UNITED STATES MARINE CORPS
Logistics Operations School
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Training Command
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LVSM 7204

STUDENT OUTLINE

MAINTAIN THE MK48 ELECTRICAL SYSTEM

LEARNING OBJECTIVES

1. Terminal Learning Objective: Given an LVS, TM 2320-20/12A, tools, and equipment, perform second echelon maintenance on LVS electrical system, per the reference. (3521.13.12)

2. Enabling Learning Objectives:

a. Given an MK48, TM 2320-20/12A, inspect the electrical system for serviceability, per the reference. (3521.13.12a)

b. Given an MK48, TM 2320-20/12A, tools, and equipment, test the electrical system, per the reference. (3521.13.12b)

c. Given TM 2320-12A and partial statements pertaining to the MK48 electrical system, complete the partial statements to describe the procedures used to diagnose a malfunctioning MK48 electrical system. (3521.13.12c)

d. Given an MK48, TM 2320-20/12A, tools, and equipment repair the electrical system per the reference. (3521.13.12d)

e. Given an MK48, TM 2320-20/12A, tools, and equipment replace components of the electrical system, per the reference. (3521.13.12e)

OUTLINE

1. IDENTIFICATION, LOCATION, AND FUNCTION OF THE COMPONENTS EMPLOYED IN THE MK48 ELECTRICAL SYSTEM

a. Batteries, Circuit Breakers, Relays, Wiring, Cabling, and Multi-Connectors

(1) Batteries. Power storage for the MK48 consists of four, marine type, twelve-volt batteries, negative ground, that is connected in a series-parallel circuit to produce twenty-four volts. The MK48A1 consists of four, 6TN tactical type, twelve-volt batteries, which are connected in a series-parallel circuit to produce twenty-four volts.

(a) The batteries are housed within a compartment mounted on the left fender. The MK48 compartment also provides a receptacle for slave starting. The MK48A1 slave-starting receptacle is located on the quick start ether bottle bracket.

(b) While the batteries can power all of the systems in the MK48 for a limited time, their primary purpose is to store energy provided by the alternator when needed and to supply power to the engine starting circuit.

(2) Circuit breakers

(a) The vehicle electrical system is protected against overloads by automatic reset circuit breakers. These circuit breakers are located in the cab console beneath a panel and by the starter relay.

(b) A circuit breaker is a thermal mechanical device that serves a purpose similar to that of a fuse. Circuit breakers are designed to open a circuit when the current flow exceeds the safe limits of the circuit.

(c) There are fourteen circuit breakers that protect the MK48 electrical system, thirteen within the cab console and one next to the starter relay. Each of them is numbered for easy identification. To identify an individual circuit breaker within the cab console, count from the driver's side over to the passenger side of the cab. To make it easy for you to determine the "hot" side of the circuit breaker during testing, the battery side of the circuit breaker will always face forward and the load side will face rearward.

(3) Relays

(a) The vehicle electrical system is also controlled by relays. These relays are also located in the cab console, to the front of the circuit breakers.

(b) A relay is a device, usually consisting of an electromagnet and an armature, by which a change of current or voltage in one circuit can be made to produce a change in the electrical condition of another circuit, or to affect the operation of other devices in the same or another electrical circuit.

(4) Wiring and cabling. All components in the electrical system are connected by the appropriate size wiring and cabling. Each wire and cable is identified by a number that is embossed on tape that is wrapped around each wire and cable near its terminal end or it is stamped on the wire or cable itself at selected intervals.

(5) Multi-connectors. There are several multi-connectors located throughout the MK48. They vary in size and use depending on where they are located within the wiring harness.

b. Ignition Switch, Neutral Safety Switch, Starter Relay, Starter Solenoid, Starter, and Circuit Breaker No. 5

(1) Ignition switch

(a) The ignition switch is a three-position switch that is located on a vertical panel below the right side of the instrument panel.

(b) The three positions are "OFF," "ON," and "START."

(c) The ignition switch controls the charging, accessory, and starting circuits. When the ignition switch is moved to the "ON" position, the ignition and accessory circuits are activated. When the switch is further moved to the "START" position, and the transmission range selector is in the "NEUTRAL" position, the engine will crank if the system is functioning normally.

(2) Neutral safety switch. The neutral safety switch is located under the transmission range selector.

(a) Access to the neutral safety switch can be gained by removing the panel that is located below the transmission range selector, as viewed from the left side of the vehicle.

(b) The neutral safety switch is designed to prevent the starter from engaging if the transmission range selector is in any position other than neutral.

(3) Starter relay switch. The starter relay switch is located on a bracket inboard of the battery box.

(a) The starter relay is sometimes referred to as a magnetic switch.

(b) The starter relay is used to isolate the ignition switch from the starter.

