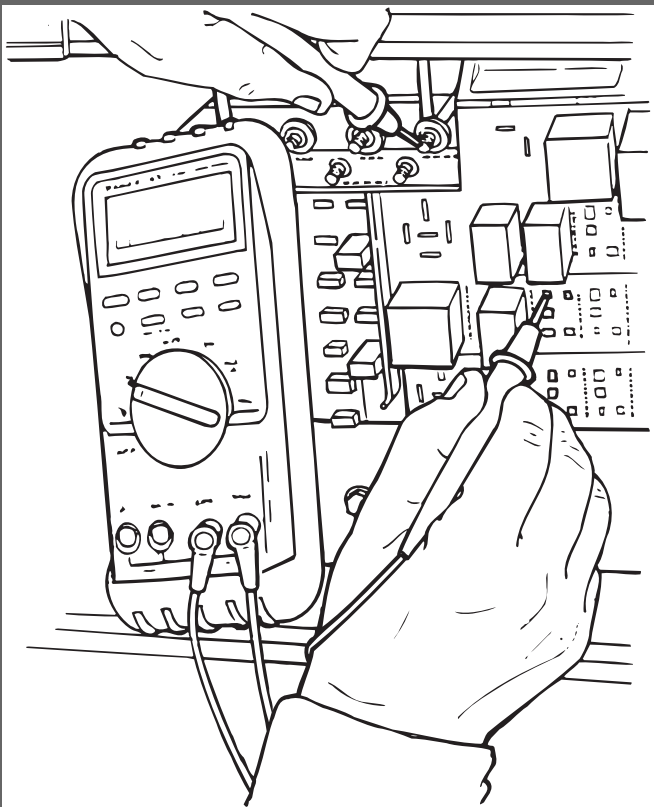
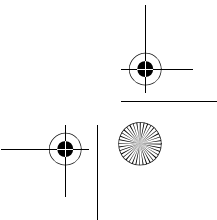
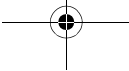
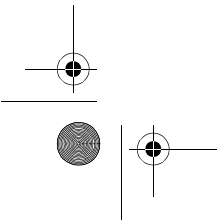
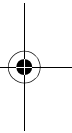
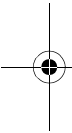
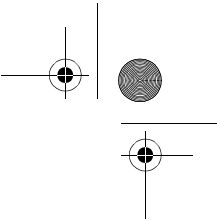
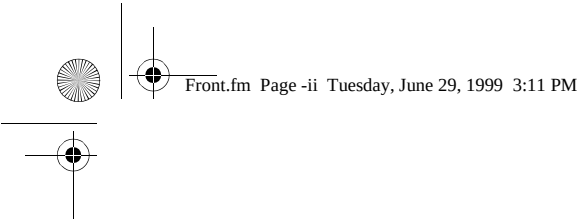




ELECTRICAL TROUBLESHOOTING SERVICE MANUAL



OCTOBER 1999
(NEW ISSUE)
8-212





PLEASE LET US KNOW!

Your comments and suggestions will help
us improve this manual!

Please complete and mail this form or FAX
your comments to: (610) 709-3800.

Manual: _____ Publication Number: _____

Vehicle Model: _____ Model Year: _____

Do you find procedures properly organized and easy to follow? ☐ Yes ☐ No

If not, please explain: _____

Manual page numbers: _____

Are there any important procedures or other information presently not in this
manual that you would like to see included? ☐ Yes ☐ No

If yes, please describe: _____

Did you find any errors in the procedures or illustrations? ☐ Yes ☐ No

If yes, what pages? _____

Please explain: _____

Please include a copy of each page in question and mark your comments and
suggestions.

Name: _____ Phone: (____) ____ - ____

Company: _____

Address: _____

City: _____ State: _____ Zip: _____

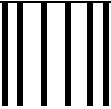
Position Title: _____

Thank You For Your Assistance
Mack Trucks, Inc.

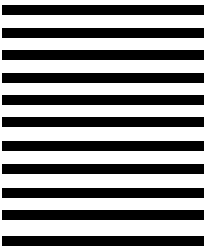
(ATTENTION: RTS STAFF, 6S3)

DO NOT STAPLE — USE TRANSPARENT TAPE

FOLD ALONG THIS LINE • DO NOT STAPLE • USE TRANSPARENT TAPE



NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES



BUSINESS REPLY MAIL
FIRST CLASS MAIL PERMIT NO. 1602 ALLENTOWN, PA

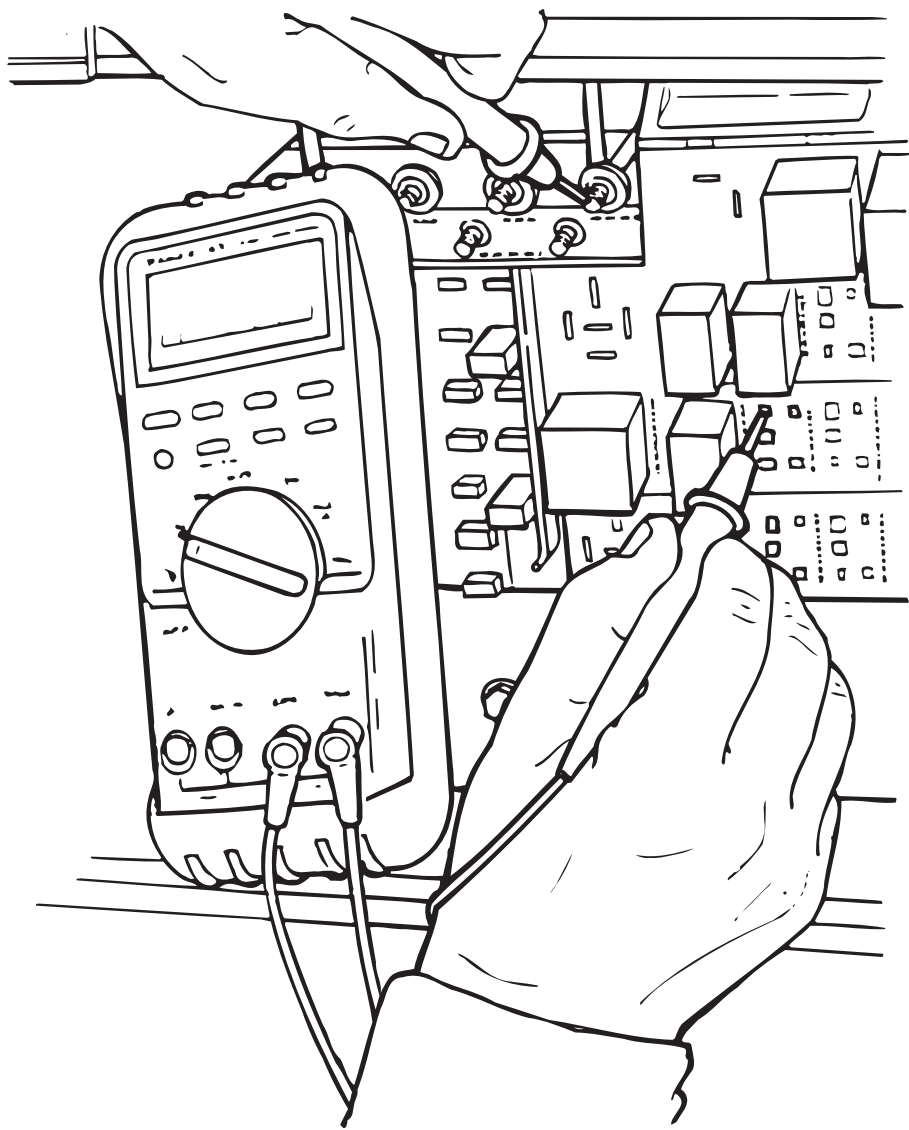
POSTAGE WILL BE PAID BY ADDRESSEE
SERVICE PUBLICATIONS (RTS), 6S3
MACK TRUCKS INC
WORLD HEADQUARTERS
PO BOX M
ALLENTOWN PA 18105-9972



FOLD ALONG THIS LINE



ELECTRICAL TROUBLESHOOTING SERVICE MANUAL



OCTOBER 1999
NEW ISSUE

© MACK TRUCKS, INC. 1999
8-212



ATTENTION

The information in this manual is not all inclusive and cannot take into account all unique situations. Note that some illustrations are typical and may not reflect the exact arrangement of every component installed on a specific chassis.

The information, specifications, and illustrations in this publication are based on information that was current at the time of publication.

No part of this publication may be reproduced, stored in a retrieval system, or be transmitted in any form by any means including electronic, mechanical, photocopying, recording, or otherwise without prior written permission of Mack Trucks, Inc.



SAFETY INFORMATION

SAFETY INFORMATION



SAFETY INFORMATION

Advisory Labels

Cautionary *signal words* (Danger-Warning-Caution) may appear in various locations throughout this manual. Information accented by one of these signal words must be observed to minimize the risk of personal injury to service personnel, or the possibility of improper service methods which may damage the vehicle or render it unsafe. Additional Notes and Service Hints are utilized to emphasize areas of procedural importance and provide suggestions for ease of repair. The following definitions indicate the use of these advisory labels as they appear throughout the manual:

CAUTION

Directs attention to unsafe practices which could result in damage to equipment and possible subsequent personal injury or death if proper precautions are not taken.

WARNING

Directs attention to unsafe practices which could result in personal injury or death if proper precautions are not taken.

DANGER

Directs attention to unsafe practices and/or existing hazards which will result in personal injury or death if proper precautions are not taken.

NOTE

An operating procedure, practice, condition, etc., which is essential to emphasize.

SERVICE HINT

A helpful suggestion which will make it quicker and/or easier to perform a certain procedure, while possibly reducing overhaul cost.

000001a



SAFETY INFORMATION

Service Procedures and Tool Usage

Anyone using a service procedure or tool not recommended in this manual must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects. Individuals deviating in any manner from the instructions provided assume all risks of consequential personal injury or damage to equipment involved.

Also note that particular service procedures may require the use of a special tool(s) designed for a specific purpose. These special tools must be used in the manner described, whenever specified in the instructions.

⚠ WARNING

1. Before starting a vehicle, always be seated in the driver's seat, place the transmission in neutral, be sure that parking brakes are set, and disengage the clutch (if equipped).
2. Before working on a vehicle, place the transmission in neutral, set the parking brakes, and block the wheels.
3. Before towing the vehicle, place the transmission in neutral and lift the rear wheels off the ground, or disconnect the driveline to avoid damage to the transmission during towing.

⚠ DANGER

Engine driven components such as Power Take-Off (PTO) units, fans and fan belts, driveshafts and other related rotating assemblies, can be very dangerous. Do not work on or service engine driven components unless the engine is shut down. Always keep body parts and loose clothing out of range of these powerful components to prevent serious personal injury. Be aware of PTO engagement or nonengagement status. Always disengage the PTO when not in use.

REMEMBER,
SAFETY . . . IS NO ACCIDENT!



NOTES



TABLE OF CONTENTS

TABLE OF CONTENTS



TABLE OF CONTENTS

SAFETY INFORMATION	iii
ADVISORY LABELS	iv
SERVICE PROCEDURES AND TOOL USAGE	v
DESCRIPTION AND OPERATION	1
INTRODUCTION	2
ELECTRICAL CONCEPTS	2
Understanding Electricity	2
VOLTAGE	4
Sources of Voltage	5
CURRENT	7
Actual	7
Conventional	7
Types of Current	8
RESISTANCE	10
Resistance, Heat and Current Flow	10
CIRCUIT TYPES	11
Series Circuits	11
Parallel Circuits	11
Series-Parallel Circuits	12
OHM'S LAW	13
EXPRESSING ELECTRICAL VALUES	15
DIAGNOSTIC TOOLS	16
Jumper Wire	16
Multimeter (Volt-Ohm Meter)	16
Multimeter (Volt-Ohm Meter) Usage	17
TROUBLESHOOTING METHOD	22
Diagnostic Techniques	22
Diagnostic Applications	22
Locating Shorts or Grounded Circuits	25
Circuit Continuity Checks	26
Checking Circuit Grounds	28
POWER DISTRIBUTION	30
Battery-Powered Circuits	30
Key-Powered Circuits	31
Ground Circuits	32
TYPICAL ELECTRIC EQUIPMENT PANEL	33
CIRCUIT BREAKERS	34
SAE Type 1	34
SAE Type 2	34
SAE Type 3	35
Testing Circuit Breakers	35
WIRE SIZES	36
WIRE IDENTIFICATION	37
BATTERIES — GENERAL INFORMATION	39
Description	39
Operation	40
Types of Batteries	41
Periodic Maintenance	41
Battery Tests	42



TABLE OF CONTENTS

STARTING SYSTEM	45
Operation	45
Troubleshooting	46
CHARGING SYSTEM	52
Operation	52
Charging System Tests	53
MISCELLANEOUS CIRCUITS — DESCRIPTION/FUNCTION	55
Lighting	55
Gauges	56
Sending Units	58
TROUBLESHOOTING	61
TROUBLESHOOTING OF INSTRUMENT CLUSTER, GAUGES, SENDING UNITS, SENSORS AND HORN	62
Gauge Testing	62
Specific Gauge and Sending Unit Tests	64
Speed Sensors	72
Horn	74
REPAIR PROCEDURES	79
COMMON ELECTRICAL PROCEDURES	80
Correct Use of Tie Wraps	80
Typical Connectors	83
Chassis Electrical Sealant Application	101
SPECIAL TOOLS & EQUIPMENT	103
RECOMMENDED ELECTRICAL TOOLS	104
INDEX	105



NOTES



DESCRIPTION AND OPERATION

DESCRIPTION AND OPERATION



DESCRIPTION AND OPERATION

INTRODUCTION

Electricity provides the power necessary for starting the engine and operating the various lights and other auxiliary systems installed on the chassis. Diagnosing problems that can occur in a truck electrical system involves a basic understanding of electrical concepts, and testing and measurement procedures. The purpose of this manual is to familiarize the technician with basic electrical concepts and diagnostic procedures. It is not intended to be vehicle specific.

ELECTRICAL CONCEPTS

Understanding Electricity

Electricity is the movement of electrons through a conductor. An electrical circuit can easily be compared to a hydraulic (or pneumatic) circuit, where hydraulic fluid (or compressed air) is pushed through a conductor to an actuator that performs a function.

