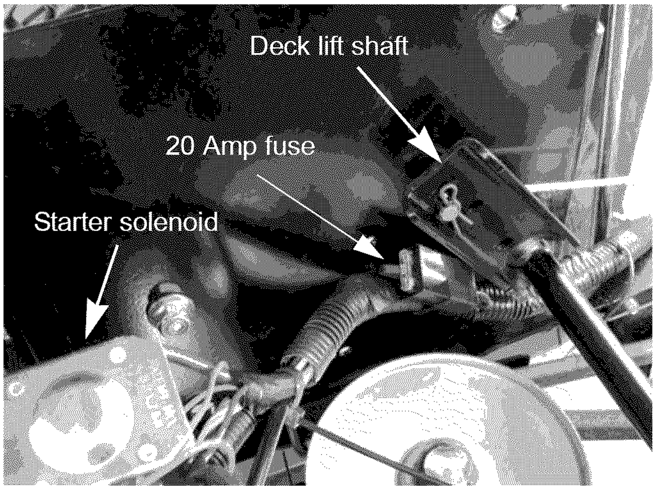


Figure 7.24

- The solid red wire feeds the fuse with power picked-up from the battery cable connection to the "hot" post of the starter solenoid.
- The red wire with white trace carries fused power to the B terminal on the key switch.
- A failed fuse will disable most of the tractor's electrical system.
- Remember that a failed fuse has done it's job of protecting the rest of the circuit from an overload. If a fuse blows, figure-out why and correct the core problem before returning the tractor to service.

ELECTRICAL DIAGNOSIS

NOTE: Electrical diagnostic procedures and tools are the same for all Cub Cadet and MTD tractors. This section is written in a way to provide basic trouble shooting skills that can be used on any tractor.

With a basic understanding of the behavior of electricity and the tools used to measure that behavior, a technician can be about 80% effective at finding electrical problems. 80% effective is not bad, but the remaining 20% of the diagnoses are the really difficult ones that can devour the same amount of time as the easy 80%. Experience plays a big part in successfully diagnosing the really difficult electrical problems. Experience leads to greater understanding.

Two German Physicists, working independently during the late 18th and early 19th centuries summarized what they had figured-out about electricity into some basic laws that can help a technician understand how a system works or why it does not work. Their names were Gustav Kirchhoff and Georg Ohm, and their laws are named for them.

There are basically three things that a technician is likely to test in trying to identify an electrical problem: Volts, Resistance, and Current. To help technicians understand the behavior of electricity, this section begins with an explanation of:

- Basic electrical values.
- Ohm's law.
- Kirchhoff's current law.
- Kirchhoff's voltage law.
- How the system is wired together.

NOTE: A graphic explanation of Kirchhoff's laws can be found at the following web site: http://online.cctt.org/physicslab/content/phyapb/lessonnotes/DCcircuits/lessonKirchoff.asp

The section then continues by explaining handy tools and techniques for diagnosing electrical problems on outdoor power equipment.

Electronics

The outdoor power equipment has historically had relatively simple electro-mechanical controls. Customer expectations and regulatory demands continue to drive change in the industry, while electronic controls have become relatively inexpensive.

In many cases, electronic controls can simplify a system that would otherwise be very complex. Instead of creating a huge mass of switches and relays that are tied together by spaghetti-like wiring harness, sensors (switches) in an electronic system send signals to a processor. These input signals are processed by a control module that produces outputs.

Outputs can include power to run an electric PTO clutch, a trigger signal to a starter solenoid, or the grounding of a magneto to turn-off an engine if an unsafe condition exists.

Most electronic devices are quite dependable, but they are vulnerable to things that simple electrical devices are not bothered by. Examples include:

- **EMI:** Electro-Magnetic Interference is created by electronic “noise”. This noise is created by ignition systems in general with non-resistor spark plugs being especially “noisy”. Alternators, and even power passing through wires can also generate EMI. Countermeasures against EMI include metal shielding (take a look at the ignition system on a fiberglass-bodied Corvette), and filtering devices built into vulnerable components. Something as simple as putting non-resistor spark plugs in a machine with electronic controls can disable the controls.
- **Voltage Spikes:** A dramatic increase in voltage will damage many electronic devices. Such spikes may be caused when jumper cables are disconnected or a voltage regulator fails. Some early automotive systems could even be damaged by personal discharge of static electricity. Most are better protected now.
- **Low Voltage:** Many electronic devices simply stop working if system voltage falls below a given threshold. If a 12 volt system is run at 11 volts with a failing alternator, electronic controls may stop working.
- **Bad Grounds:** Bad grounds can reduce the effective system voltage, create resistance and heat, and send false signals. This is the single most common breeding ground of electronic gremlins.
- **Heat and Vibration:** Heat and vibration are hard on most mechanical devices. The same is true of electronics.
- **Moisture:** Moisture causes a nasty combination of corrosion and shorts. Corroded connections and wires create resistance that results in low voltage and ground issue. Many electronic components are “potted” or encased in a sealant that protects them from moisture. They are still vulnerable to bad inputs caused by corroded external connections and damaged switches.
- **Improper Tools:** Some test lights can overload electronic circuits.

Electrical environment: AC Vs. DC

Most modern outdoor power equipment that has an electrical system complex enough to require diagnosis will be equipped with an alternator that produces alternating current (AC). In most systems, this current is immediately rectified to direct current (DC), and regulated to a nominal 12 Volts. The presence of AC is very limited. The primary concern of this section is 12 Volt DC systems, though much of the theory and techniques apply equally well to other DC systems.

1. **Voltage:** Pressure

- Voltage is the “pressure” that electricity has. It is the amount of force pushing electrons through a circuit.
- The unit of measurement for this pressure is volts.
- The capital letter “V” is used to represent volts.
- Most (not all) outdoor power equipment operates on a nominal 12 volts. In practice, system voltage may run as high as 13.5V or 14V.

2. **Amperes:** Flow

- Current is the “flow” of electricity. It is the amount of electrons flowing in circuit.
- The flow of current is measured in Amperes or Amps for short.
- The capital letter “I” is used to represent Amps.

3. **Ohms:** Resistance

- Resistance is the opposition to current flow. It is a restriction that slows down the flow of current.
- Resistance is measured in Ohm’s.
- The greek letter omega “W”, or the letter ”R” for Resistance is used to represent Ohm’s.
- Resistance creates heat. A circuit with too much electrical load, or too much resistance for the load placed on it will get hot.

4. **Ohm’s Law:** relates voltage, amperage, and resistance

- Ohm’s law states that voltage is the product of resistance times current.
- It is written as V = I x R.
- In simplest terms, it goes like this:
  It takes 1 volt to push 1 amp through a resistance of 1 ohm (1 = 1 x 1).
- This equation can be rearranged using algebra to solve for any one variable.
- Those who were traumatized by algebra can represent Ohm’s law as a triangle. When using the triangle, cover the value to be found, and the two values left exposed signify how to obtain that value. See Figure 7.25.

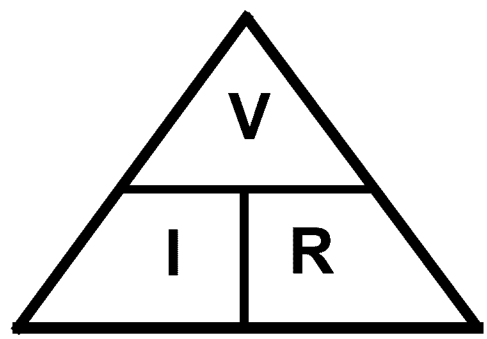


Figure 7.25

- As an example if the “R” is covered, the “V” is over the “I” which means “V” divided by ”I” will solve for the covered letter “R” (V/I = R). If the “V” is covered, “I” and “R” are exposed on the same line, meaning that the product of “I” times “R” will solve for the unknown “V” (I x R = V).

5. Kirchhoff's current law:

- Kirchhoff's current law deals with nodes. Nodes are the junction of two or more wires or the junction of a wire to a component.
- Kirchhoff's current law states that what ever current goes into a node must come out.
- As an example: Three wires are connected with a wire nut. One wire has 5 amps going into the connection.
- The sum of the currents coming out of the other two wires must equal 5 amps. That could be 3 amps in one wire and 2 amps in the other or it could be 2.5 amps in each wire, but the total coming out must be the same as the current going in. See Figure 7.26.

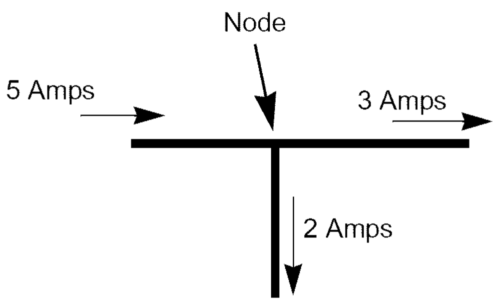


Figure 7.26

6. Kirchhoff's voltage law:

- Kirchhoff's voltage law deals with voltage drops. A voltage drop is the amount of voltage used up or "dropped" by resistance in a circuit. Ohm's law states that V = IxR, every component in a circuit has resistance, even the wires. To push current through resistance, it takes voltage. Kirchhoff's voltage law states that the sum of all the voltage drops equals the source voltage.
- As an example, imagine a circuit that has a 12V battery that produces 4 amps of current powering a light bulb that creates 3 W of resistance. The wires are assumed to have 0 W resistance*. The light bulb uses 12 volts (4 amps x 3 ohms = 12 volts). The battery produces 12 volts that equals the 12 volts used by the light bulb. See Figure 7.27.