(4) Starter solenoid. The starter solenoid is mounted on the top of the starter.

(a) The starter solenoid makes and breaks the circuit between the batteries and the starter motor.

(b) This solenoid also shifts the starter drive in and out of the flywheel ring gear.

(5) Starter motor. The starter motor is located on the left hand side of the flywheel housing.

(a) The starter converts the electrical energy from the batteries into rotational torque to turn the engine crankshaft.

(b) The starter motor contains a starter drive, armature, commutator, and brushes.

(6) Circuit breaker No. 5. Although circuit breaker No. 5 is not part of the starting system, it is appropriate to address it at this point.

(a) Wire 430, routed from the positive side of the starter relay to circuit breaker No. 5, is the hot wire that feeds battery voltage to the ignition switch through wire 431. Both of those wires are attached to the same side of circuit breaker No. 5. Therefore, the condition of circuit breaker No. 5 will not affect the starting circuit as long as both wires have good contact with each other.

(b) Wire 430 also feeds battery voltage to the engine shutdown solenoid through circuit breaker No. 5 and wire 096. If the circuit breaker were open or defective, no electricity would be delivered to the engine shutdown solenoid when the engine shutdown switch in the cab is cycled. Thus, a defective circuit breaker would not prevent cranking and starting, but it would prevent shutting down the engine with the engine shutdown switch in the cab. You will be given additional instruction on the shutdown solenoid at a later time.

c. Alternator, Voltage Regulator, Diode, Relay No. 2, and Circuit Breakers No. 8, 9, and 14

(1) Alternator. The alternator produces electricity (27.8 to 29.1 volts) to maintain battery voltage and power the electrical components of the vehicle. The alternator, which is mounted on and driven by the engine blower, generates 65 amps for charging the batteries and operating the accessories.

(2) Regulator. Incorporated on top of the alternator is an adjustable output voltage regulator that regulates the alternator output. The voltage regulator can be set for high, middle, or lower voltage output.

(3) Diode

(a) A diode is placed in line between the alternator and the starter. It is mounted on a bracket inboard of the battery box, next to the starter relay, and attached to the output side of circuit breaker No. 14.

(b) The purpose of the diode is to prevent current from flowing in the wrong direction if polarity is accidentally reversed.

(4) Relay No. 2

(a) Relay No. 2 is located in the center console panel, second relay from the left as viewed from the driver's compartment.

(b) Relay No. 2 activates the alternator ignition circuit through circuit breaker No. 9 when the ignition switch is turned to the "ON" position.

(5) Circuit breaker No. 8

(a) Circuit breaker No. 8 is located in the center console panel and is the eighth circuit breaker from the left as viewed from the driver's compartment.

(b) This circuit breaker will allow power to flow to circuit breaker No. 9 by way of a tie bar (bus bar).

(6) Circuit breaker No. 9

(a) Circuit breaker No. 9 is located in the center console panel and is the ninth circuit breaker from the left as viewed from the driver's compartment.

(b) This circuit breaker will continue the flow of power directly to the alternator ignition terminal, exciting the alternator field windings.

(7) Circuit breaker No. 14

(a) Circuit breaker No. 14 is located on a bracket inboard of the battery box, next to the starter relay, and is connected in-line between

the alternator and starter positive terminals, with the diode placed on its output terminal.

(b) Circuit breaker No. 14 protects the charging system circuit in the event of an overload.

d. Miscellaneous Electrical Components.

(1) Directional relief valve

(a) The directional relief valve is an electrically operated, hydraulic valve located on a bracket to the left of the hydraulic reservoir.

(b) The directional relief valve is controlled by an electrical solenoid at the valve. The position of the parking brake switch and the neutral safety switch determines the opening and closing of the solenoid.

(c) When the transmission is in neutral and the parking brake is set (pulled out), the directional (yaw) relief valve directs oil to the hydraulic reservoir. But, during vehicle steering operation, the hydraulic oil is directed to the yaw control valve for yaw steering.

(2) Fan control valve

(a) The fan control valve is an electrically/thermostatically operated hydraulic valve located directly behind the auxiliary selector valve.

(b) The fan control valve is controlled by an electrical solenoid at the valve and by a thermo switch mounted on the left thermostat housing of the engine. The fan control valve will not activate until the engine temperature reaches 180 degrees Fahrenheit or above.

(c) The fan control valve is used to control the flow of hydraulic oil to either the fan motor or back to the hydraulic reservoir.

2. OVERVIEW OF THE MK48 ELECTRICAL SYSTEM SCHEMATICS

a. Electrical Schematics. The schematics are generalized plans that contain outlays of the electrical system. There are a total of four sheets of the electrical system schematics.

(1) Electrical system component designators. The following is a breakdown of the alphanumeric designators used in identifying the various electrical components that are located on FO-3.