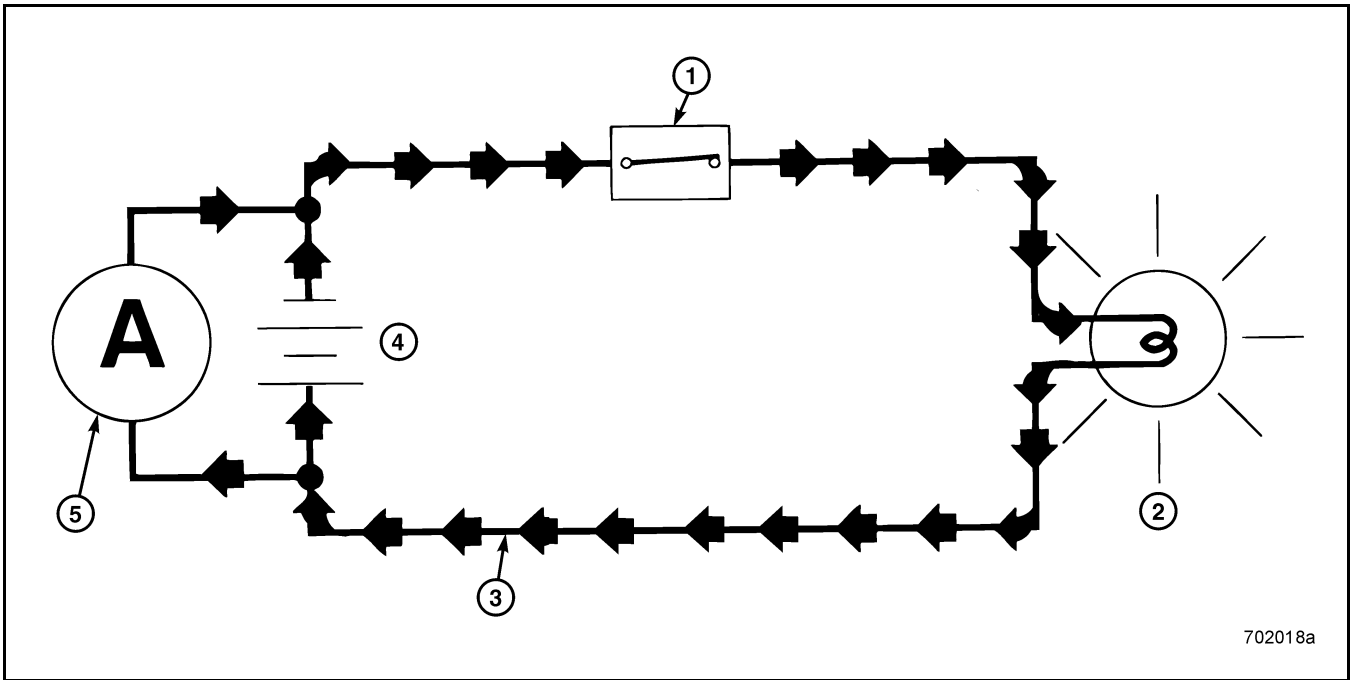


Figure 1 — Electrical Circuit

1. Switch (Control) 2. Light Bulb (Load) 3. Electron Flow	4. Battery (Voltage Storage & Source) 5. Alternator (Voltage Source — Electron Pump)
---	---



DESCRIPTION AND OPERATION

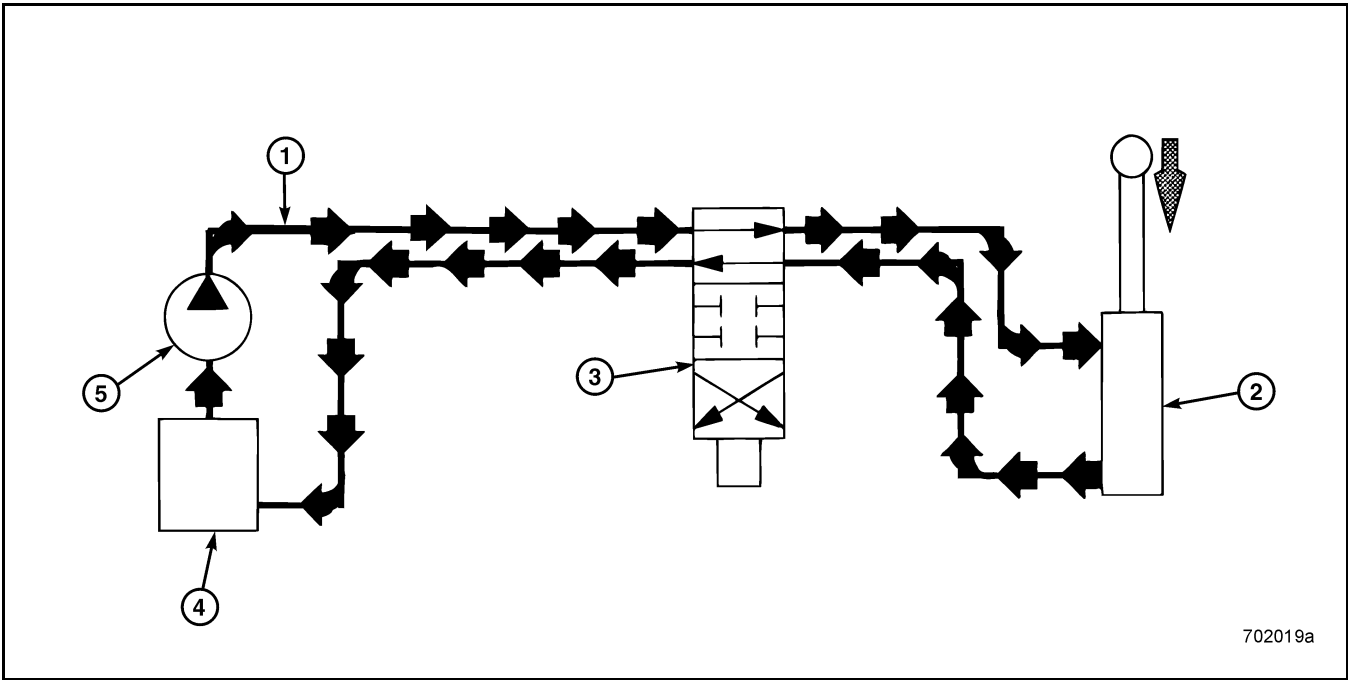


Figure 2 — Hydraulic Circuit

1. Fluid Flow 2. Cylinder (Load) 3. Valve (Control)	4. Reservoir (Fluid Storage) 5. Fluid Pump
---	---

A basic understanding of electricity begins with an understanding of a few basic electrical terms and concepts. They are:

- Voltage
- Current
- Resistance
- Circuit Types
- Ohm's Law



DESCRIPTION AND OPERATION

VOLTAGE

The force that causes the electrons to move is called “electromotive force.” Electromotive force is more commonly known as voltage. Voltage is the potential difference in electron pressure between two points. The potential difference is an excess of electrons on the negative side and a lack of electrons on the positive side.

The movement of electrons requires:

- An excess of electrons on one side.
- A lack of electrons on the other side.
- A path between the two.
- A force capable of moving the electrons.

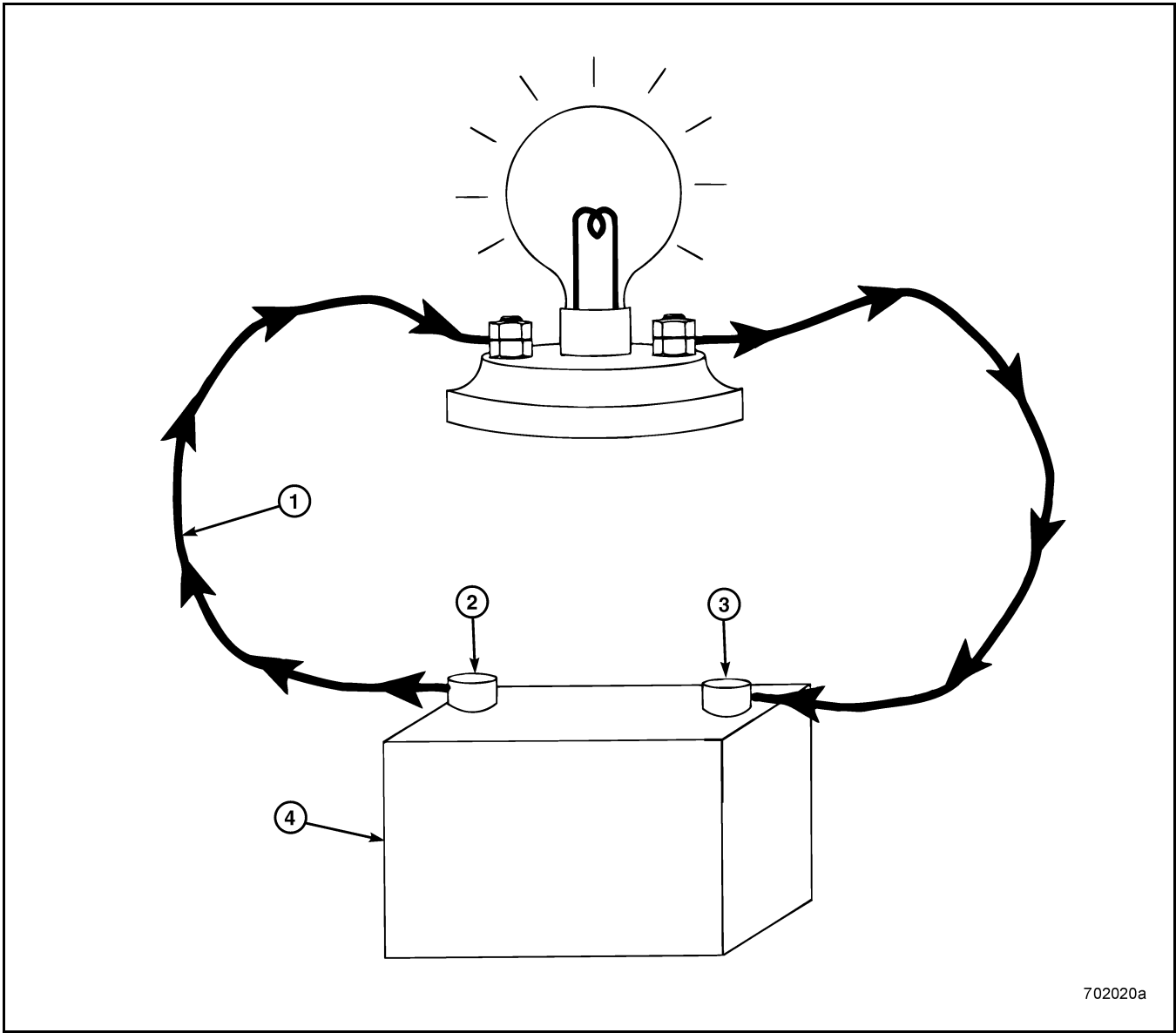


Figure 3 — Voltage (Electromotive Force)

1. Path for Electron Flow (Wire and Bulb Filament)	3. Positive Battery Terminal — Lack of Electrons
2. Negative Battery Terminal — Excess of Electrons	4. Battery (Force That Moves Electrons)



DESCRIPTION AND OPERATION

Sources of Voltage

Voltage can be generated by:

- Heat
- Friction
- Light
- Pressure
- Chemical Reaction
- Magnetism

The two sources of voltage available in a truck electrical system are chemical reaction and magnetism.

Voltage is created in a storage battery by chemical reaction. The reaction that takes place between the sulfuric acid/water (electrolyte) and lead plates inside the battery, produces a potential difference in electron pressure between the positive and negative terminals. As the free electrons are drawn from the battery, the reaction continues until the chemicals inside the battery are exhausted.

The battery provides and stores the voltage necessary for the starting system to crank the engine. The battery also provides the additional voltage needed when electrical demands exceed the electron flow supplied by the charging system.

CHEMICAL REACTION

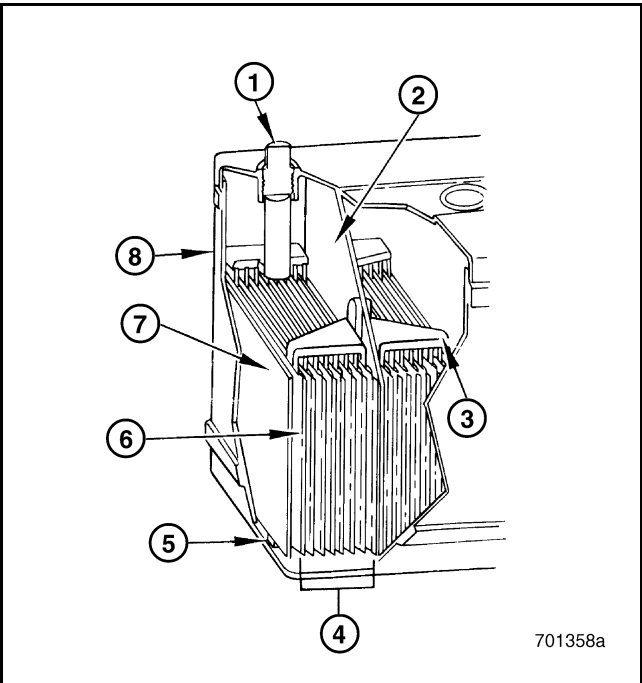


Figure 4 — Chemical Reaction (Battery)

1. Terminal Post	5. Element Rest
2. Cell Partition	6. Positive Plate (Lead Peroxide)
3. Intercell Connections	7. Negative Plate (Sponge Lead)
4. Plates and Separators	8. Case

MAGNETISM

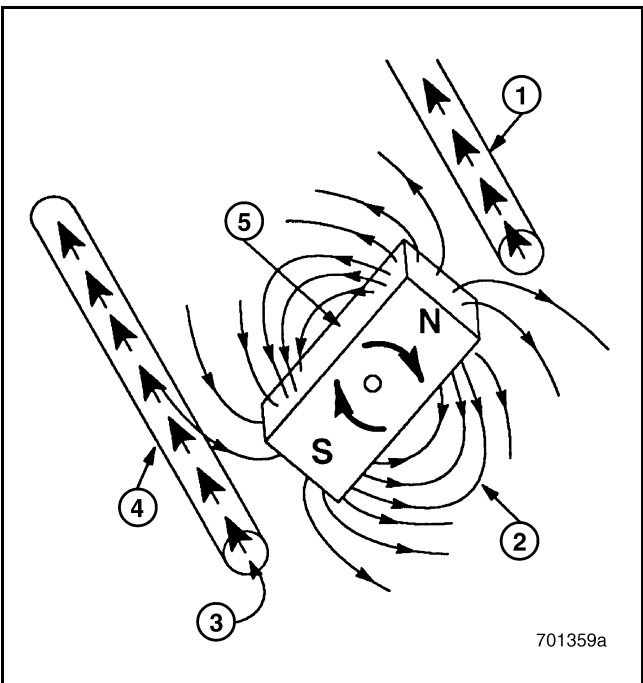


Figure 5 — Magnetism (Magnet and Conductor)

1. Conductor	4. Conductor
2. Magnetic Field	5. Permanent Magnet
3. Electron Flow	



DESCRIPTION AND OPERATION

Voltage is also generated when a wire is physically passed through a magnetic field. This process is called "induction." As an example, an alternator generates electricity when a magnetic field (rotor) is passed over a coil of wire (stator). Another example of voltage generated by the principle of induction is the speed sensor used to determine engine speed or vehicle speed. When a toothed gear passes in front of a magnetic pick-up, the magnetic field is broken and an electrical pulse is generated.

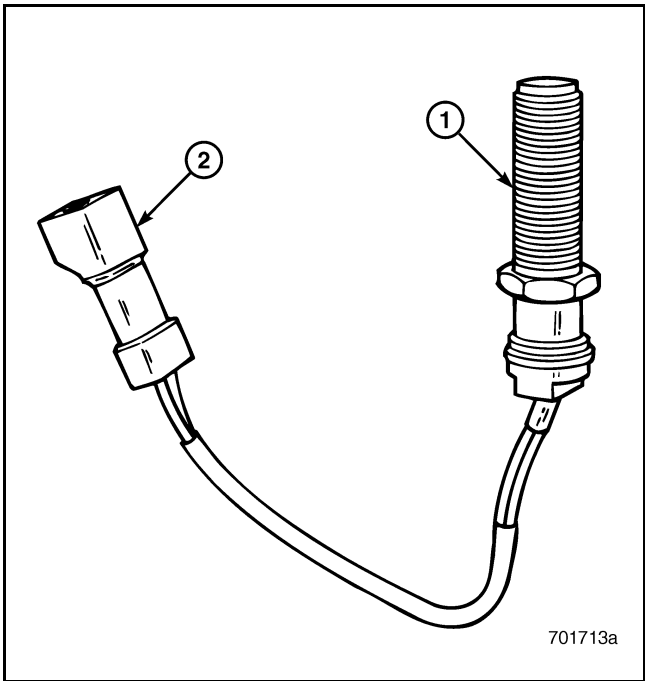


Figure 6 — Speed Sensor

1. Speed Sensor	2. Speed Sensor Connector (Integral)
-----------------	--------------------------------------



DESCRIPTION AND OPERATION

CURRENT

Electrical current is the movement of electrons through a conductor. Just as flow in a hydraulic system is measured as the amount of fluid flowing past a given point in a certain amount of time (expressed as gallons per minute), electrical current is measured as the amount of electrons moving past a certain point in a given amount of time. Electron flow is expressed in amperes or amps.

One AMP equals 6.25 trillion electrons flowing past a given point in one second.

Actual

Actual current flow is the flow of free electrons through a conductor. Current flow is the movement of negatively charged electrons from one atom to the next atom. The positive side of a voltage source (which has a lack of electrons) attracts the free electrons from the negative side (which is giving up electrons). Electrons flow from negative to positive.