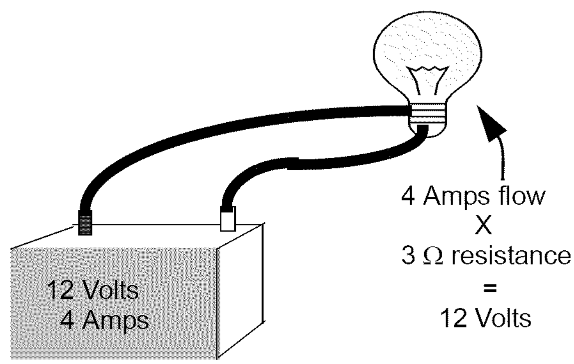


Figure 7.27

NOTE: * If the proper size wire is used and there is no corrosion in the wire, the resistance will be too small to worry about.

7. How the system is wired together

The Rules: All circuits have some basic rules that must be followed:

7a. All circuits must have at least one voltage source. It could be a battery, an altenator or both.

7b. All circuits must have a load. A circuit without a load is the same as shorting out the power source. Typical loads could be:

- lights
- a motor
- a solenoid

7c. All circuits must have a complete path back to the voltage source. This is also known as having continuity.

NOTE: On outdoor power equipment, the frame of the machine is frequently used as the return path to the battery. This is referred to as grounding the machine. Any point on the frame should be the same as the negative post of the battery (Electrically) unless there is a bad connection between the battery and the frame or between the frame and the component or cable that is assumed to be grounded to it.

7d. Most circuits have additional components like switches and fuses.

Types of circuits

There are three ways a circuit can be wired:

- Series
- Parallel
- Series/parallel

Series

- Series circuits are wired so that the current has only one path to follow. If one component in the system fails, the circuit will be broken and whole system will not work. See Figure 7.28.

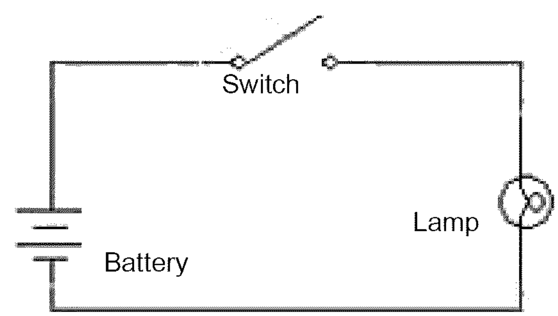


Figure 7.28

Parallel

- Parallel circuits are wired so that current has multiple paths to follow. If a component in one of the parallel paths fails, the rest of the circuit will keep working. See Figure 7.29.

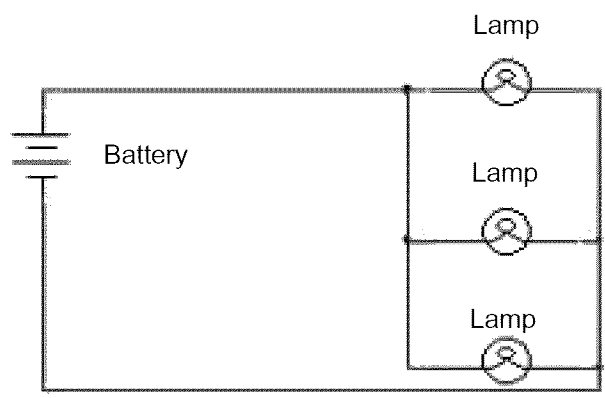


Figure 7.29

Series/parallel

- Series/parallel circuits have some sections wired in series and some in parallel. See Figure 7.30.

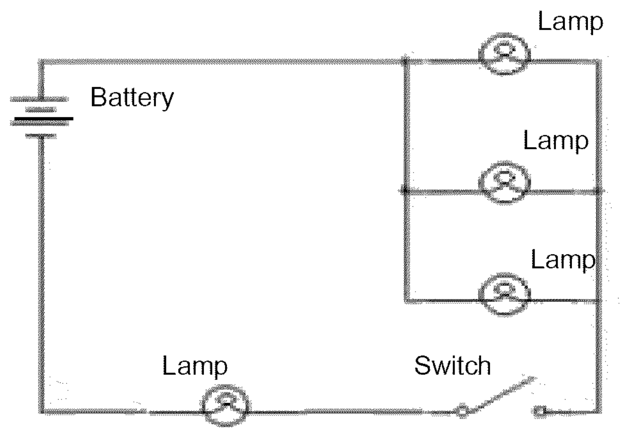


Figure 7.30

What can go wrong?

There are three types of failures that can occur in an electrical circuit:

1. Shorts
2. Opens
3. Increased resistance

Shorts

- A short is when electricity takes a path that it was not designed to take by-passing a component in the circuit.
- An common example of a short is a wire with insulation that chafed through, exposing the copper conductor. The bare copper will short the circuit when it touches a ground source.

Opens

- An open is when current can not complete its path back to the power source.
- A common example of this is a burned-out lamp (light bulb) in a series circuit.

Increased resistance

- Increased resistance is, as the name implies, an increase in resistance.
- Causes: This can be caused by loose or corroded connections, or connections that are insulated by grease, paint, or coatings. Fasteners finished in oil/phosphate or black oxide are bad conductors. Use bright fasteners (zinc coated).
- Resistance can be a problem on the ground side as well as the hot side of a system: remember that electricity must complete a loop (circuit) back the battery post. Any resistance in that loop will interfere with the flow.
- Arguably the most common electrical failure, and the hardest to find, increased resistance can have more subtle symptoms than outright open circuits. Many times effected circuits will still partially function. It is not an open because there is some current that can get through, but the increase in resistance is enough to affect the circuit.

The Tools

Equipment needed to diagnose an electrical system:

- DMM (Digital Multi-meter)
- Wiring schematic or diagram

Equipment that may be useful:

- Fused jumper wires.
- Test light (high impedance)
- Ammeter
- Battery charger
- Battery tester
- Battery jumper cables
- Hand tools to gain access to components.
- Flash light.

Digital Multi-meter

- A DMM is the most useful tool to trouble-shoot any electrical system. There is an amazing variety of DMMs on the market. Some are very basic, others are tailored to specific industries, and some high-end graphing meters function like oscilloscopes. Even the most basic ones are quite versatile. See Figure 7.31.

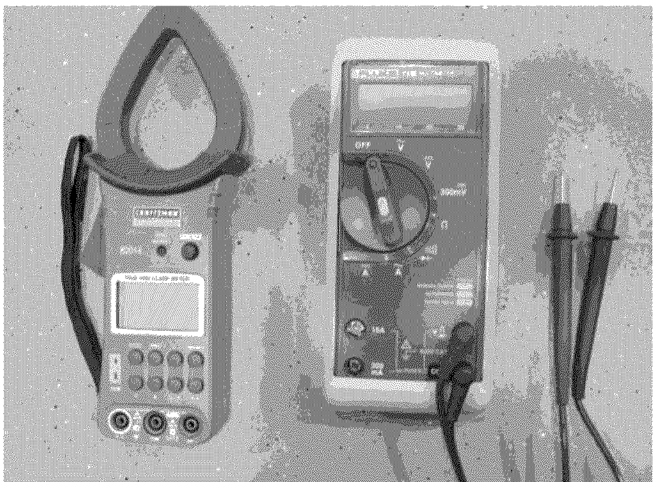


Figure 7.31

Uses:

Voltage: Set meter to read "Volts DC (_ _ _)" if using an auto-ranging meter or to an appropriate scale (typically 20 Volts DC) if using a more basic model.

- Connect the **meter in parallel** to the circuit being measured, between the test point and a known-good ground. Turn-on the circuit to be tested, and read the meter. For most tests the engine need not be running, but the key will be turned-on.
- If there is question about which end of the circuit the electricity is coming from, the circuit may be disconnected near the test point.
- If the meter is connected with the **polarity** reversed, a "-" will appear in front of the voltage reading. It has no ill effects on the meter nor on accuracy.
- If the meter is set to Volts AC (~) the reading will be much lower that expected, but no physical harm will be done to the meter nor the equipment being diagnosed. It may waste some time though.

Amperage: Most DMMs have a very limited capacity to test amperage (2-3 Amperes). When measuring current flow, the meter must be connected in series with the component to be measured. That means opening the circuit and having the circuit go through the meter.

- Some meters have an inductive "Amp clamp" accessory that can be used without breaking the circuit.
- Testing amperage beyond the capacity of the meter can burn-out an internal fuse in some meters. The fuses can be expensive.

Resistance: Set the meter for the "W" scale.

- Isolate the part of the circuit to be tested (disconnect it from the source of power).
- Ohms are read on a scale of 0 to 1, with "0" indicating no resistance and "1" indicating infinite resistance.
- Most auto-ranging meters will provide readings on several scales. For outdoor power equipment, the straight Ohm scale is most appropriate. If a letter appears next to the W on the screen of the DMM, it indicates different scales of sensitivity.

  "**m**" is micro-Ohms (.001 W), a more sensitive scale that effectively moves the decimal point three places to the left of its location for plain W

  "**K**" is Kilo-Ohms (1,000 W), a less sensitive scale that effectively moves the decimal point three places to the right of its location for plain W

  "**M**" is Meg-Ohms (1,000,000 W), is the least sensitive scale that effectively moves the decimal point six places to the right of its location for plain W

- A reading of "0" may be called "**Continuity**". A reading of "OL" may be referred to as "**No Continuity**".
- Mistaken Ohm readings most frequently come from bad technique. Poor connections between the probes and the point to be read can throw-off readings. False readings can be generated if the technician touches both probes with their fingers while taking the reading.
- The meter has it's own power source to measure resistance. Connecting the meter to a component that has current going through it will damage the meter (usually beyond repair).

Wiring diagram or schematic

- A wiring or a schematic diagram, and the ability to read it are very important in troubleshooting a circuit. The diagram shows how the circuit was designed and what paths the electricity is suppose to flow.