(a) Switches. Designators beginning with the letter "S" identify a component as a switch that will require manual/mechanical operation.

(b) Pressure switches. Designators beginning with "PS" identify a component that is controlled by pressure.

(c) Temperature switches. Designators beginning with "TS" identify a component that is thermostatically controlled.

(d) Lights. Designators beginning with "L" identify a component that has a light.

(e) Relays. Designators beginning with "R" identify a component as being a relay.

(f) Multiple connectors. Designators beginning with "MC" identify a connector.

(g) Circuit breakers. Designators beginning with "CB" identify a circuit breaker.

(h) Miscellaneous. Designators beginning with an "M" identify a component in the miscellaneous category.

(2) Code sort. This section identifies the following:

(a) Wire number,

(b) Routing and where it goes to, and

(c) Sheet. (What page of the schematic sheet it can be located on.)

(3) Vehicle schematics

(a) Sheets 2 of 4 (FO-4) and 3 of 4 (FO-5) identify the routing of all components and wiring that are on the MK48 unit.

(b) Sheet FO-7 identifies the routing of the instrument panel wiring of the MK48.

3. PRINCIPLES OF OPERATION FOR THE MK48 ELECTRICAL SYSTEM

a. Power to the Battery Terminal of the Ignition Switch

(1) Positive wire connections (red)

(a) The battery system positive cable (wire 139) is connected to the starter solenoid.

(b) From the starter solenoid, cable 046 proceeds on to the starter relay.

(c) Now, at the starter relay, cable 430 continues the power flow through MC13 and MC5 up to circuit breaker No. 5.

(d) Finally, from circuit breaker No. 5, wire 431 completes the circuit at the battery terminal of the ignition switch.

(e) Wires 816 and 818 from the starter solenoid are for STE/ICE use.

(2) Negative wire connections (brown)

(a) The battery negative cable (Wire 138) is connected directly to the back of the starter motor.

(b) Cable 148 is the ground strap, which completes the ground from the back of the starter motor to the vehicle frame.

(c) Wire 819 from the starter motor is for STE/ICE use.

b. Power to the Output Terminals of the Alternator

(1) Positive wire connections (red)

(a) Cable 833, which is connected to the starter solenoid along with battery positive cable 139 and wire 046, routes to the input side of circuit breaker No. 14.

(b) From the output side of circuit breaker No. 14, wire 278 continues up and ends at the output terminal of the alternator.

(c) Keep in mind that a diode is connected on the output side of circuit breaker No. 14. By doing this, the diode can counteract polarity if it is accidentally reversed. This means, as long as positive voltage is running through the circuit, the diode will allow voltage to pass. In the event of reverse polarity, the diode will stop the negative flow and will not allow damage to occur to the alternator. Additionally, circuit breaker No. 14 will open due to reverse polarity.

(d) Wire 820 at the positive terminal of the alternator is for STE/ICE use.

(2) Negative wire connections (brown)

(a) Wire 128 is connected to the negative output terminal of the alternator, which is grounded to the back of the starter motor.

(b) Wire 815 on the negative terminal of the alternator is for STE/ICE use.

c. Ignition Switch to "ON" to Activate the Ignition Terminal of the Alternator (blue)

(1) The ignition switch terminal marked "IGN" (ignition), carries power from the ignition switch through cable 075 back to relay No. 2.

(2) From relay No. 2, the electromagnet is activated by completing the circuit between wires 736 (always "HOT") and 075. This will now allow power to flow from wire 735 to circuit breaker No. 8.

(3) At circuit breaker No. 8, there is a bus bar that crosses or ties to circuit breaker No. 9.

(4) Power from circuit breaker No. 9 will now flow through wire 831 back to the ignition terminal of the voltage regulator. Keep in mind that wire 831 is routed through two multiple connectors, MC6 and MC11, before it actually ends at the voltage regulator.

(5) With voltage applied at this point, the alternator field windings are activated. With the vehicle running, the alternator generates alternating current (ac), which is then passed through a set of rectifiers that change it into direct current (dc) voltage. This direct current flows through the diode and the circuit breaker and on to the starter solenoid to maintain battery charge and to power the accessories.

d. Ignition Switch to "ON" to Activate the Accessory Circuit (Blue)

(1) Again, having the ignition switch turned to the "ON" position, the terminal marked "ACC" (accessory) is also activated.

(2) Wire 640 runs the accessory circuit.

e. Ignition Switch to "START" to Activate the Starting Circuit (Green)

(1) When the ignition switch is further turned to the "START" position, power is sent to the "ST" (start) terminal of the ignition switch through wire 436 that goes to the neutral safety switch.