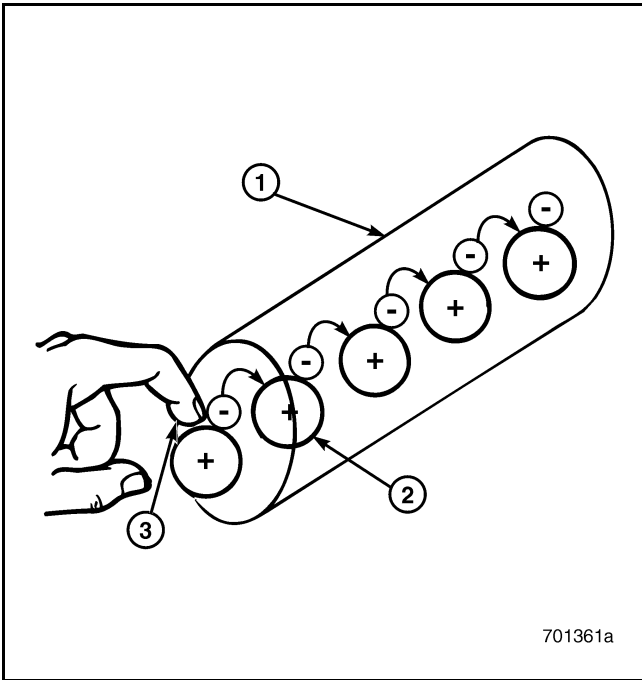


Figure 7 — Electron Current Flow Through a Conductor

1. Copper Wire	3. Voltage (Electron Push)
2. Copper Atom	

Conventional

Conventional current flow describes a circuit inside a battery. Atoms that gain or lose electrons are called ions. Excess electrons do not move through a battery, but are carried by ions. The movement of ions inside a battery is from the positive plates (or battery post) where free electrons are given up, to the negative plates (or battery post) where electrons are received. This makes it appear as though current flow is from positive to negative.

Conventional current flow is considered to be from positive to negative.

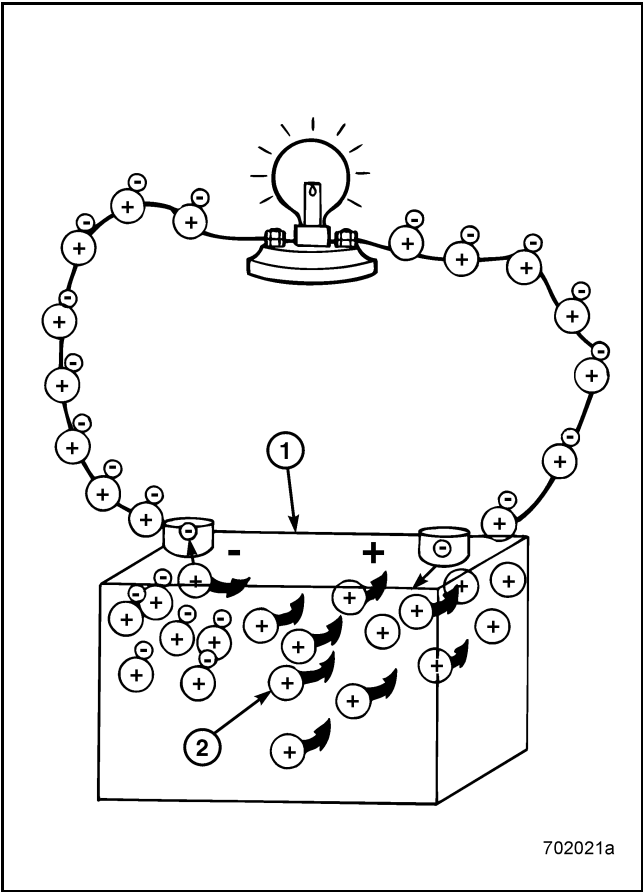


Figure 8 — Conventional Current Flow Through a Circuit

1. Battery	2. Migrating Positive Ions
------------	----------------------------



DESCRIPTION AND OPERATION

Types of Current

There are two types of current flow: Direct Current (DC) and Alternating Current (AC).

DIRECT CURRENT (DC)

In a direct current circuit, electrons flow in one direction only, from the negative terminal to the positive terminal. Direct current, supplied by the storage battery, is the type of current flow in a truck electrical system.

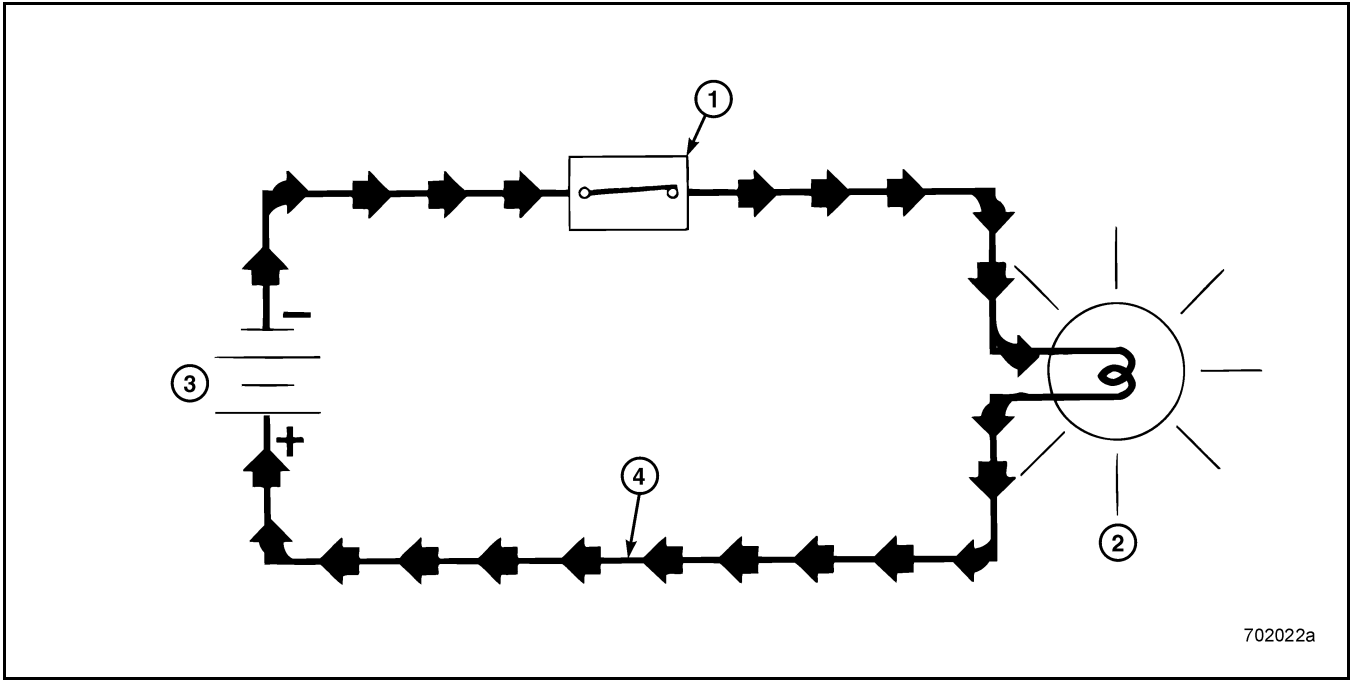


Figure 9 — Direct Current

1. Closed Switch 2. Lamp 3. Battery (Force to Move Current)	4. Electrons flow in one direction only, from negative to positive.
---	---



DESCRIPTION AND OPERATION

ALTERNATING CURRENT (AC)

In an alternating current circuit, electron flow changes direction at a fixed rate or cycle. Alternating current is the type of current produced by the charging system alternator. This type of current however, is not compatible with a vehicle electrical system. To be usable, it must be

converted (or rectified) into direct current. To accomplish this, diodes are added to the circuit. Diodes are used in an electrical system much like check valves in a hydraulic or pneumatic system. They allow current flow in one direction, and block current flow when the cycle reverses (in the opposite direction).

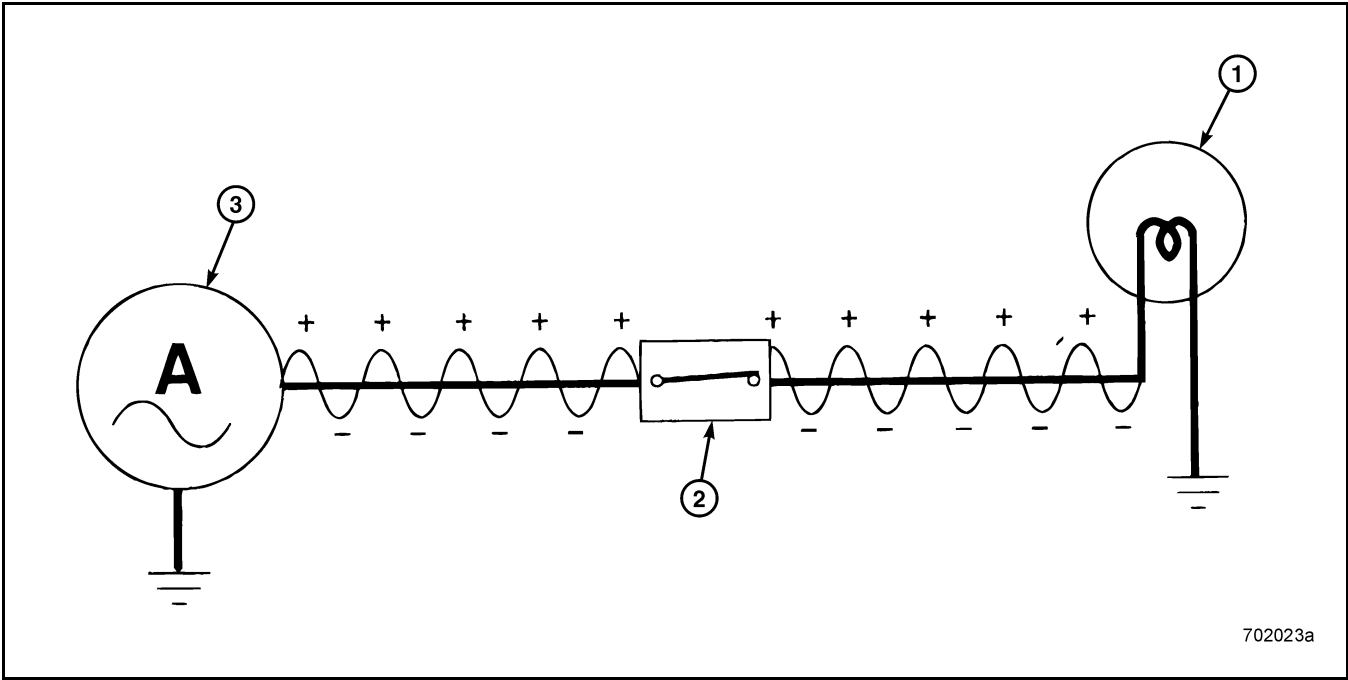


Figure 10 — Alternating Current

1. Lamp (Uses DC Current)	3. Alternator (Produces AC Current)
2. Closed Switch	



DESCRIPTION AND OPERATION

RESISTANCE

Electrical current is the movement of electrons from one atom to the next. Electrons, however, resist being moved out of their shells. The atoms of some substances (such as copper), give up their electrons more readily than the atoms of other substances (such as nickel). Atoms of substances like rubber do not give up electrons easily. Substances that readily give up electrons are called “conductors.” Substances that resist giving up electrons are called “resistors.” Substances that do not give up electrons easily are called “insulators.”

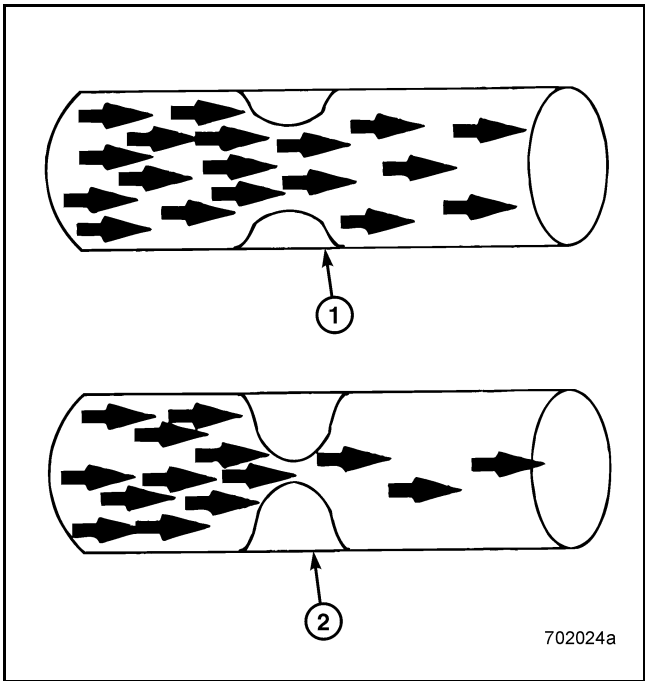


Figure 11 — Resistance in a Conductor

1. Less Resistance, More Current Flow	2. More Resistance, Less Current Flow
---------------------------------------	---------------------------------------

The capacity of a substance to resist electron flow is called “resistance.” Resistance is expressed in ohms. All components in an electrical circuit (light bulbs, motors, solenoids, sensors, horns) add to the total resistance in a circuit.

Resistance, Heat and Current Flow

Electron flow through a conductor or component generates a certain amount of heat. A light bulb illuminates when electrons flow through the filament of the bulb. The thin filament inside the light bulb offers such a great resistance to electron flow that the filament heats up and glows.

Wires used in an electric circuit are selected according to the amount of current they must carry. Thick wires have less resistance to current than thin wires, and so are used to carry greater amounts of current.

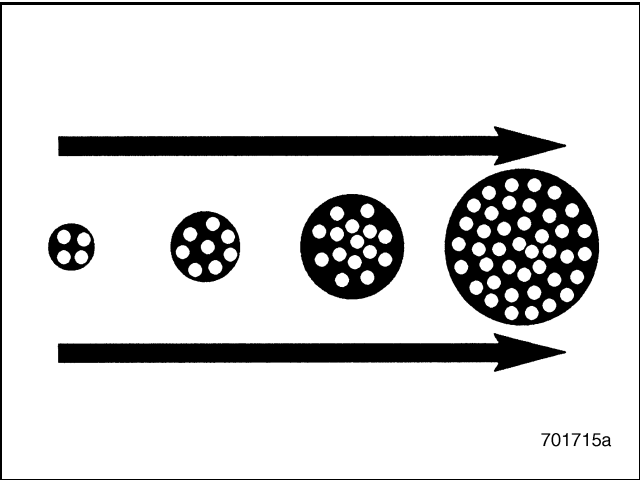


Figure 12 — Wire Size, Current Capacity and Resistance

Properly selected wires in a circuit have a low resistance. If the resistance of a wire is too high, circuit operation will be faulty in some way. Examples of high-resistance conditions include partially cut wires and loose or corroded connections. These types of faults can be compared to a faulty hydraulic circuit where oil flow is restricted by a kinked or leaking hydraulic hose. With less oil flow, the hydraulic circuit will not operate at full potential.



DESCRIPTION AND OPERATION

CIRCUIT TYPES

The three basic types of circuits are series, parallel and series-parallel.

Series Circuits

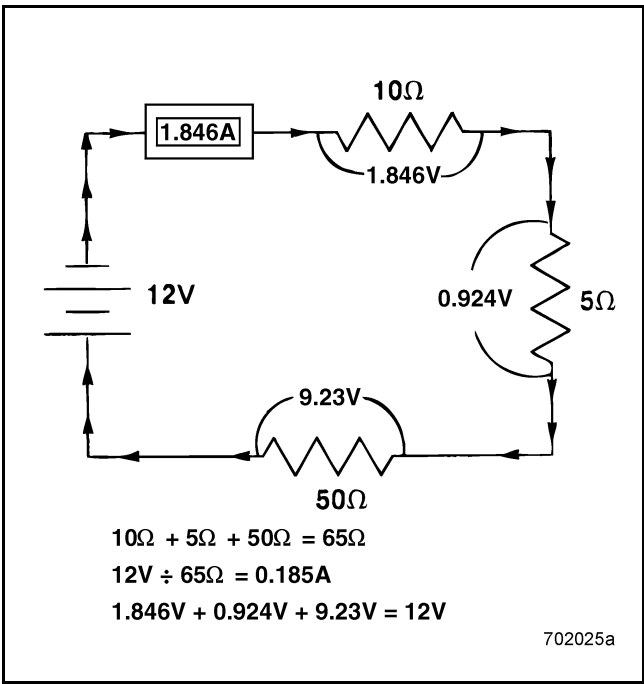


Figure 13 — Series Circuit

- Series circuits are the simplest of circuits. In a series circuit, all the resistors are connected together (end to end), to one voltage source. There is only one path for electron flow. Series circuits have the following characteristics:
- The total resistance of the circuit is equal to the sum of each resistor.
 - Current flow (amperage) through each resistor in the circuit is the same, and is equal to the total amperage through the circuit.
 - The voltage drop across each resistor equals resistance multiplied by the amperage.
 - The source voltage is equal to the sum of the voltage drops across each resistor in the circuit.