Fused jumper wires

- Fused jumper wires are handy to help find bad grounds or to jump across switches for testing purposes.

  CAUTION: Only use fused jumper wires. If there is a short in the circuit, using an unfused jump could damage components in the circuit.

Test lights (high impedance)

- Test lights are used as a quick way to verify voltage at a point in a circuit. Like DMMs, they come in a wide variety from many manufacturers.
- The most basic test lights simply use the current being checked to light an incandescent lamp. These should not be used on any equipment that has or may have solid-state circuitry. The power necessary to light the bulb is more than many solid-state circuits were designed to handle. Components will be destroyed in the process of testing them. See Figure 7.32.

  NOTE: Do not use a test light on a 900 series tractor. It can damage the RMC module.

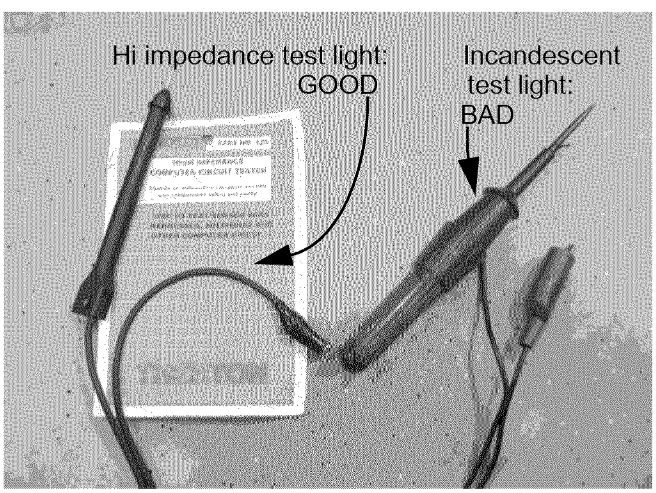


Figure 7.32

- If a test light is used at all, it should have "**high-impedance**", indicating that it only takes a sample of the electricity being tested, and illuminates an LED to indicate the presence of power.
- Some high impedance test lights are capable of indicating whether the current being sampled is AC or DC.

Battery Jumper Cables

- The obvious use: jumper cables can be used to jump-start equipment to get it into the shop. This is not recommended for any fuel injected Kohler-powered equipment.
- The clever use: If the technician suspects that there is resistance on the ground side of the system, a quick-and-dirty test can be made using jumper cables.
- Connect one cable clamp to the negative post of the battery, and connect the clamp at the other end of the same cable to the engine block.
- If there is an immediate difference in starter motor performance, use the voltage drop technique discussed later in this section to identify the source of the resistance.

Ammeters and specialized charging system testers

- Inductive ammeters are available in many forms. Some are as simple as a gauge to be held against the circuit in question when it is energized. See Figure 7.33.

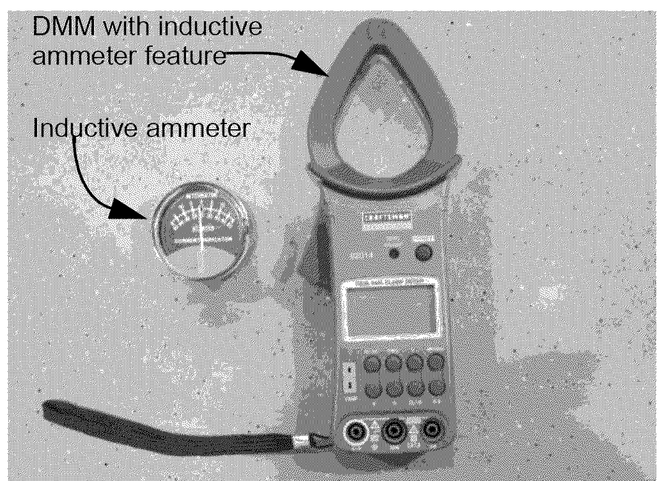


Figure 7.33

- There are two primary reasons to measure amperage:
  1. To check the out-put of a charging system or battery.
  2. To check the performance of a component that draws a substantial flow of power, typically a motor or clutch.
- Briggs and Stratton sells a DC Shunt that converts amperage into a reading on the millivolt scale of a DVOM. Briggs and Stratton part # 19359 covers low amperage systems, while part # 19468 tests higher amperage systems. See Figure 7.34.

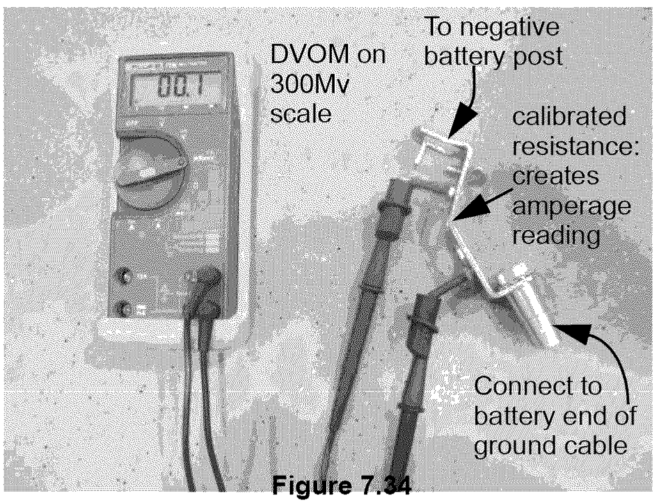


Figure 7.34

- Usage of the DC Shunt tool is detailed in the 1995 and 1999 editions of their Update Seminar materials.

  NOTE: The operating principle is based on Ohm's Law, as described earlier in this section.

- Kohler makes a proprietary Rectifier/Regulator tester (Kohler Part Number 25 761 20 and the up-dated version: 25 761 20-S). This tester works on Kohler regulator / rectifiers and the company claims it works on similar systems from other companies. See Figure 7.35.

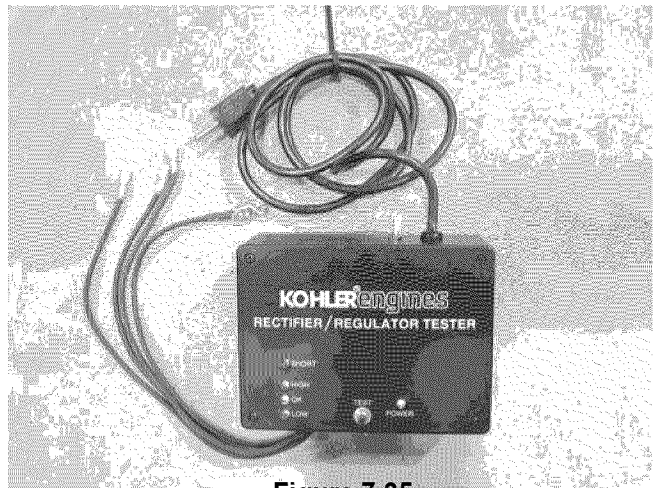


Figure 7.35

- Instructions are included with the Kohler tool (TT480-A)

Testing the charging system

Quick and dirty test: check voltage across the battery posts using a DMM set to read D.C. voltage with the engine turned-off. It will read battery voltage, typically around 12 V. Start the engine and repeat the voltage measurement. The system voltage should rise, reflecting the out-put of the charging system, typically in the range of 13.0 - 14.5 V. If the voltage does not rise, or rises significantly above this threshold, there is a problem with the charging system that needs to be identified using more in-depth techniques.

> **NOTE:** If system voltage is beyond roughly 15.7 volts, it is over-charging and there is a problem with the voltage regulator / rectifier.

To identify a specific charging system problem, isolate the components of the system and check their performance individually.

1. First check the raw AC. Voltage out-put from the stator. It will be necessary to compare it to the engine manufacturer's specified out-put. This varies from model to model.
   - 1a. With a DMM set to read AC Voltage, connect the probes between ground and one of the AC wires of the stator.
   - 1b. Leave the regulator-rectifier connected to the harness.
   - 1c. Start the engine and run it at the RPM specified by the engine manufacturer.
   - 1d. Read the voltage on the meter.
   - 1e. If the voltage is substantially low, try the other AC wire.
2. If raw out-put of the running alternator is less than the manufacturer's specifications, check the stator.
   - 2a. With the engine stopped, unplug the stator lead from the voltage regulator / rectifier.
   - 2b. Check the stator for resistance across the AC leads. The resistance should fall between the valves specified by the engine manufacturer. See Figure 7.36.

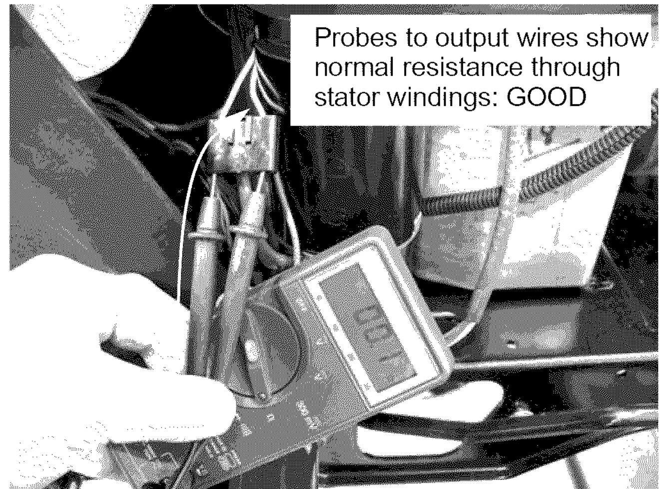


Figure 7.36

   - 2c. With the engine stopped and the stator lead unplugged from the voltage regulator / rectifier, check the resistance from each of the stator leads to ground (engine block).
   - 2d. The meter should indicate no continuity. See Figure 7.37.