(2) From the neutral safety switch, wire 021 carries the power to the starter relay through MC5 and MC13 as long as the neutral safety switch is adjusted properly and the transmission range selector is in neutral.

(3) At this time, the starter relay is energized, and battery voltage is applied directly to the starter solenoid through wire 045.

(4) When the solenoid is energized, the main contacts within the solenoid close and the starter drive pinion shifts into engagement with the ring gear on the flywheel.

(5) After the drive pinion completes its travel, it closes heavy contacts that connect the starter motor to the battery and the armature in the starter motor starts to turn.

(6) When the engine begins to run, the pinion is turned faster than the starter armature is turning and an overrunning condition exists.

(7) When the ignition switch is released, it automatically returns to the "ON" position. At this time, battery voltage is no longer applied to the output side of the solenoid and the drive pinion is disengaged from the flywheel ring gear by a spring incorporated in the drive pinion. Now that voltage is no longer applied directly to the starter, the starter motor ceases to turn.

e. Fan Control Valve Operation

(1) Engine temperature below 180 degrees Fahrenheit

(a) During engine operation when the engine temperature is below 180 degrees Fahrenheit, the fan control valve is closed due to the action of the fan control switch that is mounted on the left thermostat housing.

(b) The fan switch is operated by circuit breaker No. 9, wire 718. This wire will go through MC6 and MC11 up to the switch.

(c) Below 180 degrees Fahrenheit, the fan switch is closed and does not allow power to go to the fan control valve. Thus, the solenoid at the fan control valve will remain closed until the engine temperature is 180 degrees Fahrenheit or above.

(2) Engine temperature above 180 degrees

(a) Once the engine temperature reaches 180 degrees or above, the fan switch, located on the left thermostat housing, will break the circuit to wire 718A at the fan control valve.

(b) The fan control valve solenoid will, in turn, open and allow a full flow of oil to the fan motor to cool the system.

f. Directional Relief Valve Operation. There are several factors which determine the function of the directional relief valve.

(1) First, if the parking brake is set and the transmission range selector is in "NEUTRAL," the directional relief valve will divert oil back to the reservoir. With this condition, battery voltage is supplied to the directional relief valve solenoid through wire 859, which opens the valve. Power is supplied to wire 859 as follows:

(a) With the ignition switch in the "ON" position, CB No. 8 supplies power to wire 615 which leads to a pressure switch (PS1) mounted to the trailer air supply valve.

(b) With the parking brake set, air pressure, which closes the circuit of the pressure switch, has been exhausted and power will flow from wire 615 to wire 736B.

(c) Now, at wire 736B, power will go to relay No. 8 and a jumper to relay No. 7. Power is now provided to wire 859.

(2) If the parking brake is released, voltage is no longer applied at the solenoid, and it, in turn, closes. With this condition, the directional relief valve will provide hydraulic oil to the yaw steering circuit.

(a) With the parking brake released, the air system, which opens the circuit of the pressure switch at the trailer air supply valve, is pressurized.

(b) At this point, power from wire 736B is no longer applied at the relays. The circuit will change on the relay. Thus, power, which will close the solenoid and divert hydraulic oil to the yaw steering circuit, is no longer at wire 859.

(3) If the parking brake is set, but the transmission is in the "DRIVE" position, yaw steering will also be possible. Here's what happens:

(a) Wire 556 of the transmission neutral safety switch, located next to the selector lever of the transmission, will have a completed circuit

and provide power at relay No. 8. This will, in turn, change the circuit and break the power at the directional relief valve.

(b) Now, power is no longer applied at wire 859 and the directional relief valve will close. Hydraulic oil will now be provided to the yaw steering circuit.

(4) If the directional relief valve solenoid is disconnected from its multi-connector, then the yaw steering circuit will always operate, no matter what position the parking brake or the transmission range selector is in.

4. ORGANIZATIONAL MAINTENANCE RESPONSIBILITIES RELATIVE TO THE MK48 ELECTRICAL SYSTEM

a. Organizational maintenance (second echelon) personnel are responsible for inspecting, testing, and replacing the following items:

(1) Batteries,

(2) Battery cables,

(3) Slave receptacle or nato connector,

(4) Battery box,

(5) Starter relay,

(6) Ignition switch,

(7) Neutral safety switch,

(8) Alternator,

(9) Voltage regulator,

(10) Circuit breakers,

(11) Diode, and

(12) Wiring and cabling.

b. The organizational maintenance personnel are also responsible for adjusting the neutral safety switch and the voltage regulator. Since the neutral safety switch and the voltage regulator are adjustable, you should attempt to adjust them before condemning them.

c. The starter assembly and starter solenoid can be replaced by organizational maintenance upon determination that they are defective. If the starter is defective, the starter and solenoid will be replaced as an assembly.

d. The voltage regulator will accompany the alternator upon determination that the alternator is defective.