If one resistor in a series circuit is disconnected, the path for electron flow is broken, and the entire circuit will not operate.

Parallel Circuits

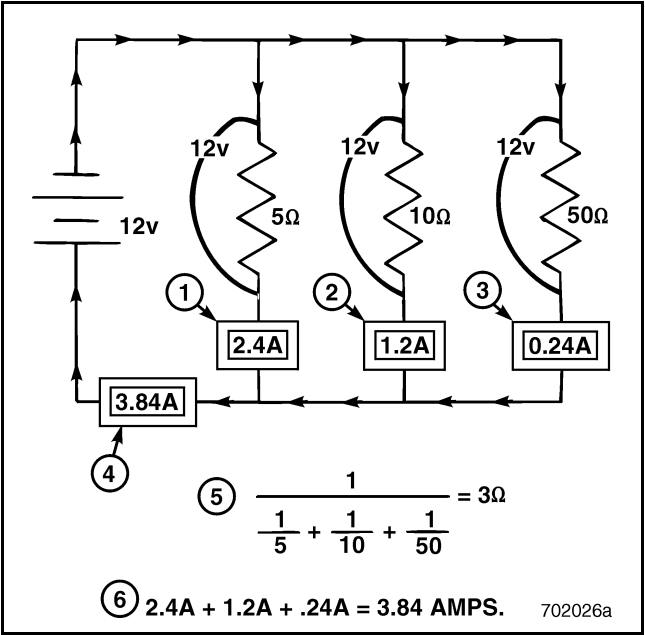


Figure 14 — Parallel Circuit

1. Branch 1 Amperage	5. Total Resistance Calculation
2. Branch 2 Amperage	6. Total Amperage Calculation
3. Branch 3 Amperage	
4. 3.84 Amps (Total Amps)	

- A parallel circuit is one in which the resistors are connected side by side, and there are several paths for current flow. Parallel circuits, which are the most commonly used circuits in truck electrical systems are parallel circuits. The following principles apply.
- Total resistance of the circuit is always less than the value of the lowest resistor.
 - Current flow (amperage) through each resistor is different and depends on the value of the resistor.
 - The voltage drop across each resistor is the same, and is equal to the source voltage.
 - Total circuit amperage is equal to the sum of the amperage through each branch.
 - If one resistor in a parallel circuit is disconnected, the remaining circuit still operates.



DESCRIPTION AND OPERATION

To calculate total resistance in a parallel circuit:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

702015a

Figure 15 — Calculating Resistance

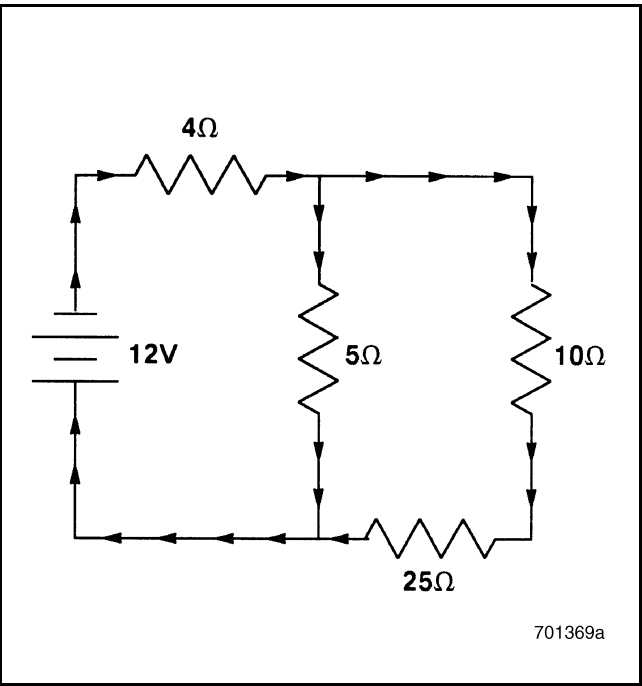
To calculate total resistance in a parallel circuit with only two branches:

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

702016a

Figure 16 — Calculating Resistance

Series-Parallel Circuits



701369a

Figure 17 — Series-Parallel Circuit

When series and parallel connections are used in the same circuit, it is called a “series-parallel circuit.” Calculating total resistance in a series-parallel circuit involves simplifying the circuit into a basic series circuit. To do this first calculate the total resistance of the parallel branches. Then add the result to the resistance value of the series part of the circuit. Once the circuit is broken down into a simple series circuit, amperage, total resistance and voltage drops can be determined. Series-parallel circuits are not used in truck electrical systems very often.



DESCRIPTION AND OPERATION

OHM'S LAW

Ohm's Law describes the relationship between voltage, resistance and amperage. When any two variables (voltage, amperage or resistance) are known, the third variable can be determined mathematically. Ohm's Law states that voltage (V) and amperage (I or A) are directly proportional to any one value of resistance (R or O), and amperage is inversely proportional to voltage when voltage remains constant and resistance changes.

The mathematical formula for Ohm's Law is:

$$V = A \times O$$
$$A = \frac{V}{O}$$
$$O = \frac{V}{A}$$

701716a

Figure 18 — Mathematical Formulas for Ohm's Law

An easy way to remember Ohm's Law is to use the following Ohm's Law circle:

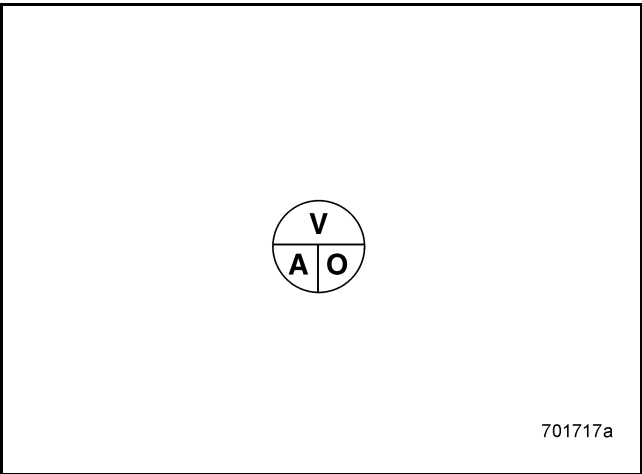


Figure 19 — Ohm's Law Circle

To use the Ohm's Law circle, simply cover the unknown variable, then perform the mathematical operation (either multiplication or division), using the two remaining variables.

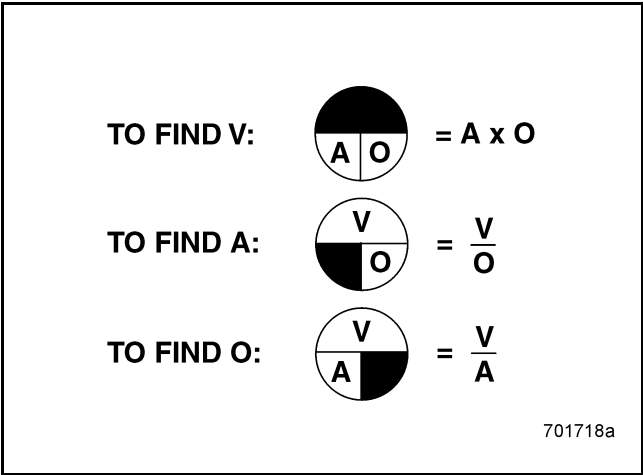


Figure 20 — Using the Ohm's Law Circle

To make it simple, the relationship between voltage, resistance and amperage can be described as follows:

- As voltage increases and resistance remains constant, current increases.
- As voltage decreases and resistance remains constant, current decreases.
- As resistance increases and voltage remains constant, current decreases.
- As resistance decreases and voltage remains constant, current increases.

It is not usually necessary to use Ohm's Law when troubleshooting an electrical problem, but understanding the relationship between voltage, resistance and amperage makes the job much easier.



DESCRIPTION AND OPERATION

Given the values for current (amps) and resistance (ohms) shown in Figure 21, use Ohm's Law to determine the value for voltage (volts). Multiply 4 amps of current by 6 ohms of resistance. What is the total voltage (volts) in the series circuit?

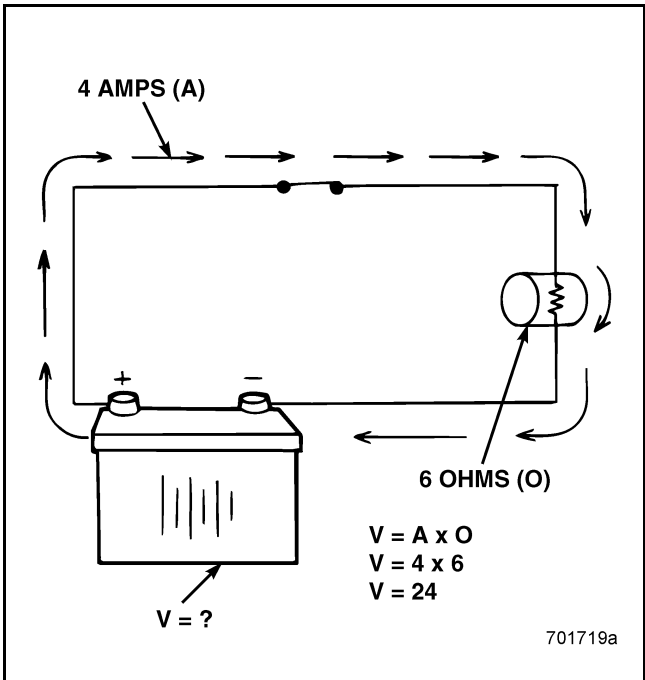


Figure 21 — Finding Voltage (Series Circuit)

Given the values for voltage (volts) and resistance (ohms) shown in Figure 22, use Ohm's Law to determine the value for current (amperage). Divide 18 volts by 36 ohms of resistance. What is the total current flow (amperage) in the series circuit?

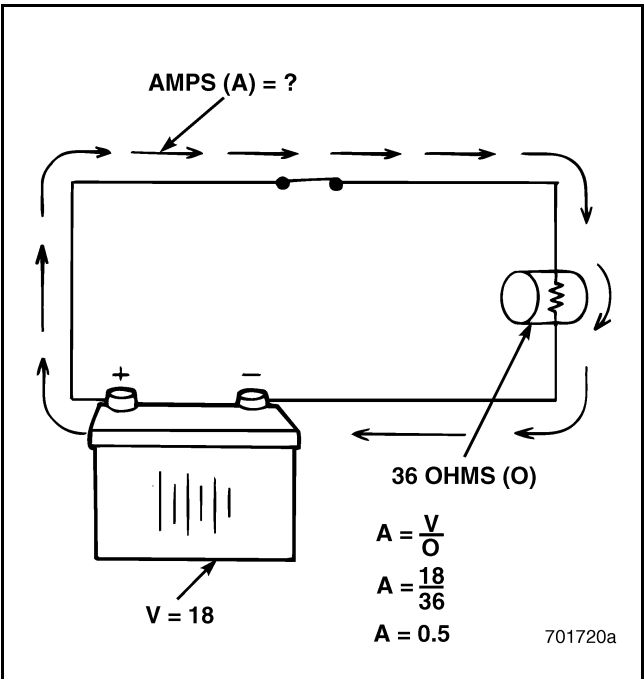


Figure 22 — Finding Amperage (Series Circuit)

Given the values for current (amps) and voltage (volts) shown in Figure 23, use Ohm's Law to determine the value for resistance (ohms). Divide 12 volts by 8 amps of current. What is the total resistance (ohms) in the series circuit?

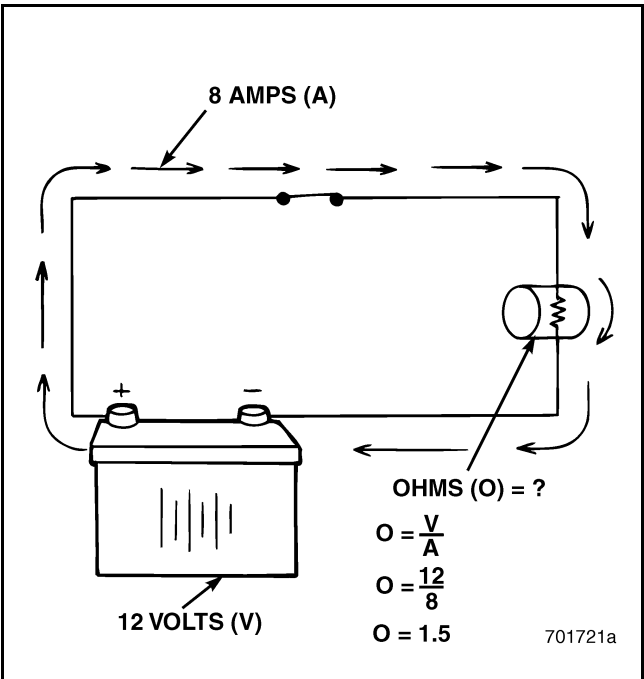


Figure 23 — Finding Resistance (Series Circuit)



DESCRIPTION AND OPERATION

EXPRESSING ELECTRICAL VALUES

In many instances, the numerical values used to express amperage, voltage and resistance, are either very large or very small. For example, resistance in a circuit may be millions of ohms, or current (amperage) may be in the milliampere range (a few thousandths or millionths of an ampere).

It is not practical to express these large or small electrical values in pure numeric form, and it is not possible for a meter to display these values.

In these cases, it is more practical to express values as multiples or submultiples of the basic values. The values are based on the decimal system of tens, hundreds, thousands and so on, with a prefix to designate the value. For small units (submultiples), “milli” and “micro” are used. For large units (multiples), “kilo” and “mega” are used. As an example, 5,000,000 ohms is written as 5M ohms. When measuring the resistance of an unknown resistor and the multimeter is displaying 12.30K, the value of the resistor is actually 12,300 ohms, not 12.30 ohms.

It is important to know and understand these prefixes. The following table lists the most common prefixes used to express large or small electrical values.

ELECTRICAL VALUES

Prefix	Symbol	Relation to Basic Unit	Examples
mega	M	1,000,000 (or 1×10^6)	5 M Ω (megaohms) = 5,000,000 ohms or 5×10^6 ohms
kilo	k	1,000 (or 1×10^3)	12.30 k Ω (kilo-ohms) = 12,300 ohms or 12.3×10^3
milli	m	0.001 (or 1×10^{-3})	48 mA (milliamperes) = 0.048 ampere or 48×10^{-3}
micro	μ	0.000,0001 (or 1×10^{-6})	15 μ A (microamperes) = 0.000,015 ampere or 15×10^{-6}



DESCRIPTION AND OPERATION

DIAGNOSTIC TOOLS

Most electrical test procedures require taking measurements of voltage, current flow (amperage), resistance and continuity. Some important diagnostic tools that will be needed are:

Jumper Wire

A jumper wire is used to bypass an open circuit by providing an alternate path for current flow. It is a short length of wire with either alligator clips or probes on each end, and provides a quick means of bypassing switches, suspected opens, and other components. Adding a 5-amp fuse to the jumper wire is recommended to protect the circuit being tested.

CAUTION

Never connect a jumper across a load, such as a motor that is wired between hot and ground. Doing so would introduce a direct short that could result in a fire and cause serious injury.