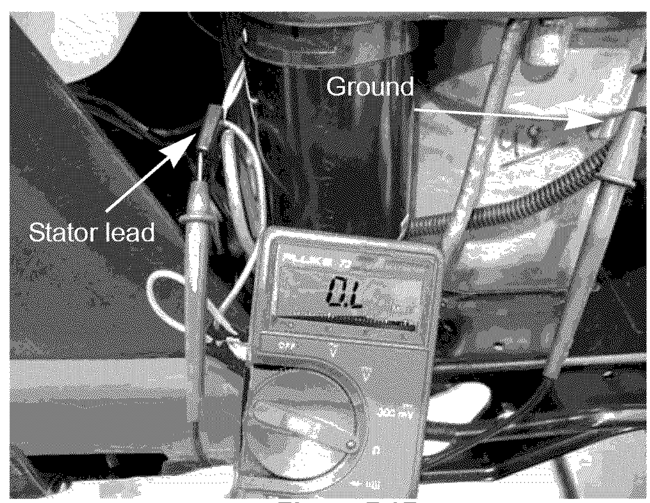


Figure 7.37

2e. Interpretation: If the ohm meter indicates no continuity between the two stator leads, there is a fault in the stator windings. If the ohm meter indicates continuity between either stator lead and ground, the stator windings are shorted to ground.

NOTE: If there is an intermittent charging system problem, perform these tests when the engine is cold, and again when the engine is hot.

NOTE: Low voltage readings may also result from poor test connections or low engine RPM.

3. If the stator is good, test the amperage out-put from the regulator / rectifier.

3a. Attach a DC shunt with DVOM or an ammeter capable of reading up to 25 amperes of DC current. The most accurate point to take a reading will be at the battery ground cable.

3b. The altenator should produce the rated current at the rated RPM under an electrical load.

3c. Connect a load tester between the battery terminals.

3d. With the engine running at the rated RPM, energize the load tester to draw amperage from the system.

3e. Read the amperage on the meter. See Figure 7.38.

Figure 7.38

NOTE: Output varies with load. A fixed-load battery tester can be used to apply enough load to test the charging system out-put.

Batteries

1. Precautions: See Figure 7.39.

CAUTION: Batteries produce flammable and explosive gases, particularly during charging:

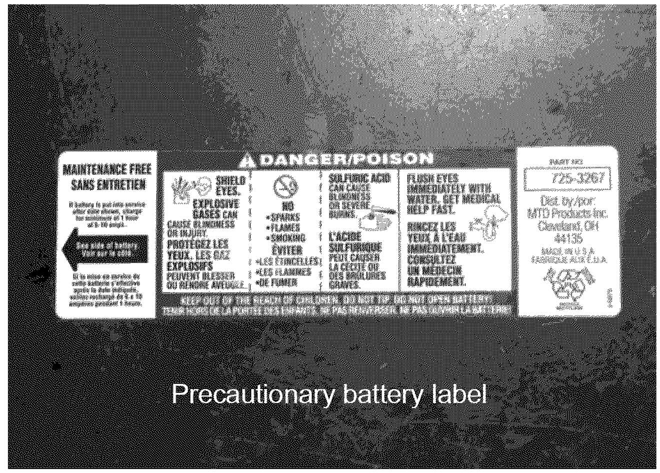


Figure 7.39

- Do not smoke or allow an open flame or heat source near the battery.
- Charge batteries in an open area
- Wear eye protection and acid resistant gloves when handling batteries.
- Do not allow direct metal contact across the posts. This will produce extreme heat that may cause direct burns or ignite flammable gas.

CAUTION: California Proposition 65 warning: Battery posts, terminals, and related accessories contain lead and lead compounds. These chemicals are known in the State of California to cause cancer and reproductive harm. Wash hands after handling.

NOTE: Some batteries used in Current Cub Cadet equipment are sealed. It is not possible to check, test or add fluid.

CAUTION: Batteries contain electrolyte, which is highly corrosive. If a battery is ruptured, neutralize the electrolyte with baking soda, then carefully rinse the effected area with water.

2. Importance of battery charge level and condition: A fully charged battery that is in good condition is an important factor when trying to diagnose other parts of an electrical system:

- Some charging systems do not work if the system voltage falls below 6V. It takes a certain amount of voltage to excite the fields in the alternator.
- Solid-state components will not work if the system voltage falls below a given threshold.
- Some solid-state components can be damaged by the jump-starting that accompanies operation with a dead battery.
- Many electric PTO clutches will fail to work dependably if battery needs to be replaced. Even though the charging system produces enough out-put to drive the clutch, it is overtaxed driving the clutch and forcing a charge into a damaged battery.
- Continued operation with a weak battery overtaxes the charging system.

3. Charging the battery:

   NOTE: It is best to remove batteries from equipment for charging to minimize corrosion from out-gassing during charging.

   CAUTION: When disconnecting or removing the battery, disconnect the ground cable first. When reconnecting or installing a battery, connect the ground cable last. These steps will minimize the chance of shorting-out the battery posts with a tool.

   3a. Batteries on most modern outdoor power equipment are 12 volts so set the charger to 12 volts.

   3b. Set the charge rate to 2 amps.

   CAUTION: Never charge an outdoor power equipment battery at a rate higher than 2 amps. Damage to the battery will result.

   CAUTION: Never attempt to charge or jump a frozen battery.

   3c. Charge the battery until it is fully charged. Most battery chargers have an amp gauge to show the charging rate. When the gauge is at zero, stop charging the battery.

4. Checking battery condition: There are three things to do when testing a battery:

- Visual inspection
- Electrolyte test
- Operational test

Visual inspection

- Inspect the battery and battery connections for corrosion. Clean if necessary. Neutralize acid with baking soda, and protect the terminals once they are cleaned.

  NOTE: Battery cable corrosion is the most common type of increased resistance circuit failures.

- Inspect the battery case for signs of damage and missing vent caps. Battery cases that bow out in the middle indicate that the battery froze or over heated and should be replaced.
- Check the electrolyte level if the caps can be removed. Fill as needed with distilled water. After initial charging, do not add electrolyte to the battery.

Electrolyte test

There are two ways to test a batteries electrolyte"

1. Electrolyte test using a Specific Gravity tester (hydrometer) to compare the density of the electrolyte in a fully charged battery to the density of water (water = 1.0 s.g.).

   1a. Hydrometer test (non-sealed batteries only) See Figure 7.40.

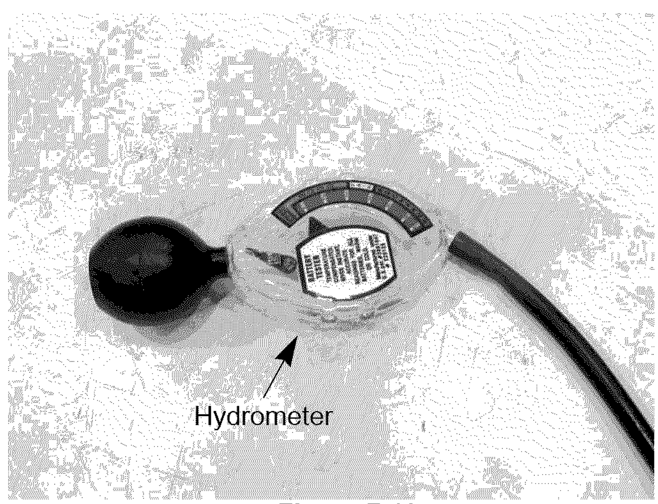


Figure 7.40

CAUTION: Always wear eye protection and acid resistant gloves when working with electrolyte. Use baking soda to neutralize any spilled acid.

1b. Give the battery at least ten minutes for the electrolyte to stabilize after charging the battery or adding water to the cells.

1c. Measure the temperature of the electrolyte in the middle cells of the battery.

1d. Squeeze the bulb on the hydrometer, then insert the hose into the cell.

1e. Release the bulb, drawing electrolyte into the hydrometer to the fill line.

IMPORTANT: Hold the hydrometer straight up and down when drawing up the electrolyte. The float needs to float free, not rubbing against the sides of the hydrometer.

1f. Write down the specific gravity of each cell.

1g. The readings must be corrected for the temperature of the electrolyte. The hydrometer manufacture should list the temperature the float is calibrated to. Most are calibrated to 80^o . To correct the reading, add .004 to the reading for every 10^o above the calibrated temperature or subtract .004 for every 10^o below the calibrated temperature.

1h. Compare the reading to the chart.

Specific Gravity	Charge Condition
1.265	Fully Charged
1.225	75% Charged
1.190	50% Charged
1.155	25% Charged
1.12	Fully Discharged

2. Electrolyte test using a Refractometer to check the density of the electrolyte by measuring the degree to which light waves bend when passing through the electrolyte.

IMPORTANT: To prevent damage to the charging system disconnect the battery to charge it.

NOTE: If battery needs to be charged, let battery sit for ten minutes to stabilize after charging. Apply a load to the battery for 15 seconds to remove the surface charge. Then re-check the battery.

Battery Testers:

There are two major ways to check a battery's operation :

- Load test that checks the out-put of the battery after the fully charged battery has done a certain amount of work. Fixed load testers are commonly available. Variable load testers are not generally found in outdoor power equipment repair shops, but are better for testing batteries.
- Capacitance test that checks the condition of the battery plate core, regardless of the level of charge.

Testing the battery:

1. Adjustable load testing

Adjustable load testing is used if an adjustable load tester is available. Follow the procedures specified by the manufacturer of the tester to connect to the battery.

1a. Disconnect the battery cables.

IMPORTANT: Disconnect the negative cable first to help prevent a shorting hazard.

1b. Measure the temperature of the electrolyte.

1c. Connect a voltmeter and the load tester to the appropriate terminals.

1d. Hook an amp probe onto the ground lead of the load tester.