5. INSPECTING THE MK48 ELECTRICAL SYSTEM FOR SERVICEABILITY

a. Batteries

(1) Visually inspect the outside of each battery for obvious damage such as a cracked or broken case or cover, which would allow electrolyte leakage.

(2) Check the battery terminals for damage. If obvious physical damage is found, replace the battery. If possible, determine the cause of the damage and correct it.

b. Battery Box. Inspect the battery box for possible corrosion damage caused by the loss of acid from the batteries. Corroded parts may be cleaned with water, some baking soda, and scrubbing with a stiff brush. Cleaned parts should be dried and painted in accordance with the technical manual.

c. Battery Cables

(1) Examine the cables to be sure they are the correct size. Battery cables must carry large starting currents with a minimum loss of voltage, since cranking speed is dependent on the voltage available at the starting motor.

(2) Examine the cables to make certain the insulation is intact and the terminal and its nuts are not corroded so badly that part of the metal is eaten away. Replace all such unserviceable parts. As the acid eats away at the terminals and cables, the resistance increases and the voltage loss between the battery and the starter increase. The increase in resistance due to corrosion also restricts the flow of the charging current to the battery. This will cause the battery to gradually become undercharged and sulfated.

(3) Clean the corroded parts and tighten the cables if necessary. Corroded cables may be cleaned with water and some baking soda and scrubbing with a stiff brush. Replace badly corroded cables or cables with defective terminals. Make certain the negative cable is making a good connection where the cable is grounded, and likewise, check the connection of the positive cable to the starter solenoid.

d. Slave Receptacle (NATO Connector)

(1) Inspect the slave receptacle for possible damage and ensure the receptacle is securely attached to the battery box. Check for corrosion on the inner and outer parts of the receptacle's metal shell. These surfaces must be clean and free of any lubricants. Check the slave receptacle cover for damage and make sure the cover fits snug on the receptacle.

(2) Examine the slave receptacle cables to make certain the insulation is intact and the terminal and its bolts are not corroded so badly that part of the metal is eaten away. Clean any corrosion as you would on battery cables. Replace badly corroded cables and bolts.

e. Circuit Breakers and Diode

(1) Inspect the circuit breakers for loose wire connections or stripped insulation. Check that all circuit breakers are secure.

(2) Inspect the alternator in-line circuit breaker and diode. Check that they are mounted securely and all wires are clean and snug.

f. Relays

(1) Inspect all relays for proper connections, ensuring they are grounded properly.

(2) Inspect relays for any discoloration due to overloads caused by the electromagnet contacting the casing of the relay.

g. Multi-Connectors

(1) Disconnect them and check for corrosion of the mating surfaces, and that all pins are secure.

(2) Check the adhesive material around the connector to ensure that moisture cannot enter.

h. Ignition Switch

(1) First, check each of the five wires at the back of the switch. The wires should be securely fastened to the switch and there should not be any corrosion at the connection points.

(2) Next, check to make certain that the knurled nut that holds the switch in place is tight and that the switch knob is secure.

(3) Complete the inspection by checking the switch to make certain it functions correctly. The switch should automatically return to the "ON" position when it is released after having been in the "START" position. Also, you should not be able to engage the starter without cycling the switch to "OFF" if the switch has been in the "START" position since it was last turned off.

i. Neutral Safety Switch

(1) You should not be able to crank the engine if the transmission selector lever is in any position other than "NEUTRAL."

(2) To visually inspect the neutral safety switch, the access panel below the selector lever must be removed, and the rubber boot on the shift control must be moved out of the way.

(a) With the boot out of the way, check the neutral safety switch mounting capscrew; it should be tight. Now check the plunger.

(b) The switch plunger should be secured to the shift lever with a washer and cotter pin.

(c) If the switch is properly secured, move the shift lever to make sure the plunger is not binding.

(d) Complete the inspection of the neutral safety switch by moving the boot back into its position and then checking the switch electrical connections. The butt connectors for both electrical circuits should be properly assembled and not corroded.

j. Starter Relay

(1) The switch should be securely fastened in place and all wires attached to the switch should be free of corrosion and secured tightly to their respective posts.

(2) The switch housing should show no evidence of damage.

k. Starter Assembly

(1) The starter solenoid should be securely mounted to the starter and the starter should be securely mounted to the bell housing. If you have reason to believe that the starter is loose, you will have to remove the batteries and the battery box to gain access to the starter retaining bolts.

(2) Once you have determined that the starter and starter solenoid are properly mounted, check all wiring and the ground strap on the starter assembly. Each of the wires, cables, and the ground strap should be securely fastened and free of corrosion and include no bare spots in the insulation.

l. Alternator

(1) Check that the alternator is securely mounted. Torque the mounting bolts to the specifications outlined in the technical manual.