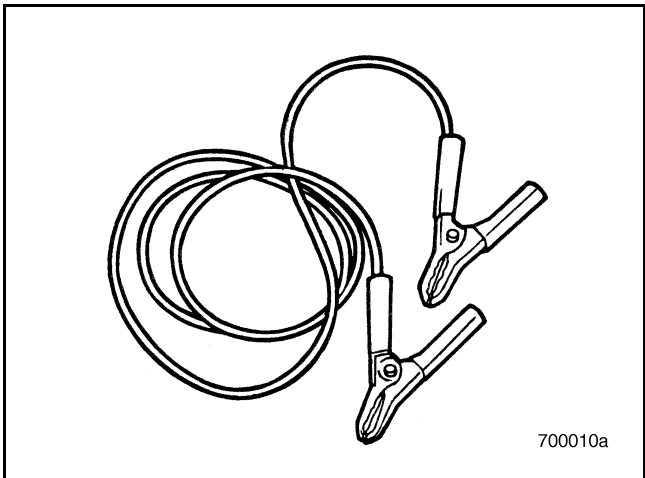


Figure 24 — Jumper Wire

Multimeter (Volt-Ohm Meter)

Probably the most valuable tool needed for diagnostics is the multimeter, which is used to take accurate measurements of voltage, amperage and resistance. Digital multimeters are recommended because of their accuracy, ease of use, circuit protection capabilities, and are required for troubleshooting circuits containing solid state components or digital circuitry.

Multimeters are available with a variety of functions. All multimeters measure voltage, current and resistance. Some meters can perform additional functions such as quick continuity checks, capacitance checks and diode tests.

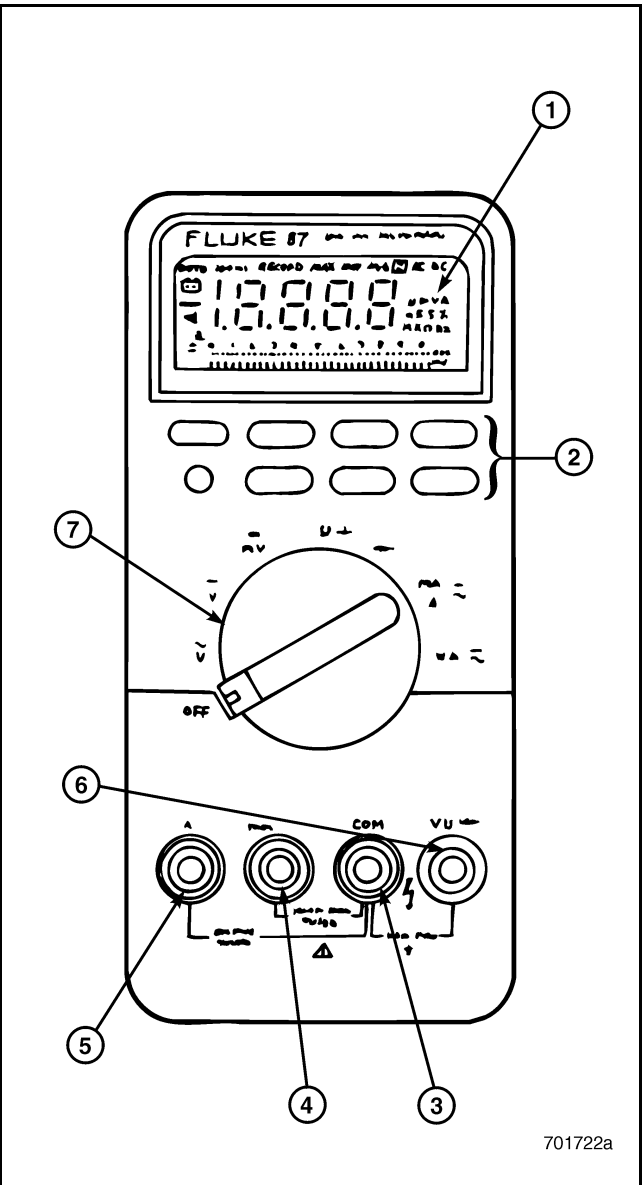


Figure 25 — Digital Multimeter (Volt-Ohm Meter)

1. Digital Display Screen	4. Milli/Microampere Lead Input
2. Function Selector Switches (continuity check, display hold, range change, etc.)	5. Amperage Lead Input
3. Common Lead Input	6. Volt-Ohm Lead Input
	7. Function Selector Dial



DESCRIPTION AND OPERATION

To get the most from the multimeter, it is important to read the instructions supplied with the instrument. Always follow the manufacturer's recommendations and safety precautions regarding proper input limits and lead connections. When working with electricity, always adhere to all safety precautions

The following illustration provides an explanation for the various symbols that may be found on most meters.

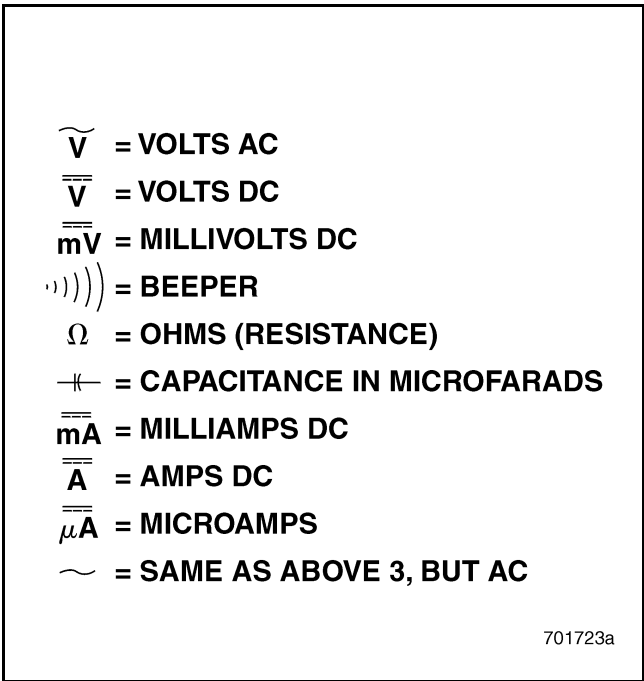


Figure 26 — Rotary Dial Selector Function Symbols

Multimeter (Volt-Ohm Meter) Usage

MEASURING VOLTAGE

The easiest way to begin troubleshooting a circuit is by checking for the presence of voltage. To check for DC voltage, use a multimeter set to the VDC function. With the circuit powered, connect the negative lead to a good ground. Then touch the positive lead to various connections along the suspect circuit.

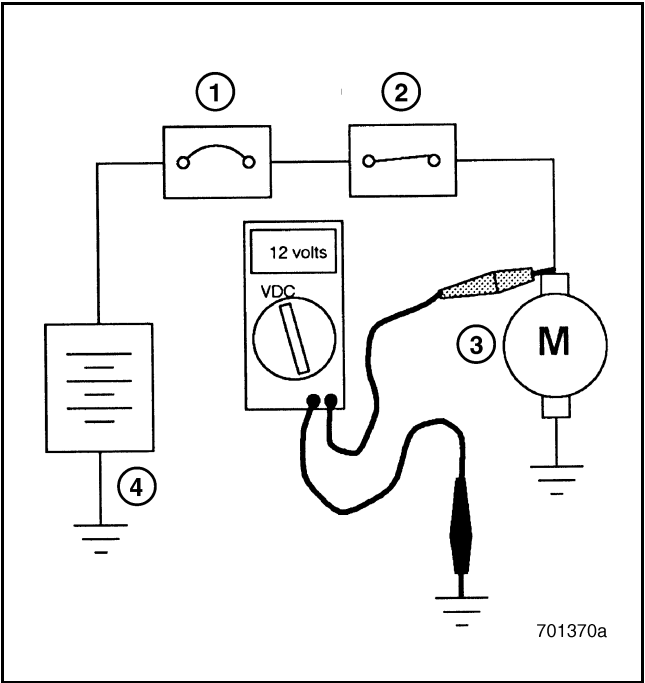


Figure 27 — Measuring Voltage

- | | |
|--------------------|------------|
| 1. Circuit Breaker | 3. Motor |
| 2. Switch | 4. Battery |

The meter should indicate the approximate source voltage, but may vary slightly due to the length of the wire runs and other factors. A difference of one or more volts, however, indicates that a high-resistance condition (loose or corroded connection, damaged wire, etc.) may exist in the circuit.

- 11 or more Volts — Circuit is OK.
- Less than 11 Volts — Poor Connections.
- 0 Volts — Circuit is Open.



DESCRIPTION AND OPERATION

VOLTAGE DROP

A circuit that is operating properly uses a specific amount of voltage. The amount of voltage used by a component is indicated by the voltage drop. As long as circuit resistance remains normal, voltage drop across a component remains normal. Voltage drop across a component in a parallel circuit should be equal to, or close to, battery voltage. If a component is dropping less voltage than expected, an unwanted resistance exists elsewhere in the circuit, and is in series with the load (component).

Devices such as switches, solenoids, cables and connectors should have no measurable, or only a fractional voltage drop. Measuring voltage drop across these types of components is useful in determining if an unwanted high resistance exists inside the components. Voltage drop is measured by placing the meter in parallel with the device.

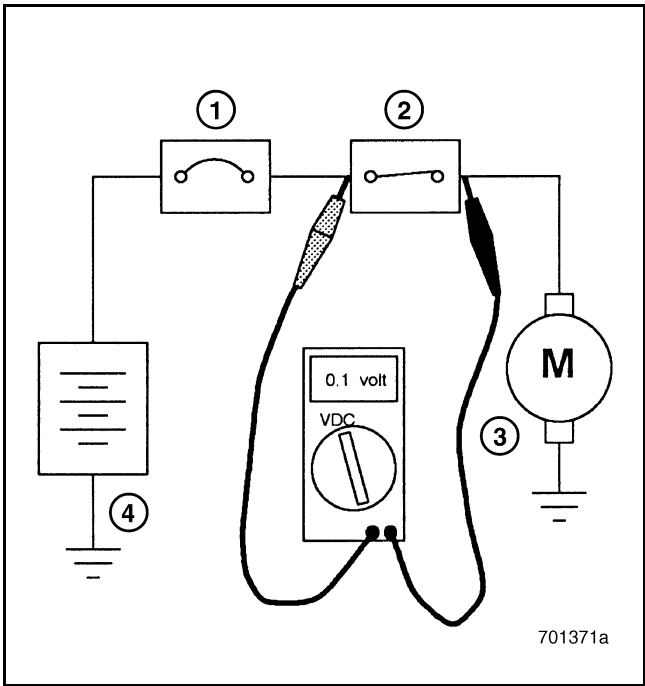


Figure 28 — Measuring Voltage Drop

1. Circuit Breaker	3. Motor
2. Switch	4. Battery

Depending on the device being tested, voltage drop should be:

- 0.1 Volt or less for a wire, switch, cable, or connector.
- 0.3 Volt across solenoid contacts.
- 0.5 Volt for an insulated or ground circuit.

AMPERAGE

Amperage is the amount of current that flows through a circuit. Measure amperage with the multimeter set to the AMPS function. Measuring amperage requires placing the meter in series with the circuit so that current passes through the meter.

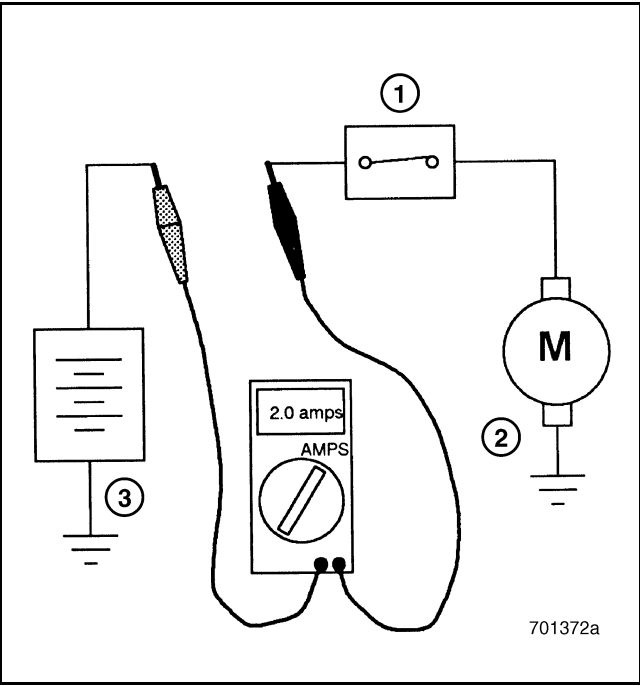


Figure 29 — Measure Amperage

1. Switch	3. Battery
2. Motor	



DESCRIPTION AND OPERATION

Measuring current involves “opening” the circuit to connect the meter. This can disturb an existing fault and prevent its discovery. To prevent this from happening, clamp-on type current probes are available that detect current through the principle of induction.

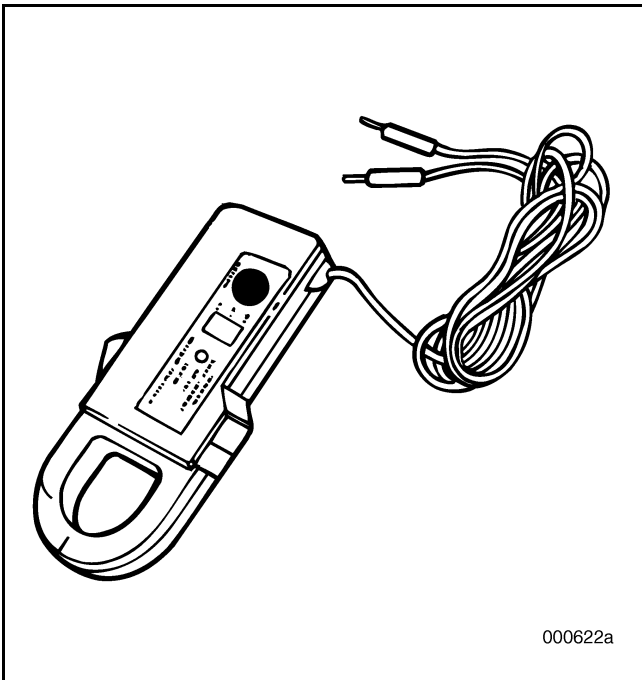


Figure 30 — Clamp-on Current Probe

RESISTANCE

Resistance is the opposition to current flow within a circuit. To measure resistance, set the multimeter to the resistance (ohms) function, and place it in parallel with the component.

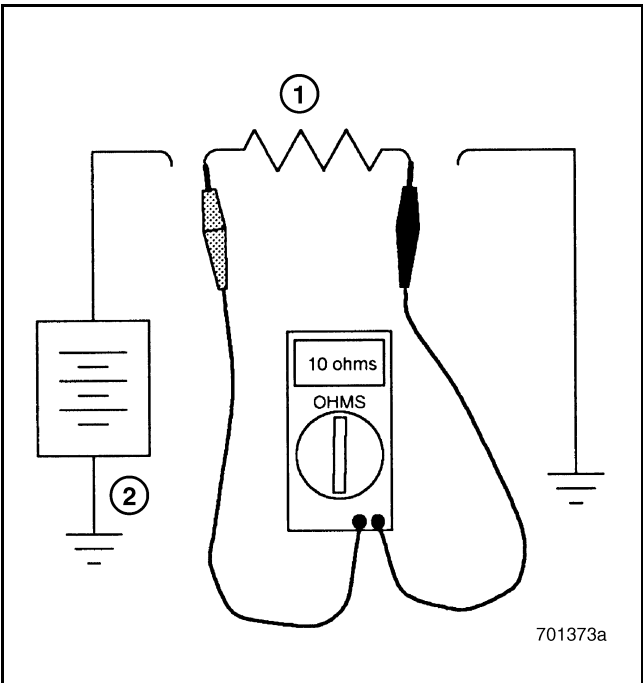


Figure 31 — Measuring Resistance

1. Resistance (disconnected from circuit)	2. Battery
---	------------



DESCRIPTION AND OPERATION

Since the multimeter measures resistance by passing a small current through the component, the power in the circuit must be turned OFF. For an accurate resistance measurement, the component should be disconnected from the circuit. Otherwise, resistance from elsewhere in the circuit may affect the measurement.