NOTE: A shunt can be used in place of the amp probe, but a second voltmeter will be needed to get a measurement from the shunt.

1e. Apply a load equal to 50% of the battery's rated CCA for 15 seconds.

NOTE: CCA stands for cold cranking amps. The rating should be on the battery for aftermarket batteries. For OEM batteries, contact the manufacturer for the CCA rating. Most riding mower batteries are 200-275 CCA. See Figure 7.41.

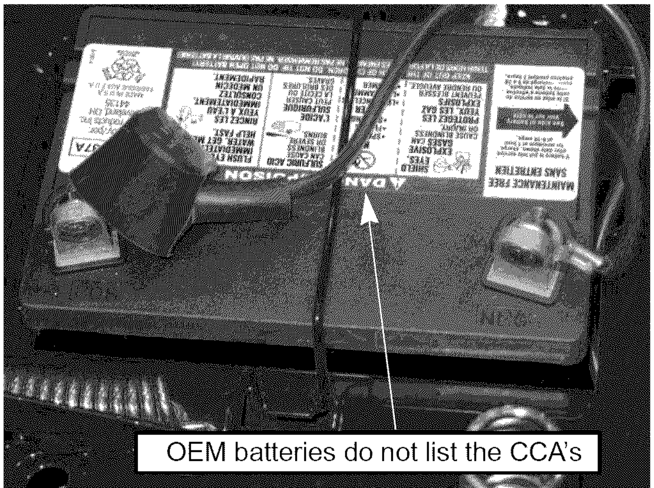


Figure 7.41

1f. Record the voltage while the load was applied. Compare the voltage to the following chart:

Electrolyte Temperature	Minimum Required Voltage
≥70 deg. f. (21deg. c.)	9.6 V
60 deg. f. (16 deg. c.)	9.5 V
50 deg. f. (10 deg. c.)	9.4 V
40 deg. f. (4 deg. c.)	9.3 V
30 deg. f. (-1 deg. c.)	9.1 V
20 deg. f. (-7 deg. c.)	8.9 V
10 deg. f. (-12 deg. c.)	8.7 V
0 deg. f. (-18 deg. c.)	8.5 V

1g. If the battery voltage is above what is listed in the chart, the battery is good. If the battery voltage is below what is listed in the chart, replace the battery.

2. Fixed load testing

Fixed load testers (sometimes called toasters) are inexpensive load testers found at any auto parts store. See Figure 7.42.

Figure 7.42

CAUTION: It is not recommended to use any fixed load tester on a battery under 200 CCA. To do so can boil the water out of the battery and damage the plates in the battery.

NOTE: Because they have a fixed load value, they do not give most batteries a reliable and safe load test. Most fixed load testers have a load that is more than 50% of the rated CCA of riding mower batteries. This makes them inappropriate to use on smaller pieces of outdoor power equipment.

2a. Disconnect the battery cables, ground first.

2b. Measure the temperature of the electrolyte in the middle cells.

2c. Connect a voltmeter and the load tester to the appropriate terminals.

2d. Apply the test load for 15 seconds. Monitor the meter on the load tester for the battery's performance.

2e. Refer to the manufacturer of the tester on how to read the test meter.

2f. The results of this test are not accurate and should only be relied on if the battery fails badly.

3. Capacitance testing

There are several brands of capacitance battery testers presently on the market. Capacitance battery testers use the battery being tested as their power source. These testers send a small AC signal through the battery to measure the capacity of the plate to hold a charge.

Capacitance testers are very easy to use and are far less damaging to the battery being tested. For these reasons, capacitance battery testing is the preferred method of battery testing.

NOTE: Contact the manufacturer of the tester being used for specific test procedures.

3a. Connect the tester to the battery.

3b. Set the tester to the CCA rating of the battery.

3c. Initiate the test.

3d. Read the display of the tester. The tester's display will indicate if the battery passed or not. See Figure 7.43.

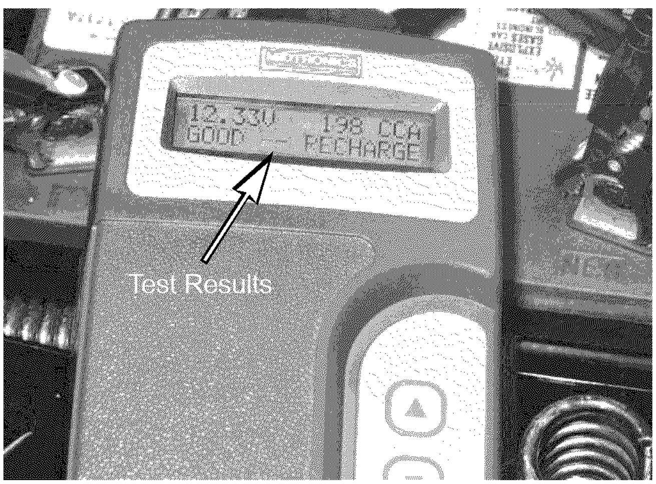


Figure 7.43

4. Battery discharge test

Occasionally a battery will discharge while sitting unused. To test for a battery that is "leaking" voltage:

4a. Confirm that operator technique is not creating a situation that causes a draw. As an example, if a homeowner habitually turns their equipment off using a safety switch (perhaps vacating the seat with the key switch still ON), that may leave a relay or fuel shut-off solenoid energized.

4b. Disconnect and charge the battery fully.

4c. Use the ammeter function of a DMM to check for a power draw between the negative post on the battery and the end of the ground cable that normally connects to it. There should be no significant D.C. Amperage flow. See Figure 7.44.

Figure 7.44

NOTE: A spark jumping from the post to the cable end is an indication that there is a substantial current draw, but should not be used repeatedly as a diagnostic tool. This is an extremely unkind thing to do to any electronic components of the tractor.

4d. Once the presence of a draw is confirmed, disconnect components of the system one at a time while monitoring an ammeter to see which makes the draw stop.

4e. If the battery is being checked independently of the equipment it powers, measure and note the battery voltage while it is disconnected, over a three-day period.

4f. There should be less than a .2 volt drop in the readings. If there is more than a .2 volt drop, the battery is bad.

5. Storage of batteries

5a. Always store a battery with a full charge (unless the battery is a dry battery and the electrolyte has not been added yet). This may require periodic re-charging.

5b. Take measures to prevent the battery from freezing in cold weather. The electrolyte in a fully charged battery has a lower freezing point than the electrolyte in a battery with a lower state of charge.

5c. Store the battery in a cool, dry place.

5d. If storing multiple batteries (primarily store stock), rotate the stock so that the oldest battery goes out first. This will increase the life of the batteries.

6. Troubleshooting

6a. The first step in troubleshooting is to always verify the complaint. Defining and verifying the problem reduces the possibility of misunderstanding and helps clarify the diagnostic approach.

6b. The next step is to check the simple stuff first:

- Check the **fuse** or fuses. Some models have ground side fuse. Failure of any fuse is an indication that there is a problem of some sort in the circuit that the fuse protects.
- Look for obvious physical damage.
- Use the hour meter and indicator lamps as a guide to direct the search. As an example, when diagnosing a "no-crank" condition on a lawn tractor with a PTO safety switch: if the PTO light is lit on the hour meter but the technician has visually verified that the PTO clutch is not engaged, the PTO circuit would be a reasonable place to check for problems.
- Check the battery. A valid diagnosis of many systems cannot be made without full system voltage applied.

6c. Take a methodical approach to finding the problem. As a rule of thumb, start at one end of the circuit and work to the other.

6d. The next step is to decide what method to use to troubleshoot the circuit.

- If checking a safety circuit that grounds the magneto, use an Ohms meter to test for continuity.
- If checking a safety circuit that enables a starter motor or accessory, us a volt meter to confirm the presence of power at each junction in the system.
- If a circuit does not work at all, look for a short or an open.
- If the circuit works slowly or intermittently, look for resistance by doing a voltage drop test.

NOTE: In all diagnosis, it is very important to understand the circuit that is being checked. The use of a schematic is recommended, even if a technician is thoroughly familiar with the system.

7. Testing for opens/shorts

NOTE: When checking circuits for continuity, disconnect the circuit at the nearest plugs and use the metal terminals of the plug as a connection point for the test probes. **DO NOT STAB THE WIRES.**

NOTE: When checking circuits for voltage, backprobe the terminals nearest the point to be checked. **DO NOT STAB THE WIRES.**
See Figure 7.45.

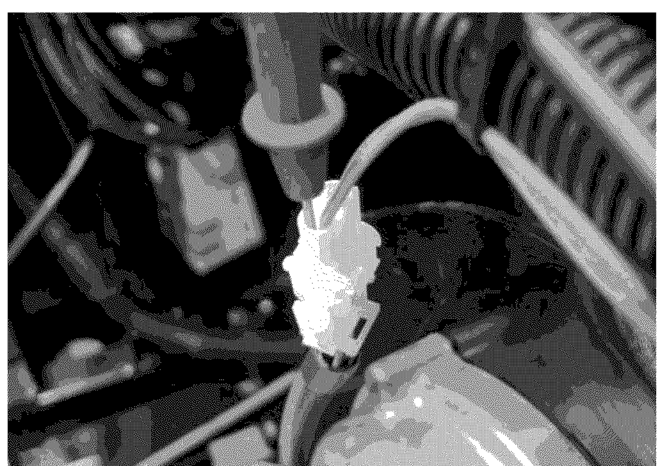


Figure 7.45

7a. Starting with a fully charged battery and battery cable connections that are clean and tight, measure the battery voltage. See Figure 7.46.