(2) Examine the area of the alternator where the voltage regulator is mounted for cracked or broken insulation. Damage will occur to the insulation if the voltage regulator capscrews are over tightened.

(3) Examine the alternator/voltage regulator wiring to be sure that all connections are clean and tight. Also, inspect the wiring for stripped insulation and exposed (bare) wires.

(4) Ensure that the wiring is routed properly and doesn't come in contact with heated or moving parts on the engine.

6. TESTING OF THE MK48 ELECTRICAL SYSTEM COMPONENTS

a. Starting System. As a first step in testing, you must determine that the batteries have sufficient voltage to crank the engine. You can use one of two methods to accomplish that task.

(1) The vehicle technical manual indicates that you should turn the ignition switch on and observe the voltmeter gage on the dash. The minimum reading you can have is 22 volts.

(2) You can check the batteries with either a multimeter or STE/ICE. Battery tests will be covered later in this lesson.

(3) Ignition switch

(a) Presuming that the batteries are fully charged, we will commence testing the ignition switch. With the voltmeter conditioned for voltage testing on a 24-volt system and the ignition switch "OFF," connect the negative multimeter lead to ground and the positive lead to the terminal marked "BATT" on the ignition switch. Note the reading obtained; you should read battery voltage. If no voltage is present, trace out wire 431 to locate the problem. You must have voltage on the terminal marked "BATT" before you can continue.

(b) Now, move the ignition switch to the "ON" position. We are still looking for voltage so make sure the multimeter is conditioned accordingly. Connect the negative multimeter lead to ground and the positive lead to either the terminal marked "ACC" or "IGN." If battery voltage is not present on either terminal or just one terminal, the switch is defective.

(c) The next portion of the test is to be conducted with the ignition switch in the "START" position.

1 Obviously, if the system were functioning normally, the engine would start with the switch in the "START" position. Since there is no requirement to periodically test the ignition switch, we will presume that the engine will not crank. However, each time you place the switch in the "START" position, hold the engine "STOP" switch down so that the engine will not start, even if it does crank.

2 Connect the negative meter lead to ground and the positive lead to the terminal marked "ST." Again, you are looking for battery voltage. If battery voltage is not available, the ignition switch is defective.

(4) Neutral safety switch. To test the neutral safety switch, you must gain access to it by removing an access panel. It is located below the transmission range selector. The ignition switch must be held in the "START" position when performing these tests.

(a) First, test for battery voltage at wire 436 at the neutral safety switch. If voltage is not present and was present at the ignition switch, repair or replace wire 436.

(b) To test the switch, connect the negative multimeter lead to ground and insert the positive meter lead into the connection between the green wire coming from the neutral safety switch and wire 021. If the ignition switch is in the "START" position and the transmission shift lever is in the "NEUTRAL" position, you should read battery voltage.

(c) If battery voltage is not obtained, the switch must be adjusted or replaced. Adjustment and replacement procedures will be covered later in this lesson.

(5) Starter relay switch. The starter relay switch is the next component that we will test. Initially, we will be looking for battery voltage, so you will need to make sure that the meter is set up for direct current voltage testing.

(a) Remember, we are working on the assumption that we have a "no crank" condition. Turn the ignition switch to "START" and probe for battery voltage at wire 021; that is the terminal at about 11 o'clock if you are looking at the starter relay from the front. Don't forget to observe polarity; place the negative lead to ground and the positive lead to wire 021 terminal. If you do not read battery voltage, trace wire 021 to locate the problem.

(b) Next, condition the multimeter for continuity testing and check for continuity between the terminal for wire 196 and ground. As you can see on the chart, wire 196 terminals are at eight o'clock on the solenoid when viewed from the front. If continuity does not exist, wire 196 must be repaired or replaced.

(c) Again set the multimeter up for voltage testing.

1 Remembering that wire 430 feeds the ignition switch through wire 431 at circuit breaker No. 5, you should also remember that wire 046 that is attached to the top (12 o'clock) of the starter relay feeds wire 430. Therefore, if you had battery voltage when you checked for it at the "BATT" terminal on the ignition switch, you know that wire 046 that attaches to the solenoid is serviceable. Wire 046 should always be "HOT," as we learned earlier.

2 Now, you are ready to complete the testing of the starter relay switch. With the multimeter conditioned for voltage testing, check wire 045 (6 o'clock) for battery voltage. With the ignition switch in the "START" position, wire 045 should have battery voltage. Observe polarity when testing for voltage.

(6) Starter assembly. Testing the starter assembly is not a difficult procedure; keep in mind that at this point you already know a lot about the condition of the starter assembly circuitry.

(a) For example, you know that you have battery voltage at wire 046. If that is so, you must have battery voltage at the starter solenoid end of cable 139. Remember, these cables are always "HOT."