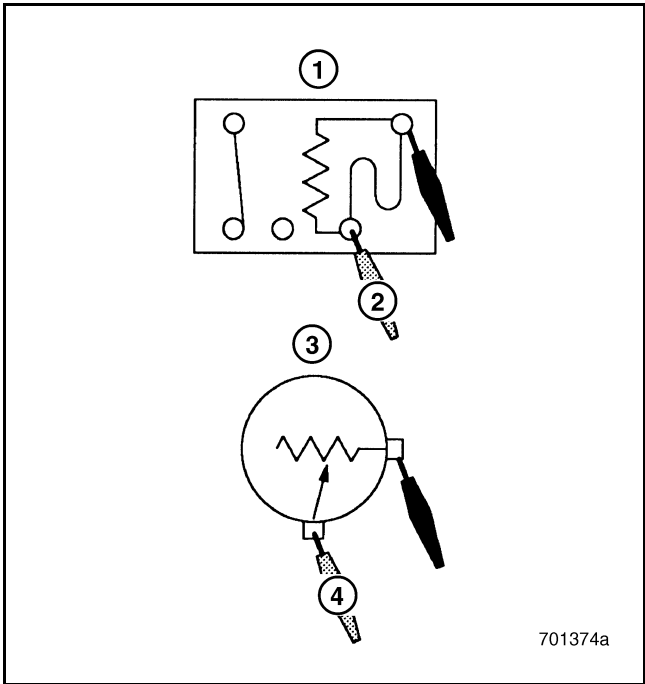


Figure 32 — Resistance Measurements

1. Relay	3. Sensor
2. Around 70 Ohms	4. Variable Resistance

CONTINUITY

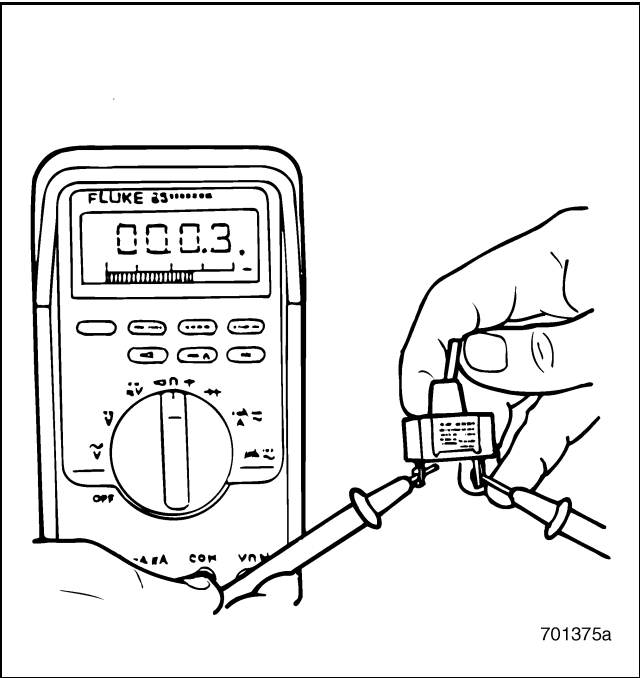


Figure 33 — Checking Continuity of a Toggle Switch

Continuity is a condition of very low or no resistance which indicates that a complete path for current flow exists. A multimeter set to the OHMS or CONTINUITY function is used to check continuity by placing the leads at each end of the component, wire, switch or other component.



DESCRIPTION AND OPERATION

Continuity is indicated by the following meter readings:

- Low to zero resistance reading
 - A continuous path for current flow exists. Circuit has continuity.
- High resistance reading
 - Poor connections, unwanted high resistance, defective component, etc.
- Infinity (indicated by OL on the digital readout)
 - Indicates an open circuit, or that the path for current flow is broken.

The meter emits an audible beep when in the continuity function and circuit continuity is detected.

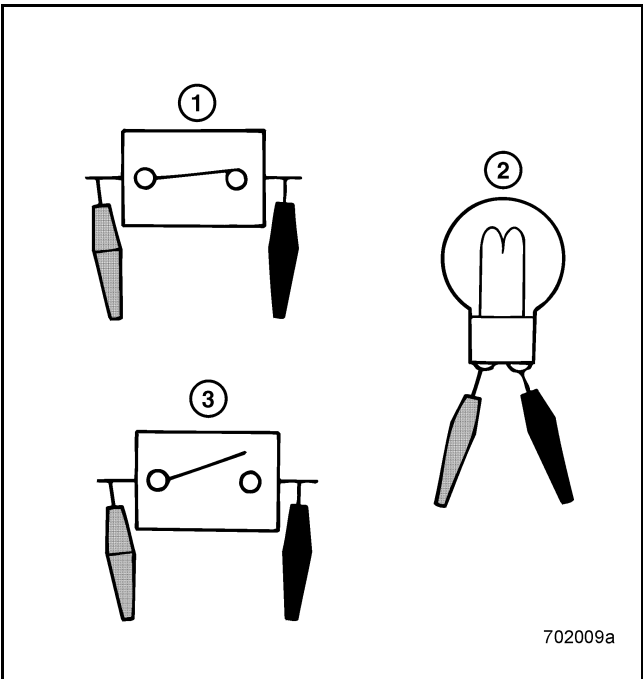


Figure 34 — Continuity Checks

1. Closed Switch (No Resistance)	3. Open Switch (Infinite Resistance)
2. Light Bulb (Very Low Resistance)	



DESCRIPTION AND OPERATION

TROUBLESHOOTING METHOD

Diagnostic Techniques

Troubleshooting an electrical problem is easy when a logical method is used to isolate the problem. Considerable time can be wasted with “hit-or-miss” diagnostic procedures. The following steps provide an orderly method for troubleshooting electrical problems:

1. VERIFY THE PROBLEM

Operate the system and check all the symptoms to verify the accuracy of the complaint. Try to learn as much about the nature, location and probable cause of the failure.

2. ISOLATE THE PROBLEM

Study the schematic diagrams to see how the circuit operates and to determine which components may share the same circuit.

Operate the faulty circuit in different modes to determine the exact nature of the failure. Check to see whether the failure is isolated to one component or affects several components on the same circuit. Also determine if the fault occurs across a number of seemingly unrelated circuits.

Narrow the possible causes and locations of the failure. Start with the obvious by first looking for broken or frayed wires, loose, corroded or disengaged connections, or poor ground connections.

3. TEST AND VERIFY THE CAUSE

Once a probable cause has been determined, use standard electrical test procedures to verify.

4. MAKE THE REPAIRS

Repair or replace the faulty component, connector or wire.

5. VERIFY THE REPAIR

Operate the system and check that the repair has eliminated the failure.

Diagnostic Applications

For a circuit to operate properly, voltage must:

- Originate at the positive (+) battery post.
- Flow uninterrupted through the conductors (wires), and through any controls (switches, relays, etc.) in the circuit.
- Flow through the component (light bulb, motor, etc.) to perform its function.
- Flow back to the negative (–) battery post.

Keep these requirements in mind when beginning the troubleshooting process. Always start with the obvious. Begin by looking for loose, broken or corroded connections or wires, burned-out bulbs, blown circuit breakers, inoperative components, misadjusted switches, and other problems.

If an obvious cause cannot be located, begin troubleshooting by consulting the wiring diagrams and analyzing the circuits. If a problem exists within an individual circuit only, correcting the fault should be a matter of simply locating and repairing or replacing the faulty item (component, conductor, control, etc.).

Circuits within an electrical system may share common connectors, grounds, power sources and other elements. Faults are frequently seen across several components within the same circuit, or across seemingly unrelated circuits. Begin troubleshooting these types of problems by first locating and isolating, and then testing the areas that the circuits have in common.

Faults that can render a circuit inefficient or inoperative are:

- Open circuits
- Short circuits
- Grounded circuits
- High-resistance circuits



DESCRIPTION AND OPERATION

OPEN CIRCUIT

A circuit in which the path for current flow has been broken is called an open circuit and will not operate.

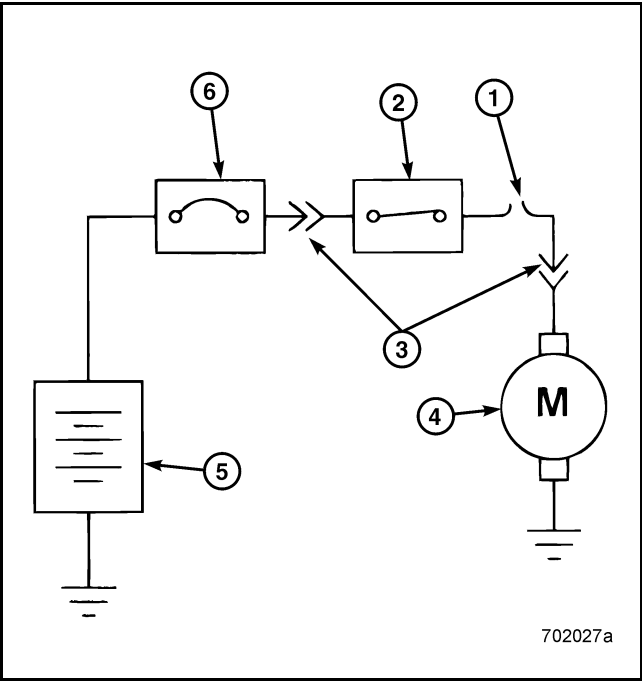


Figure 35 — Open Circuit

1. Path for current flow is broken	4. Motor
2. Switch (Closed)	5. Battery
3. Connectors	6. Circuit Breaker

SHORT CIRCUIT

A short circuit is a circuit in which an alternate path for current flow has occurred, allowing current to bypass part of its intended load. Shorts can occur within a component (inside a starter motor, relay, or other device) when the insulation of overlaying wires rubs through, allowing previously unconnected circuits to contact each other. This type of short is known as a “cross-circuit” short.

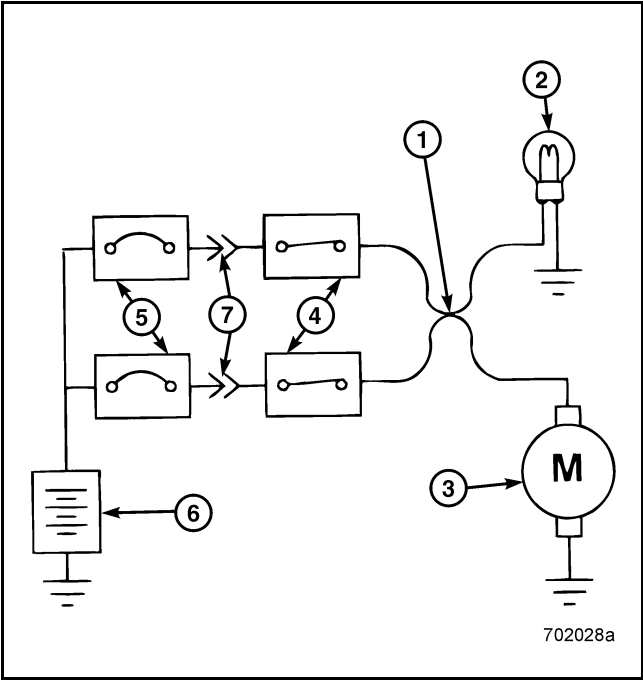


Figure 36 — Short Circuit

1. Short Across Circuits	5. Circuit Breaker
2. Lamp	6. Battery
3. Motor	7. Connectors
4. Switch	



DESCRIPTION AND OPERATION

GROUNDING CIRCUIT

In a grounded circuit, all of the current has found an alternate path of low resistance back to the negative battery terminal before reaching its intended load. A grounded circuit is evidence of an inoperative circuit, a blown circuit breaker, and/or excessive battery drain.

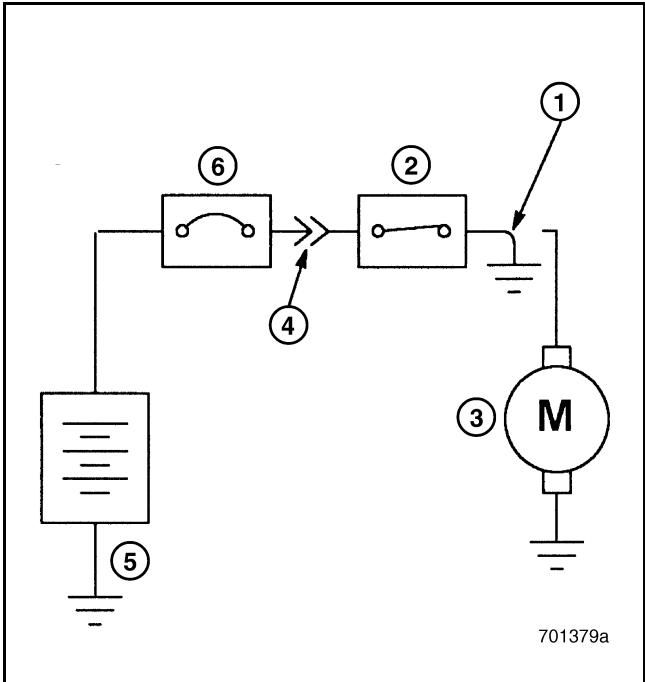


Figure 37 — Grounded Circuit

1. Alternate Current Path to Ground	4. Connector
2. Switch	5. Battery
3. Motor	6. Circuit Breaker

HIGH-RESISTANCE CIRCUIT

A high-resistance circuit is one in which an unwanted high resistance condition such as a loose, broken, or corroded wire or connector, is causing a decrease in current flow. These types of faults are usually evidenced as dim lights, slow operation, or other performance problems.

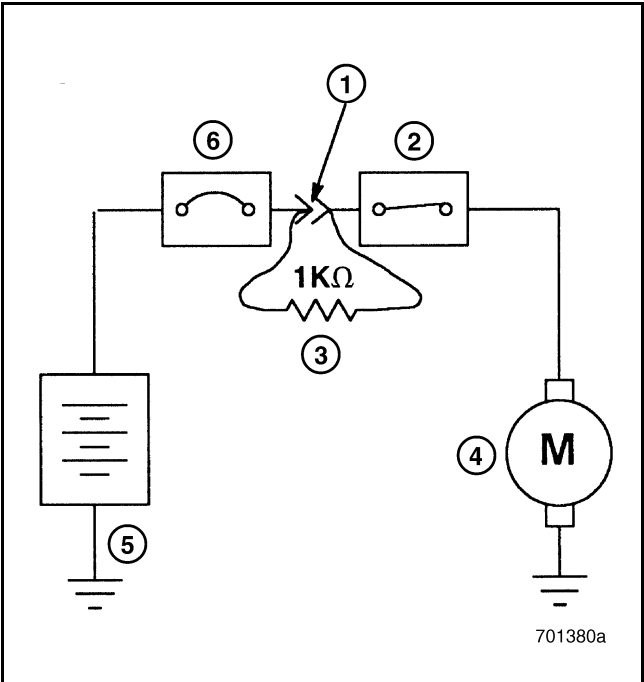


Figure 38 — High-Resistance Circuit

1. Connector	4. Motor
2. Switch	5. Battery
3. Unwanted High Resistance Inside Connector	6. Circuit Breaker



DESCRIPTION AND OPERATION

Locating Shorts or Grounded Circuits

Circuit breakers that continuously trip or do not reset, are usually indications of a shorted or grounded circuit. The following procedure can be used to locate the short:

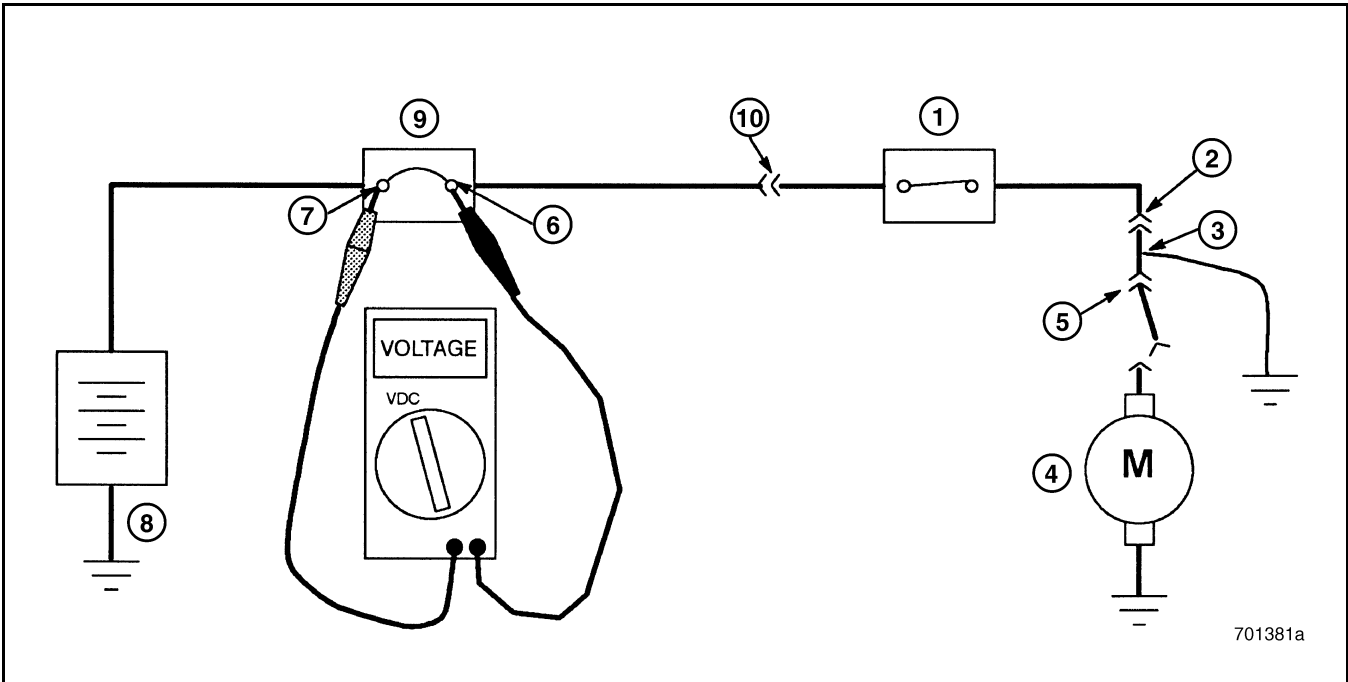


Figure 39 — Locating Shorts and Grounds

1. Switch (Closed) 2. Connector 2 (Meter Goes to Zero Volts) 3. Short to Ground 4. Motor (Disconnected) 5. Connector 3 (Meter Stays at 12 Volts)	6. "AUX" Terminal 7. "BAT" Terminal 8. Battery 9. Circuit Breaker 10. Connector 1 (Meter Goes to Zero Volts)
--	--

1. Turn OFF all components that are powered through the circuit breaker.
2. Disconnect all loads powered through the circuit breaker by:
 - Disconnecting connectors from motors, solenoids, and other devices.
 - Removing light bulbs or other loads.
3. Set the multimeter to the VDC function. Then connect the black lead to a good ground, and the red lead to the battery terminal of the suspect circuit breaker.
 - The multimeter should indicate battery voltage. (If the circuit breaker is powered through the key switch, the key must be turned ON.)
4. Disconnect the multimeter lead from ground. Then connect to the load side of the circuit breaker.