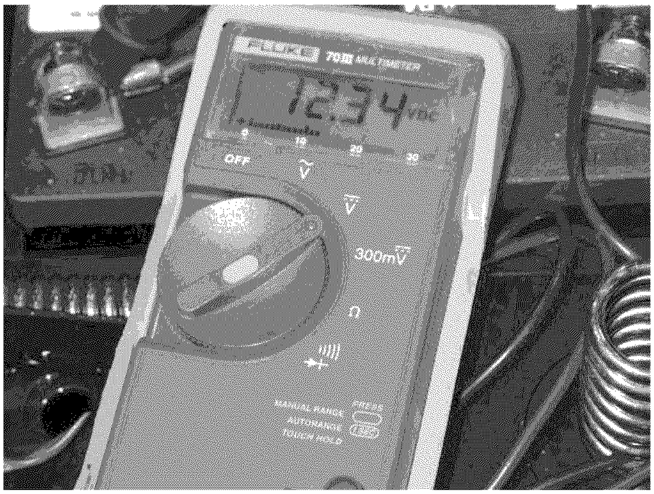


Figure 7.46

7b. With the circuit energized, start at either end of the circuit and check for voltage.

- If starting at the battery-end of a powered circuit, trace it through until power vanishes.
- If starting at the far end of a powered circuit, trace it through to the point that power appears.
- If there is low voltage at the far end of the circuit, do a voltage drop test (as described later in this section) on the circuit to find the source of resistance.

NOTE: When working toward the battery, check each junction with the connector disconnected, then re-check with the junction reconnected. If there is voltage with the connector unplugged but not when it is connected there is a short between that point and the last connector tested.

NOTE: When working toward the battery, if one junction has lost power, but the next connector has voltage with its junction still connected, there is an open between the two junctions.

8. Continue checking each connector until the other end of the circuit is reached or the fault is found.

Voltage Drop Test

To review:

- Ohm's law states that it takes voltage to push current through a resistance.
- Kirchhoff's voltage law states that the sum of all the voltage drops equals the source voltage.
- Combining those two laws, we see that any restriction in a circuit (e.g.: loose connector damaged wire, or corroded terminal) will use up some voltage as the current is pushed through.
- A voltage drop test is a way of looking for that voltage.
- Because electricity needs to complete a full circle (circuit), voltage drop tests are useful on both the positive or the negative side of the system.
- This text will address the negative side to begin with. Bad grounds are responsible for as many electrical failures as the positive side of the system, yet the ground side is frequently neglected by technicians. See Figure 7.47.

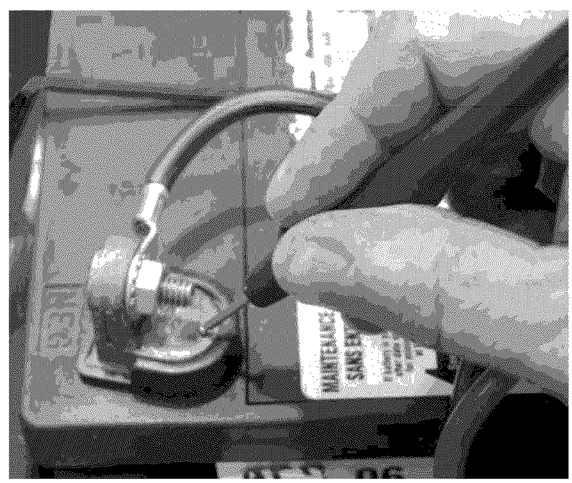


Figure 7.47

IMPORTANT: Ultimately, all current will find its way back to the negative post of the battery.

To check ground-side voltage drop: set-up a multimeter to measure 12V DC.

1. Make a good electrical connection between the black (-) probe and the negative post on the battery.
2. Make a good electrical connection between the red (+) probe and the suspect point of ground.
3. Power-up the circuit in question.

4. The voltage that shows-up on the meter is the voltage that is being used to pass current through a resistance in the circuit.

5. Voltage drop on a good circuit should be less than 0.1 volts. A voltage drop reading on the meter of greater than 0.2 volts indicates a fairly substantial problem that demands attention.

- As an example, if the starter solenoid does not engage properly, check for voltage drop between the ground point for the starter solenoid and the negative post on the battery. See Figure 7.48.

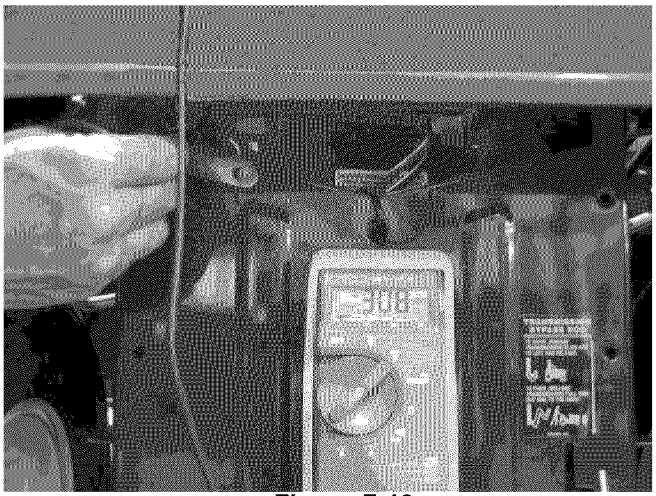


Figure 7.48

NOTE: With the starter engaged, this machine exhibited a voltage-drop reading of 0.308 volts, indicating a poor ground connection.

6. A similar ground-side test on a tractor with a slow-cranking starter motor can be conducted between the engine block and the negative battery post. See Figure 7.49.

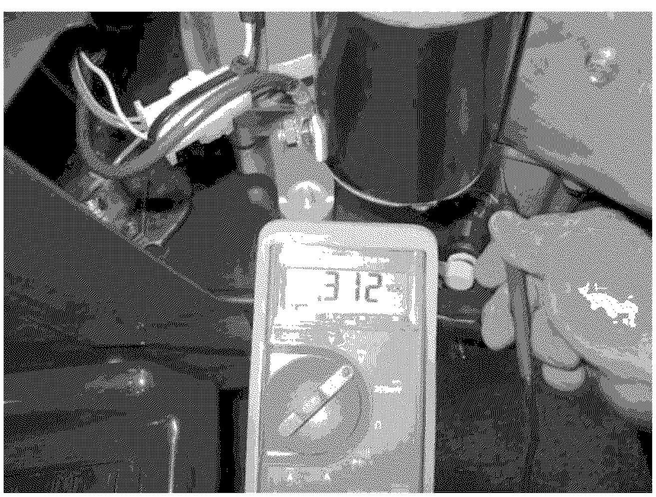


Figure 7.49

7. With the starter engaged, this machine exhibited a voltage-drop reading of 0.312 volts, indicating a poor ground connection.

8. Individually, these readings should lead a technician to inspect the connection between the solenoid and the ground path on the first tractor (e.g. mounting hardware, green wire with eyelet beneath head of solenoid mounting bolt), or the engine and the frame on the second tractor (e.g. loose or rusty engine mounting bolts).

9. If both of these readings were found on the same tractor, a common point in the system would be the primary suspect (e.g. poor connection between negative battery cable and frame).

10. Applying this principle to the positive side of the system. See Figure 7.50.

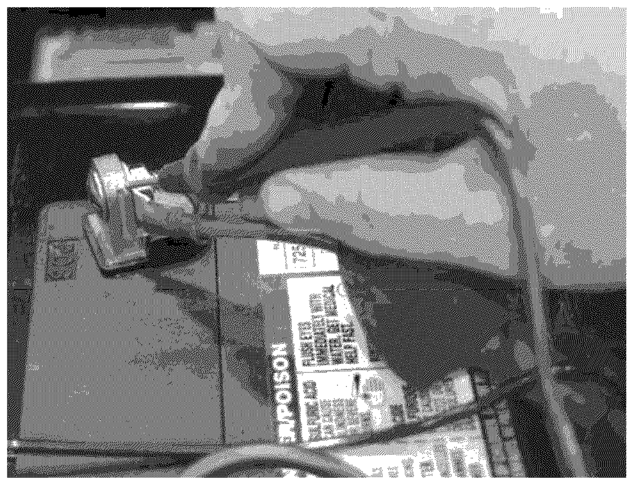


Figure 7.50

IMPORTANT: Ultimately, all positive current will find its way from the positive post of the battery to the negative post.

11. To check hot-side voltage drop: set-up a multi meter to measure 12V DC.

12. Make a good electrical connection between the red (+) probe and the positive post on the battery.

13. Make a good electrical connection between the black (-) probe and the suspect point of the circuit.

14. Power-up the circuit in question.

15. The voltage that shows-up on the meter is the power that is not following the intended path back to the negative battery post.

16. Voltage drop on a good circuit should be less than 0.1 volts. A voltage drop reading on the meter of greater than 0.2 volts indicates a fairly substantial problem that demands attention.

- As an example, if the tractor had a slow-turning starter, the ground-side voltage drop measured below 0.1 volts, and there was not a parasitic load on the engine (e.g. PTO clutch that is not fully disengaged), it would be logical for the technician to check voltage drop to the starter. See Figure 7.51.

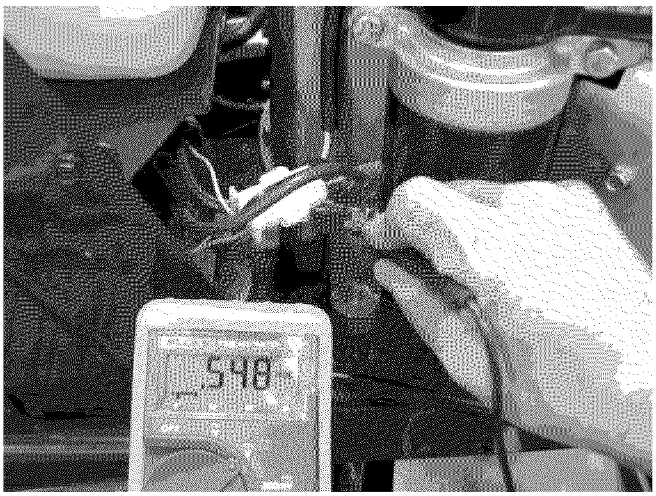


Figure 7.51

- With the starter motor engaged, the voltage drop reading here is nearly 0.6 volts, indicating a serious problem in the heavy-gauge circuit between the starter and the battery.