(b) Now, check for battery voltage at the starter solenoid end of wire 045. If the ignition switch is in the "START" position, you should read battery voltage. If battery voltage is not available at the solenoid end of wire 045 and it was available on the wire at the starter relay switch end, check wire 045 for continuity. If you do not read continuity, repair or replace the wire.

(c) If the starter assembly has passed the previous two tests, you should test for battery voltage at the jumper plate terminal. You will notice that there is a rigid metal strap between the starter frame and the solenoid. With the ignition switch in the start position, battery voltage should be available at the jumper plate terminal on the starter solenoid. If voltage is not available, check the ground strap, wire 148, for continuity. Repair or replace wire 148 if continuity is not found. If voltage is still not available after checking the ground strap, replace the starter solenoid.

(d) At this point, you have gone as far as you can go in the diagnosis of the malfunction "ENGINE FAILS TO CRANK." If you have battery voltage up to the solenoid and the grounding strap between the starter and the starter solenoid has continuity, replace the starter assembly to correct the malfunction.

b. Battery/Charging System

(1) Evaluate the charging system using the vehicle instrument panel voltmeter.

(a) Normal operating voltage for the vehicle is between 27.8 to 29.1 volts dc. An overcharge condition may exist if the voltmeter continuously reads above the safe limit of 29.1 volts dc. However, the voltmeter may read above normal if having the accessories on without the engine running has depleted the battery voltage. An overcharge condition can be caused from an improperly adjusted or defective voltage regulator or from internal battery problems.

(b) An undercharged condition exists when the voltmeter continuously reads lower than the normal output of 27.8 volts dc. An undercharged condition can be caused from corroded, loose or broken battery cables, improperly adjusted or defective regulator, loose wire connections at the alternator, or a malfunctioning alternator.

(2) Testing the alternator. Before beginning the test, ensure that the batteries are fully charged and that all connections are clean and tight.

(a) Test No. 1. During this test, we will presume that the ignition is operating properly. Now, with the ignition switch "ON," use a multimeter to check for battery voltage (around 24 volts) at the ignition terminal (IGN) on the voltage regulator. If voltage is not present, then you must check the wiring circuit from the alternator to the ignition switch. By reviewing our schematics, we can route and isolate the problem.

(b) Test No. 2. Now, turn the ignition switch and the accessories "OFF" and use a multimeter to check for battery voltage on the

positive and negative output terminals on the back of the alternator. Record the voltmeter reading. If you do not get a voltage reading, check the wiring circuit from the alternator to the batteries. Remember, the diode and circuit breaker No. 14 are in line between the batteries and the alternator.

(c) Test No. 3. Bypass voltage regulator as follows:

1 First, disconnect the negative battery cable.

2 Next, remove four capscrews and the rear cover plate from the alternator's brush holder.

3 With the rear cover plate removed, insert a paper clip or small wire into the brush holder access hole.

4 Now, connect a jumper lead from the paper clip to the negative output terminal of the alternator.

5 With the jumper wire in place, connect the voltmeter to the positive and negative output terminals of the alternator, and connect the negative battery cable.

6 Turn off all electrical accessories and start the engine, and run it at 1200-1500 rpm.

7 Now, record the voltmeter reading and shut down the engine. If the voltage reading is lower or the same as in Test No. 2, the alternator must be replaced. If the voltage reading is higher, check the voltage output, Test No. 4.

(d) Test No. 4. Remove the jumper lead from the negative output terminal and the paper clip. Remove the paper clip from the brush holder. Start the engine and run the engine at 1200-1500 rpm. Check the output voltage. If the voltage reading is lower than 27.8 volts or higher than 29.1 volts, adjust or replace the voltage regulator.

(3) Individual battery test

(a) Check the specific gravity with an AO/DUO Check.

(b) If available, use STE/ICE to perform a battery resistance test. This test will be explained to you during the STE/ICE lesson.

(c) Test each battery with a multimeter to determine if it has sufficient voltage.

7. REPLACEMENT OF THE MK48 ELECTRICAL SYSTEM COMPONENTS

a. Replacement of the Neutral Safety Switch

(1) Removal procedures

(a) First, disconnect the vehicle batteries.

(b) Next, with the batteries disconnected, remove the access panel next to the shift control and the skid plate grill for accessibility.

(c) Now, remove all nylon ties and the electrical tape holding the wires to the shift cable.

(d) Tag and disconnect the three wires from the shift control.

(e) After the wires are disconnected, remove the capscrews that hold the boot in place and slide the rubber boot down and back out of the way.

(f) Now remove the cotter pin and washer from the neutral switch. Discard the cotter pin.