DESCRIPTION AND OPERATION

5. Close or jumper any normally opened switches found in the circuit.
- If the multimeter indicates no voltage, the short is located in one of the disconnected components.
 - If the multimeter indicates battery voltage, the short is located in the wiring. To isolate the short, disconnect and then reconnect each connector found in the circuit one at a time, beginning with the connector closest to the circuit breaker.
- If the multimeter drops to 0 voltage when a connector is disengaged, the wiring between the connector and the circuit breaker is good.
 - If the multimeter remains at battery voltage when a connector is disengaged, the short exists somewhere between that connector and the last connector disconnected. Refer to the previous illustration.

Circuit Continuity Checks

Continuity checks can be used to locate a short, ground or open in a circuit.

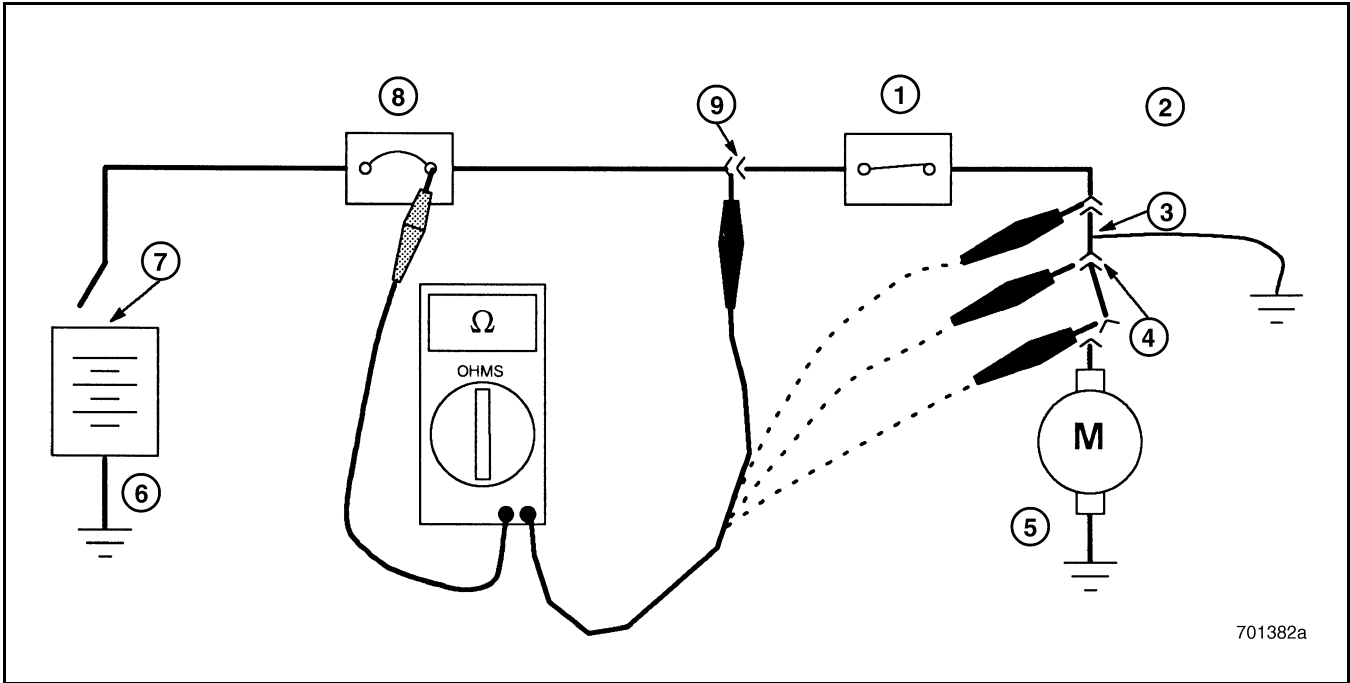


Figure 40 — Continuity Check

1. Switch (Closed)	6. Battery
2. Connector 2	7. Disconnect Power
3. Short to Ground	8. Circuit Breaker
4. Connector 3	9. Connector 1
5. Motor (Disconnected)	



DESCRIPTION AND OPERATION

NOTE

Power in the circuit must be turned OFF, and the ground must be isolated before performing any continuity checks.

1. Disconnect the load by:
 - Disconnecting connectors from motors, solenoids, and other devices.
 - Removing light bulbs or other loads.
2. Set the meter to the OHMS or CONTINUITY function.
3. Connect one lead to the "AUX" terminal of the circuit breaker.

NOTE

Close or jumper any normally opened switches found in the circuit.

4. Probe the circuit by touching the other lead at various connections along the circuit, while watching the meter.
 - Readings of zero ohms, fractions of ohms, indicate a completed circuit.
 - Infinite (OL on the digital meter) indicate an opened circuit.

Use one of the following procedures to isolate an intermittent shorted, grounded or opened circuit.

If the approximate area of the problem is known:

1. Insert one meter lead into the connector of the suspect harness, and connect the other lead to a good ground.
2. Begin wiggling the wires, and continue every couple of inches along the harness while watching the meter.
3. When the resistance reading changes (drops to zero ohms from an infinite [OL] reading, or goes to infinity [OL] from a zero ohms reading), the problem is located near that point.

If the area of the problem is not known:

1. Connect the meter between a good ground and the "AUX" terminal of the circuit breaker.
2. Starting at the circuit breaker, begin wiggling the harnesses.
3. Continue with this procedure while watching the meter. When the readings change, the approximate area of the problem has been located.



DESCRIPTION AND OPERATION

Checking Circuit Grounds

For a circuit to operate properly, a completed path for current flow must exist between the positive battery terminal, through the load, and back to the negative battery terminal. It would not be practical for circuits to terminate at the negative battery post, so the negative side of the battery is connected directly to the chassis frame, and all circuits are then connected to the frame. Ground straps provide a connection between the frame and any component (such as the engine, transmission, cab, etc.) that would be electrically insulated.

Faults such as dim lights or components that operate too slowly can generally be attributed to bad ground connections. The following checks can be used to locate a bad ground connection:

VOLTAGE CHECKS

1. Set the multimeter to read VDC.
2. Power the circuit.
3. Connect the red lead to a good ground on the frame.
4. Probe the ground connections with the black meter lead. Any voltage reading indicates a bad ground.

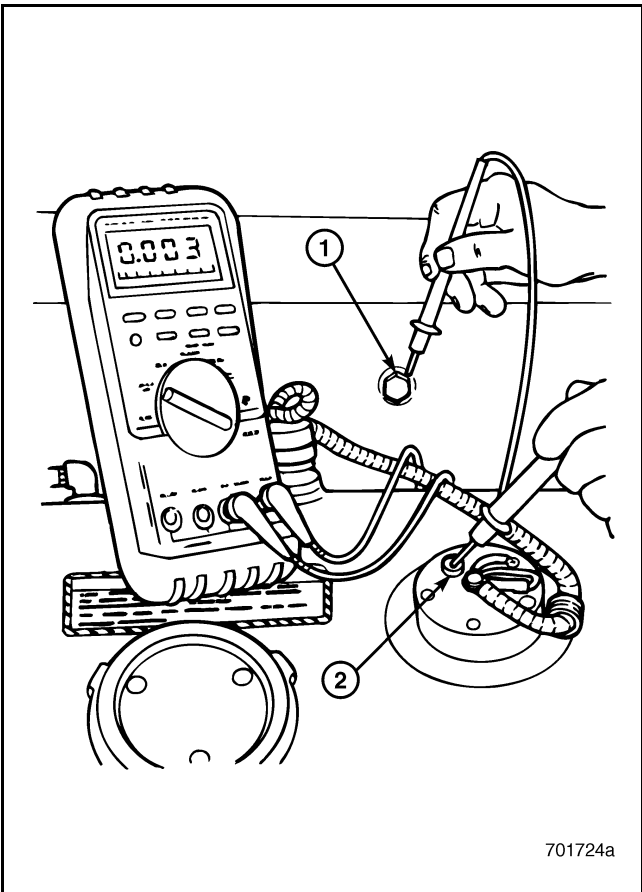


Figure 41 — Using Voltage to Check Grounds

1. Positive Lead to Frame Ground	2. Negative Lead on Sending Unit Ground Terminal
----------------------------------	--



DESCRIPTION AND OPERATION

CONTINUITY CHECKS

1. Turn the power to the circuit OFF.
2. Set the meter to the resistance function.
3. Connect one meter lead to a good ground.
4. Probe the ground circuits and ground connections with the other lead. Meter readings of zero ohms or fractions of ohms indicate the ground connections are good. High-resistance readings or infinite (OL on the digital meter) indicate that the ground connection is bad.

Referring to the schematic diagrams is the easiest way to pinpoint common areas in a circuit. When looking for a problem that affects several circuits, check the diagram and look for common power or common ground connections. If only part of the circuit fails, however, check for connections between the part of the circuit that functions properly and the part that does not.

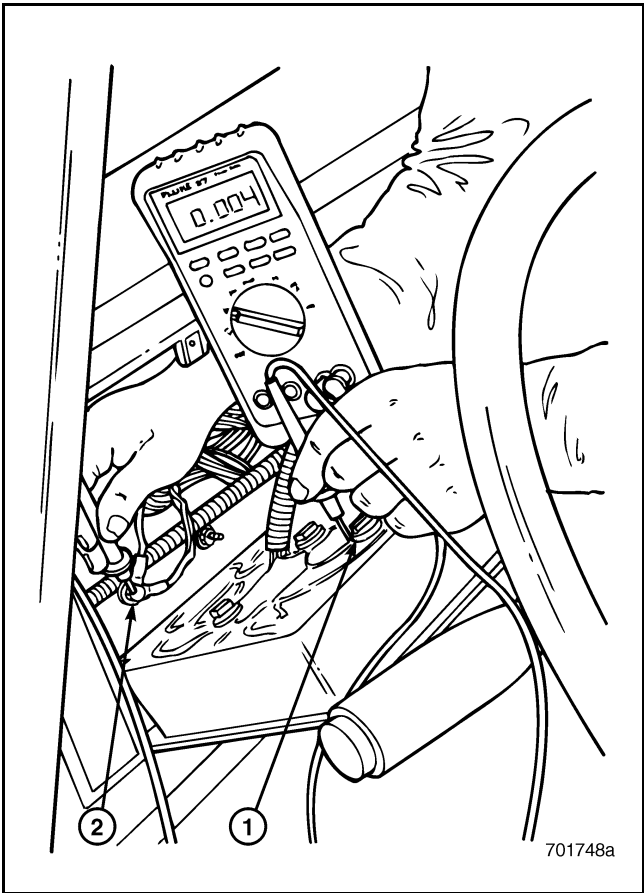


Figure 42 — Using Resistance to Check Grounds

1. Ground Circuit Terminal	2. Dash Panel Ground
----------------------------	----------------------



DESCRIPTION AND OPERATION

POWER DISTRIBUTION

Power distribution is broken down into battery power and keyed power.

Distribution points include the batteries, circuit breakers and key (ignition) switch.

Battery-Powered Circuits

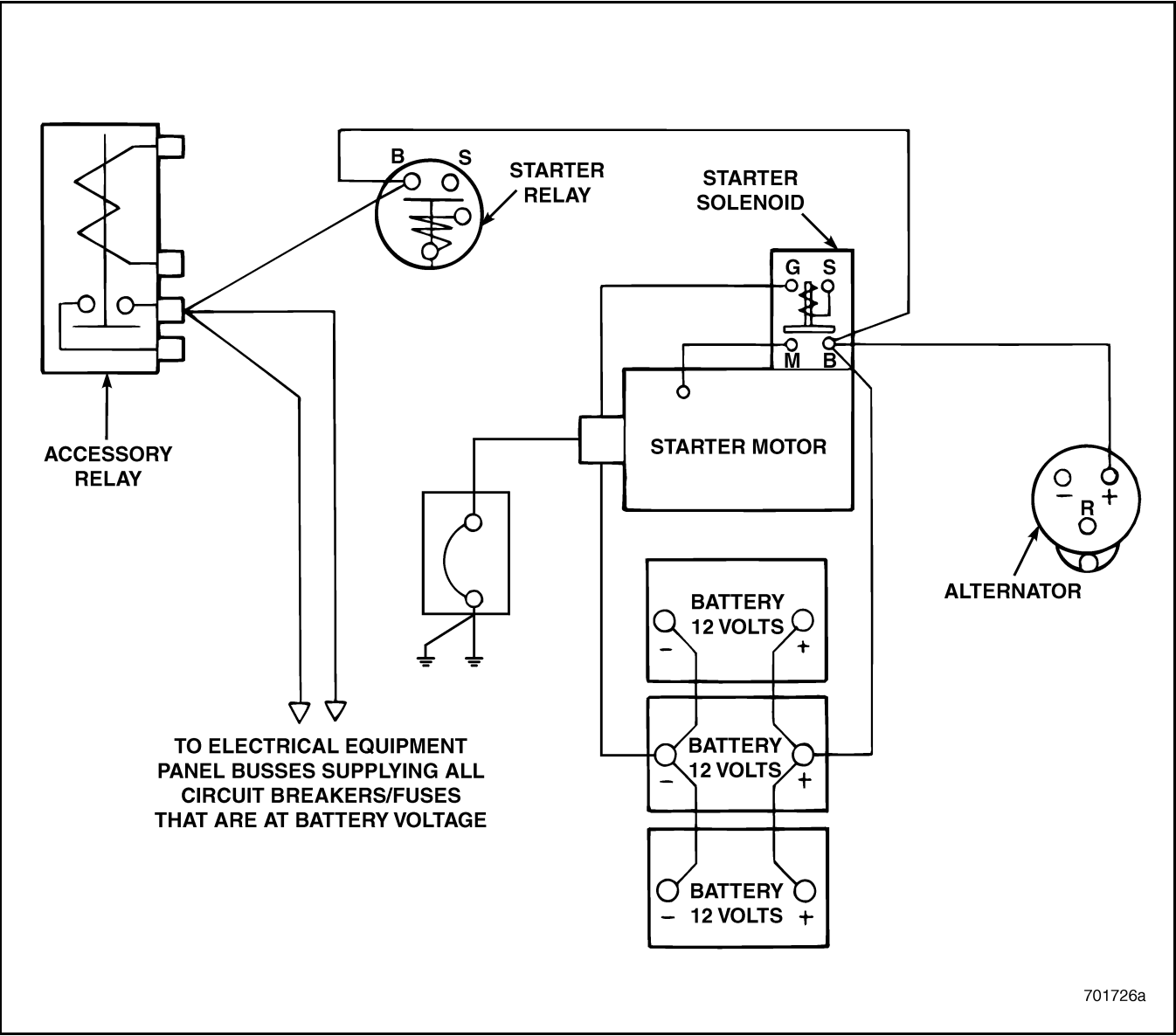


Figure 43 — Battery Power

The positive terminal of the battery is connected directly to the battery terminal of the starter solenoid. From the starter solenoid, voltage is distributed to the starter relay and the accessory

relay. From the accessory relay, battery voltage is distributed to the electrical equipment panel (bus bar) where voltage is supplied to those circuits that are at battery voltage at all times.