  NOTE: Checking voltage-drop at various points along the circuit can help pin-point the problem.

- Check voltage-drop at the output lug on the starter solenoid:
- If there is a significant difference, the problem lies between the lug on the solenoid and the lug on the starter.
- If there is little change, the problem lies further up-stream.
- Check voltage drop at the input lug on the solenoid. If there is significant difference between the reading here and the reading at the output lug (greater than 0.10 volt), then the contacts inside the solenoid may be burned. If there is little change, the problem lies further up-stream, between the battery and the solenoid.
- Results may be cross-checked by testing voltage drop across the two posts of the starter solenoid while cranking the starter motor.

Testing switches

- Refer to the "Components" section of this chapter that describes the function of the individual switches to be tested.
- Switches can be tested "hot" by looking for voltage at the appropriate posts. This is not definitive, since the source of the voltage is not always confirmed. Checking for voltage does not work on switches that work by providing a ground path to the magneto primary windings or a solid state control device.
- The most valid way to test switches is a continuity test.
- Understand the internal functions of the switch. Key switches and PTO switches can be fairly complex.

1. Isolate the switch from the rest of the circuit.
2. Test each pair of terminals for continuity <u>in all modes</u> of switch operation: at-rest, and actuated.

- Many switches on Cub Cadet equipment are typed by their at-rest state: Normally Open, Normally Closed, Common.
- Normally Open (N.O.) contacts do not complete a circuit when the switch is at-rest (plunger extended). They close to complete a path through the switch when the plunger is depressed.
- Normally Closed (N.C.) contacts complete a circuit when the switch is at-rest (plunger extended). They open to break the path through the switch when the plunger is depressed.
- Some Cub cadet switches contain more than one pair of contacts. The same switch housing can contain normally open and normally closed switch elements.
- When testing a switch that contains more than one set of contacts (elements), the male spade terminals associated with Normally Closed contacts will be stamped "N.C."

- The male spade terminals that are associated with each-other face each-other broad-surface to broad surface. See Figure 7.52.

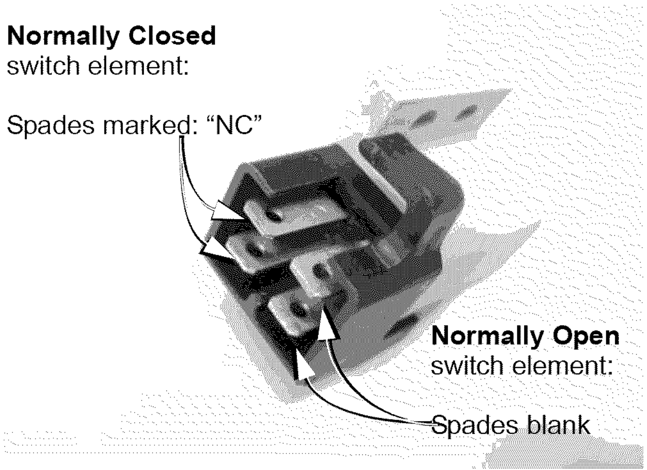


Figure 7.52

Relay

Most of the relays used by MTD or Cub Cadet have five pins. See Figure 7.53.

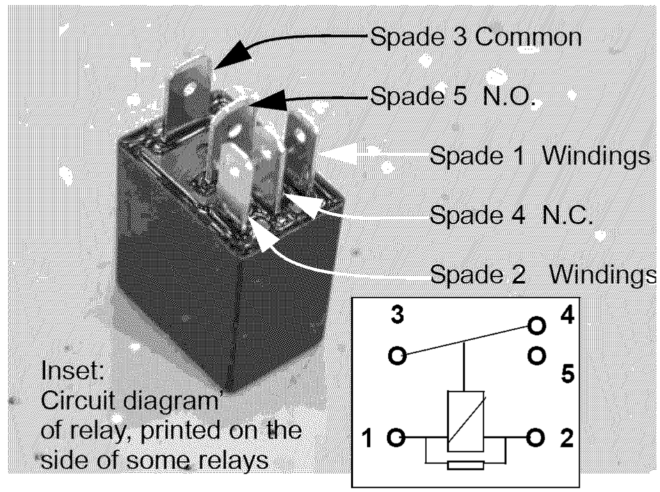


Figure 7.53

- Windings: Terminals 1 & 2 are the outer-most of the row of three small spade terminals. When one has power and the other is connected to ground, the relay is energized.
- Normally, a resistance reading between terminals 1&2 will produce a measurement of about 100W. This is the resistance in the windings around an iron core that energize an electro-magnet or a solid-state equivalent.
- Terminal 3 is a "Common" connection. It may be connected to power or ground, depending on the application. It is the large spade terminal near the edge of the relay.
- Terminal 4 is the "Normally Closed" contact. When the relay is not energized, terminal 4 is connected to terminal 3. When the relay is energized, this connection breaks. An Ohm meter should show zero resistance or "0.0W" between 3 & 4 when the relay is at rest, and it should read no continuity when the relay is energized.
- Terminal 5 is the "Normally Open" terminal. It connects to terminal 3 when the relay is energized. When 3 & 4 are connected, 3 & 5 are disconnected, and vice-versa. An Ohm meter should show zero resistance, or "0.0W" between 3 & 4 when the relay is at rest, and it should read no continuity when the relay is energized.

To test a relay:

1. Test for continuity between the common and the NC terminals using a DMM.
2. Test for continuity between the common and the NO terminals using a DMM.

   NOTE: There should be continuity with the NC terminal and no continuity for the NO terminal. If the results vary from this the relay is bad.
3. Apply 12 volts to terminals 1 and 2. This will active the relay.
4. Test for continuity between the common and the NC terminals.
5. Test for continuity between the common and the NO terminals.

   NOTE: There should be no continuity with the NC terminal and continuity with the NO terminal. If the results vary from this the relay is bad.

   NOTE: To test the relay for burn contacts, do a voltage drop test across the relay contacts while the circuit is being used.

Diodes

What is a diode? A diode acts like a one way valve, allowing current to flow in only one direction. See Figure 7.54.

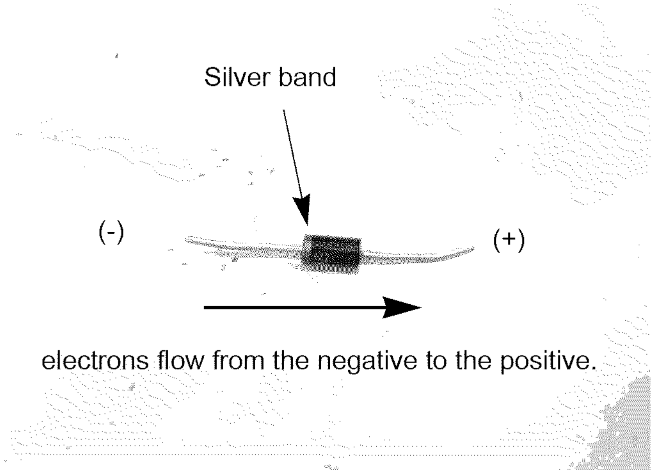


Figure 7.54

Which way does this electrical check-valve work? There will be a band on one end of the diode. The band indicates the negative side of the diode

- Most DVOMs have the ability to test a diode.

Testing a diode:

1. Isolate the diode in the circuit.
2. Set the DVOM to the diode or W scale. See Figure 7.55.

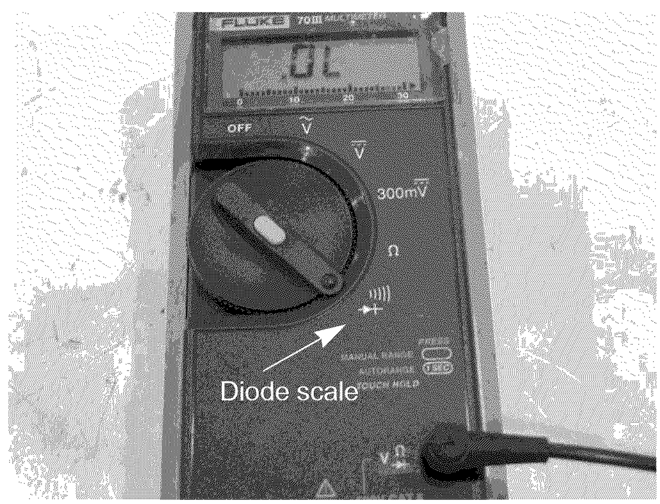


Figure 7.55

3. Attach the negative lead of the DVOM to the side of the diode with a band on it.
4. Place the positive lead on the other side of the diode.
5. There should be continuity. See Figure 7.56.