(g) The next step is to remove the hardware that is used to attach the neutral safety switch to the shift lever bracket and remove the neutral safety switch.

(2) Installation and adjustment procedures

(a) If the switch you are going to install is a new one, you will have to attach male butt connectors to the white, green, and blue wires on the switch. You will also have to cut the black and red wires back to within one inch of the neutral safety switch. The black and red wires are not used in this installation.

(b) Position the neutral safety switch on the shift lever bracket and install the capscrew, spacer, and washer, and then install the nut, finger tight.

(c) Next, install the plunger of the neutral safety switch onto the shift lever. It will fit into either of two holes. Use the forward hole. Secure the plunger with a washer and a new cotter pin.

(d) Now the switch must be adjusted; you will need a multimeter and it must be conditioned for continuity testing.

1 First, place the transmission shift lever in neutral.

2 Next, connect the multimeter leads to the white and green wires on the neutral safety switch. Polarity is of no concern during this procedure. Move the neutral safety switch back and forth until you find a position where the multimeter indicates zero ohms. Working carefully so as not to move the switch, tighten the capscrew securely. Recheck to make certain the multimeter still indicates zero ohms after the neutral safety switch is secured in place.

(e) Now slide the boot up over the wires and secure it in place with four capscrews and washers.

(f) All that remains to be accomplished is to plug the wires into the connectors and wrap them with electrical tape. Do not forget to install the access cover and skid plate grill.

b. Replacement of the Voltage Regulator

(1) Removal procedures

(a) First, disconnect the battery cables.

(b) Next, remove the nut and washer retaining the ignition wire leads to the back of the voltage regulator. Remove the ignition lead.

(c) With the ignition lead wire removed, remove the four capscrews and lock washers holding the voltage regulator to the alternator. Discard all lock washers.

(d) Now, lift the regulator from the brush housing and discard its gasket.

(2) Adjustment procedures. Before replacing the alternator, you would first attempt to correct the problem by adjusting the regulator.

(a) Turn the voltage regulator over to expose the voltage adjusting screw. You may encounter one of two different types of voltage regulators found mounted on the alternator.

1 One type of voltage regulator has an adjusting screw that can be removed and placed in one of three desired ranges; low (26.9-27.5 volts), middle (27.8-28.2 volts), or high (28.5-29.1 volts), to obtain the desired alternator voltage output of 27.8 to 29.1 volts.

2 Another type of voltage regulator that you may encounter will have an adjusting screw that can be turned from low to high to obtain the desired voltage output of the alternator.

(3) Installation procedures

(a) Once the desired voltage range is selected, a new voltage regulator gasket should be installed on the alternator.

(b) The voltage regulator contact pins must be aligned with the connector holes in the brush holder housing and the regulator pressed into place on the housing. The four retaining lock washers and capscrews can now be installed and torqued to the specifications outlined in the technical manual.

(c) The ignition wire lead can be connected to the "IGN" terminal and the retaining washer and nut installed, and the nut securely tightened.

(d) Now, the battery cables should be connected and the alternator checked for proper voltage output.

c. Replacement of the Alternator

(1) Removal procedures

(a) First, disconnect the battery cables before performing the repairs.

(b) Next, remove the air inlet tube from the metal tube back to the turbocharger.

(c) Now, remove the exhaust crossover tube.

(d) Tag the negative wires and remove the nut and lock washer holding the wires to the negative terminal on the back of the alternator. Remove the wire lead and reinstall the nut on the negative terminal, finger tight.

(e) Tag the positive wires and removes the nut and lock washer holding the wires to the positive terminal on the back of the alternator. Remove the wire lead and reinstall the nut on the positive terminal, finger tight.

(f) Tag the ignition wire and remove the nut and washer holding the wire to the ignition (IGN) terminal of the voltage regulator. Remove the wire lead and reinstall the nut on the ignition terminal, finger tight.

(g) Next, remove the three alternator mounting capscrews, lock washers, and plain washers.

(h) Now, pull out the alternator, its drive coupling, and mounting gasket, and discard the gasket.

(2) Installation procedures

(a) To install the new alternator, first place a new gasket and the drive coupling on the alternator and position the alternator on to the adapter.

(b) Now, install three plain washers, lock washers, and mounting capscrews. Torque the capscrews to specifications described in your technical manual.

(c) Connect the ignition wire lead to the "IGN" terminal. Secure the wire with a lock washer and nut.

(d) Connect the positive wire leads to the positive terminal. Secure the wires with a lock washer and nut.

(e) Connect the negative wire leads to the negative terminal. Secure the wires with a lock washer and nut.

(f) Install the exhaust crossover tube.

(g) Install the air inlet tubing to the turbocharger and metal ducting.

(h) Now, connect the battery cables and check the alternator for proper operation.

REFERENCE:

TM2320-20/12A