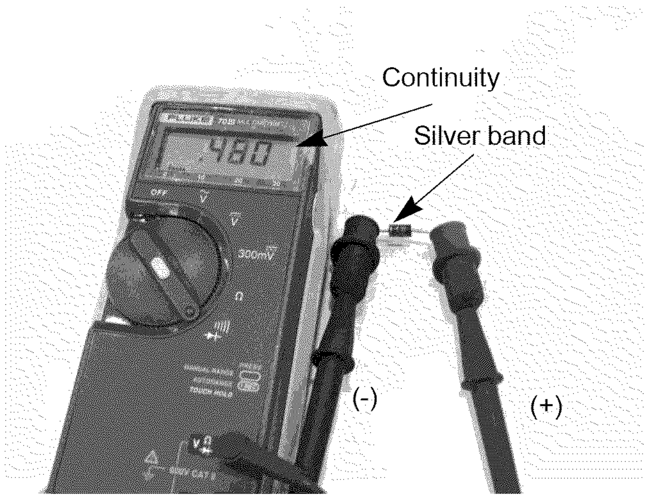


Figure 7.56

6. Switch the leads.
7. The meter should indicate no continuity. See Figure 7.57.

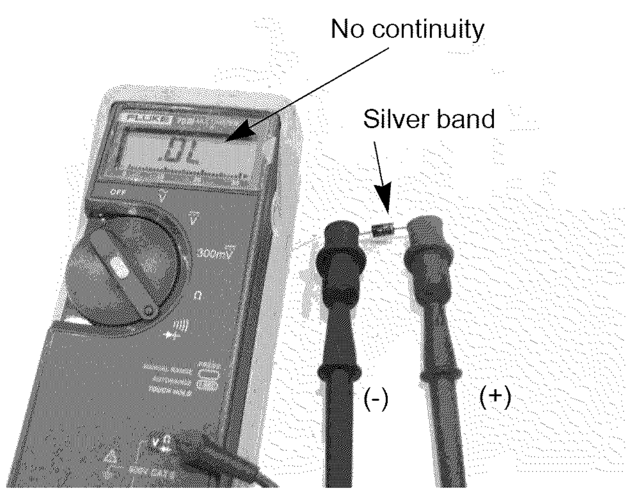
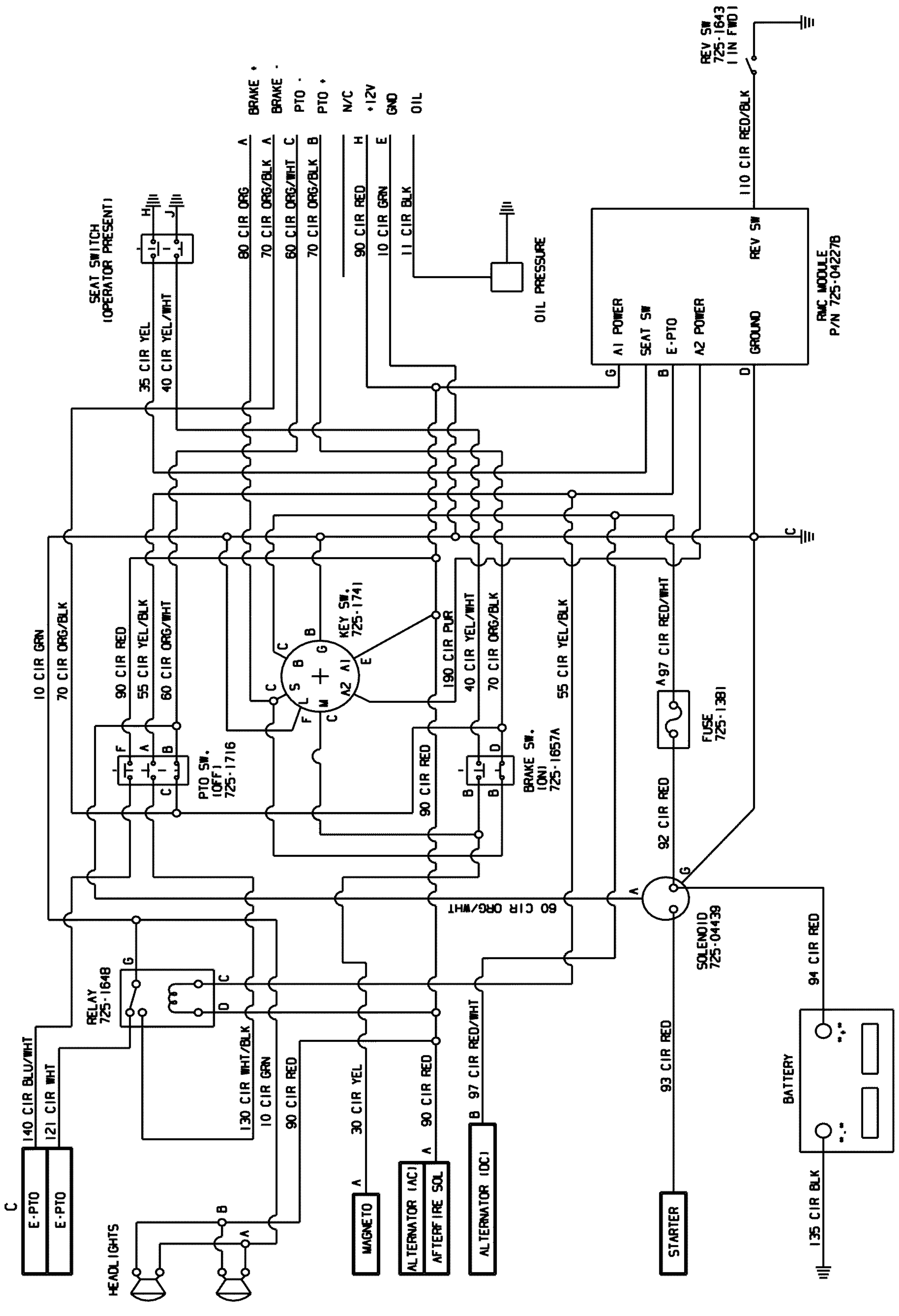


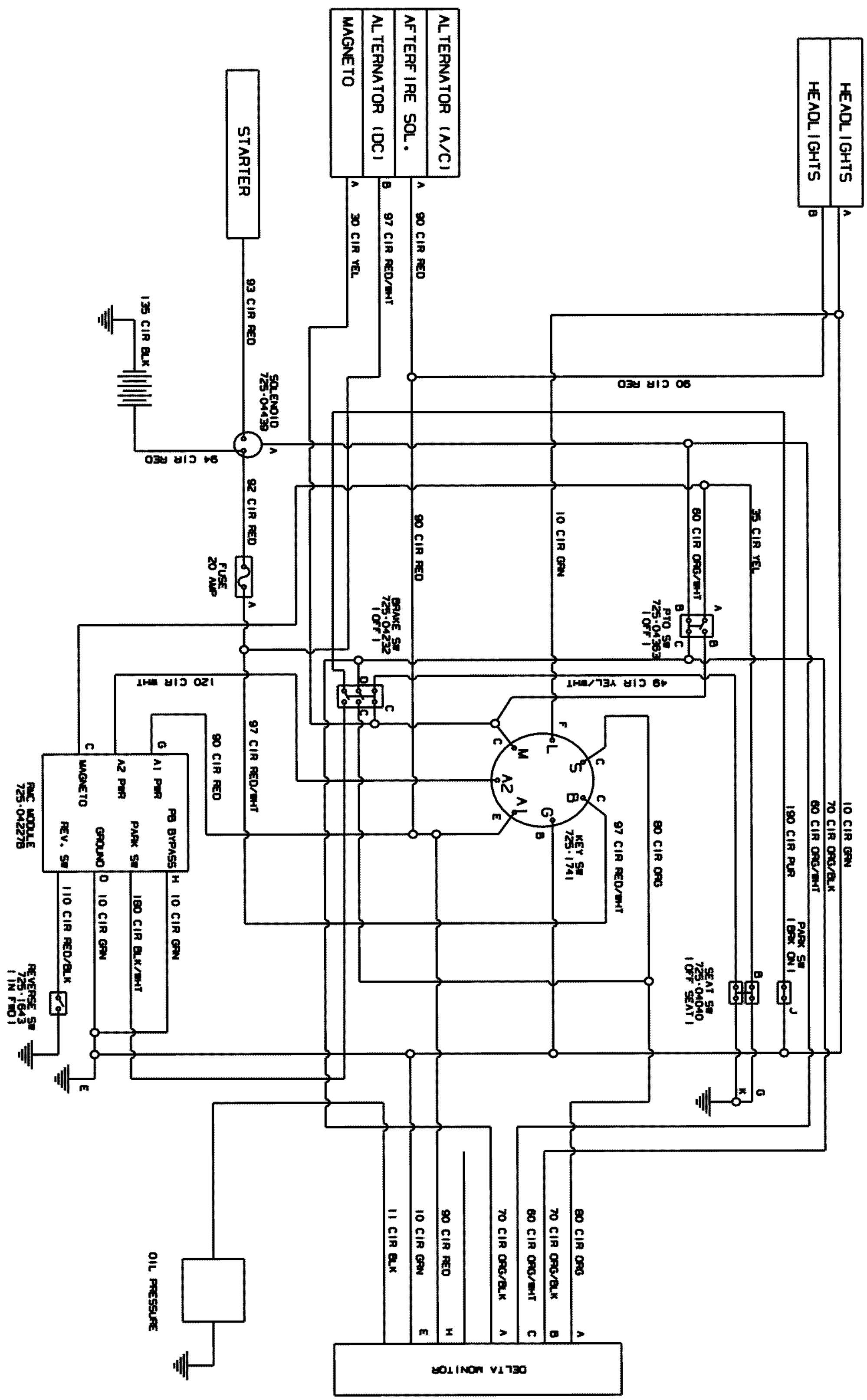
Figure 7.57

8. If the results do not match the above, replace the diode.

SCHEMATICS



Elec ric PTO


HEADLIGHTS
HEADLIGHTS
ALTERNATOR (A/C)
AFTERFIRE SOL.
ALTERNATOR (DC)
MAGNETO
STARTER
SOLENOID
725-04439
FUSE
20 AMP
BRAKE SW
PTO SW
KEY SW
725-1741
SEAT SW
PARK SW
REVERSE SW
RMC MODULE
OIL PRESSURE
DELTA MONITOR

Manual PTO