DESCRIPTION AND OPERATION

Key-Powered Circuits

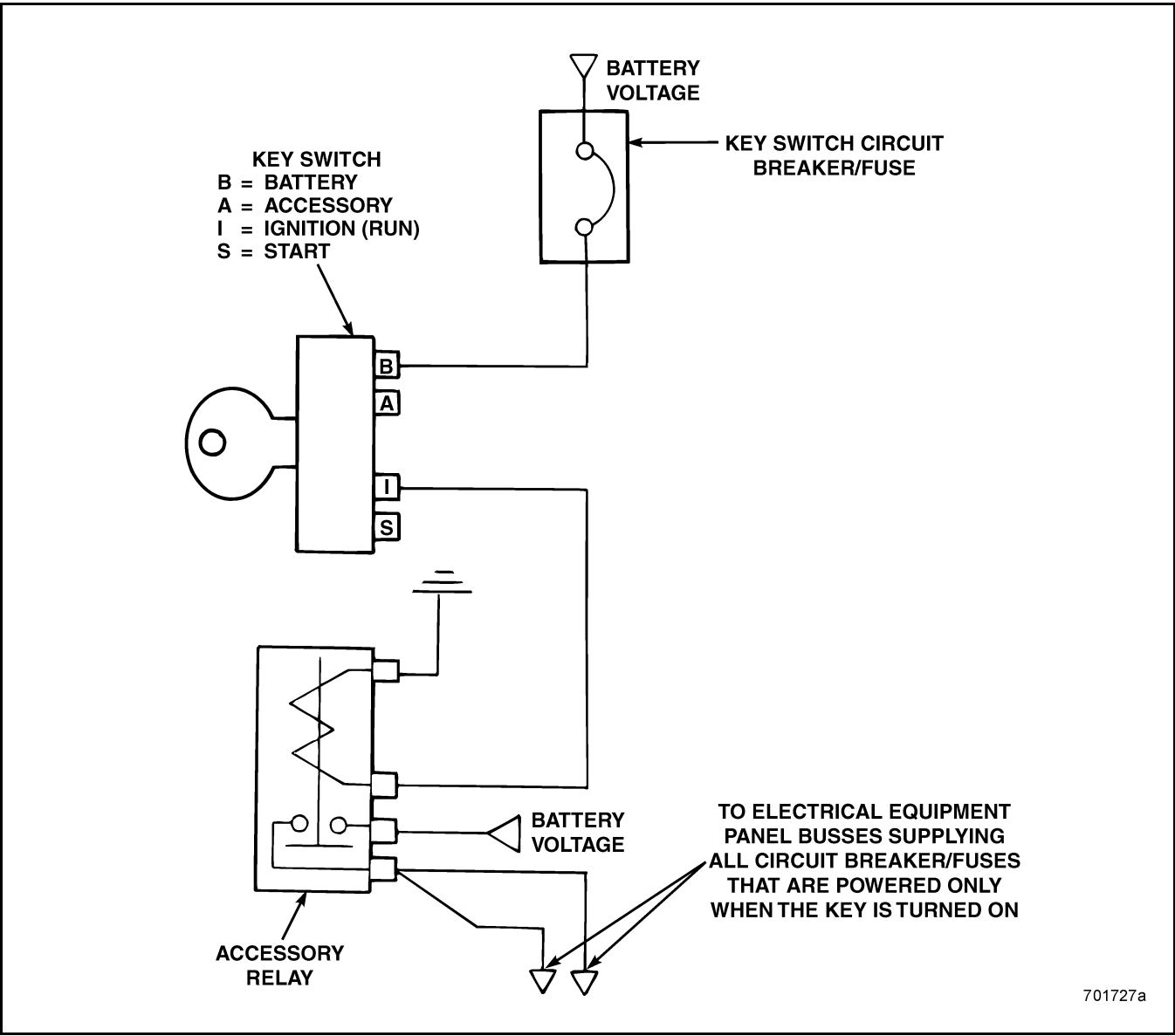


Figure 44 — Keyed Power

From one of the circuit breakers that are at battery voltage, power is supplied to the battery terminal of the ignition key switch. When the ignition switch is turned to the RUN position, current flows through the ignition switch to ground through the coil of the accessory relay. With current flowing through the accessory relay coil, the relay energizes, which closes the relay contacts. Current then flows to the electrical equipment panel bus to supply power to those circuit breakers that are only powered through the key switch.

NOTE

On V-MAC III vehicles, the accessory relay is energized by a signal from the V-MAC III Vehicle Electronic Control Unit (VECU).



The diagram illustrates the electrical connections for a 12V system. On the left, a battery is represented by three stacked cells, each labeled "BATTERY 12 VOLTS" with "-" and "+" terminals. The positive terminal of the battery is connected to the positive terminal of the starter solenoid (labeled "S"). The negative terminal of the battery is connected to a common ground point. This ground point is also connected to the negative terminal of the starter motor (labeled "M"), the negative terminal of the alternator (labeled "A"), and the negative terminal of the engine ground (labeled "E"). The starter solenoid is connected to the starter motor. The alternator is connected to the engine ground. The engine ground is also connected to the engine harness ground. The hood harness ground is connected to the hood ground. The cab harness ground is connected to the cab ground. The trailer ground is connected to the trailer ground. The frame ground is connected to the frame ground.

For an electrical circuit to operate, a path for current flow must exist between the positive side of the battery, through the load and back to the negative side of the battery. Since it is not possible to have all circuits terminate back at the negative battery terminal, a common ground must be provided. The negative battery terminal is connected to the starter ground terminal. The

ground circuit is protected by a high amperage circuit breaker, in case of overload in the ground side of the electrical system. The starter ground terminal is connected to one side of the ground circuit breaker, which is then connected to the frame. The frame provides the common connection point for all circuit grounds that terminate at the negative battery terminal.



DESCRIPTION AND OPERATION

TYPICAL ELECTRIC EQUIPMENT PANEL

Power is distributed to the various circuits of the electrical system by the electrical equipment panel. This panel contains the fuses (or optional

circuit breakers) that protect the system from overload, as well as some of the various relays that provide electrical control. A typical electrical equipment panel is shown below.

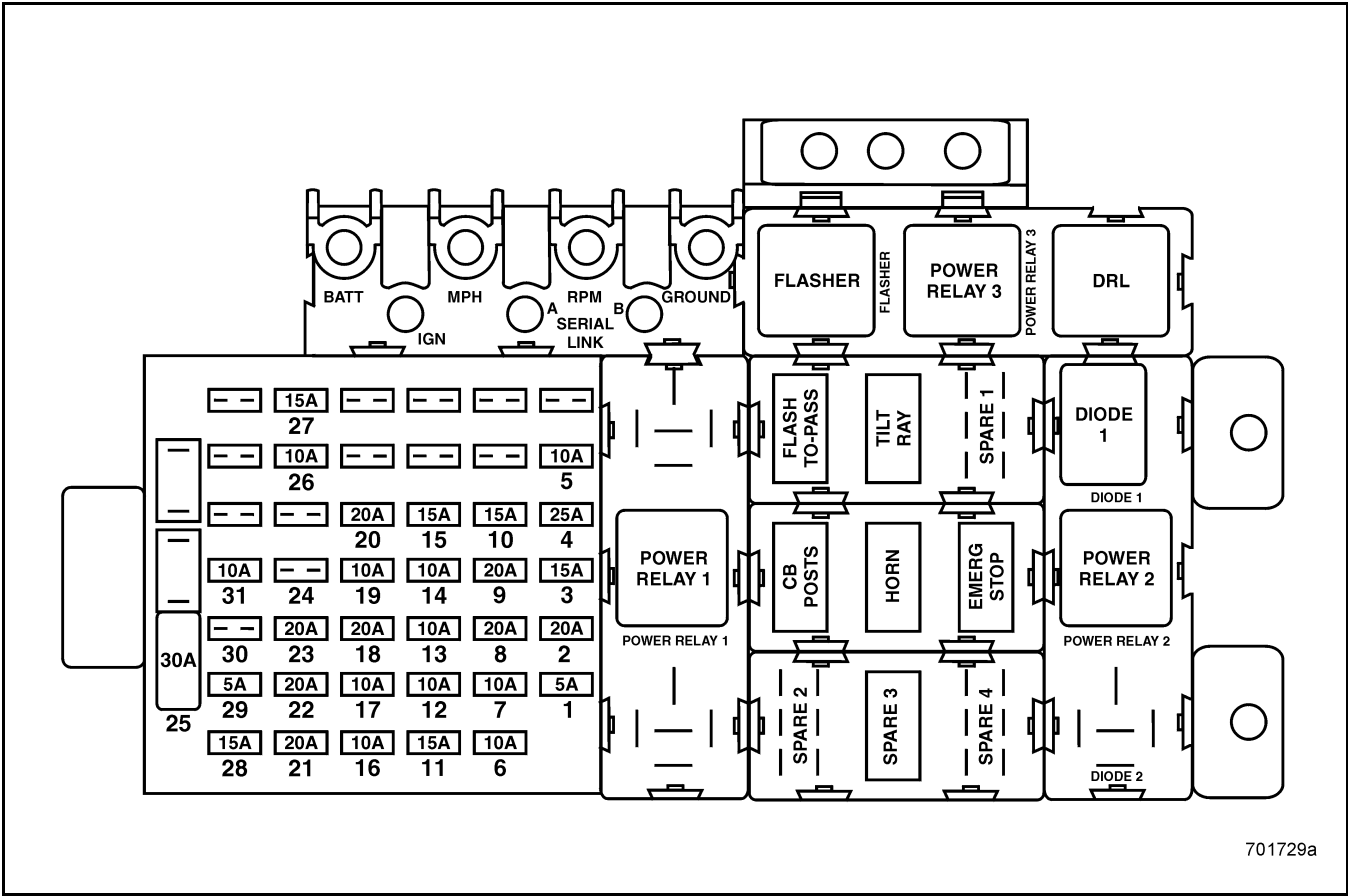


Figure 46 — Typical Electric Equipment Panel

Location of the electrical panel varies by vehicle model. Consult the specific vehicle operator's manual for the exact location of the panel on the chassis.



DESCRIPTION AND OPERATION

CIRCUIT BREAKERS

Fuses are standard on a MACK chassis, but circuit breakers are available as an option. There are two different types of circuit breakers: SAE Type 1 and SAE Type 2.

SAE Type 1

Circuits that require quick restoration of power (e.g., headlamp and windshield wiper circuits), use SAE Type 1 breakers. These circuits automatically reset without having to remove power from the circuit. This prevents unsafe situations from occurring, such as totally losing headlamps while driving at night, or losing the windshield wipers while driving in rain.

The Type 1 circuit breaker consists of a bimetallic strip that heats up and breaks the circuit, if an overload occurs. The circuit remains open until the bimetallic strip cools, at which point, the breaker contacts close and power in the circuit is restored. This cycling continues until the overload is repaired.

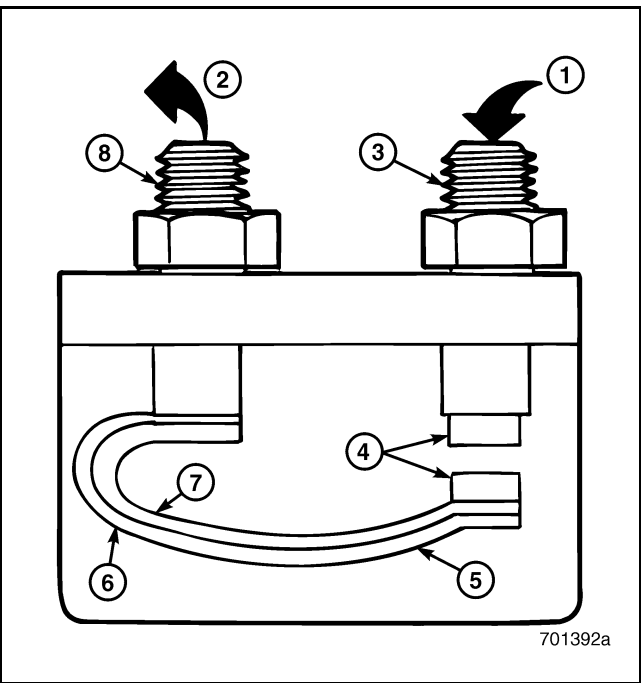


Figure 47 — SAE Type 1 Circuit Breaker

1. Path of Current Flow (In)	5. Low-expansion Metal
2. Path of Current Flow (Out)	6. Bi-metallic Strip
3. "BAT" Terminal	7. High-expansion Metal
4. Contacts	8. "AUX" Terminal

Whether or not the chassis is equipped with fuses or optional circuit breakers, SAE Type 1 circuit breakers are always used in the headlamp and windshield wiper circuits.

SAE Type 2

Circuits that do not require quick restoration of power use SAE Type 2 circuit breakers. This type of circuit breaker will not reset, but remains open until power is removed from the circuit, either by turning off the power in the circuit, or by removing the circuit breaker. The type 2 circuit breaker consists of a bimetallic strip that heats up and breaks the circuit when an overload occurs. The circuit breaker also contains a coil that surrounds the bimetallic strip. When a circuit overload occurs, the circuit breaker contacts open the circuit. Current, however, continues to flow through the coil of wire which keeps the bimetallic strip heated. Because the bimetallic strip remains heated, the circuit breaker contacts remain open until power is removed from the circuit breaker or the circuit breaker is removed.

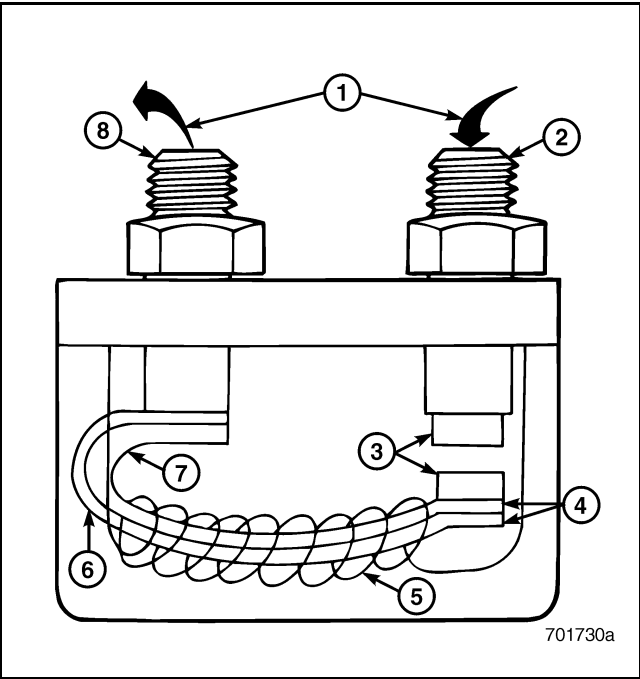


Figure 48 — SAE Type 2 Circuit Breaker

1. Path of Current Flow	5. Coil
2. "BAT" Terminal	6. Low-expansion Metal
3. Contacts	7. High-expansion Metal
4. Bi-metallic Strip	8. "AUX" Terminal



DESCRIPTION AND OPERATION

When using a continuity test, or measuring resistance to test the functionality of an SAE Type 2 breaker, remember that the coil of wire acts like a closed circuit. A good circuit breaker should have very low resistance or none at all. If the multimeter indicates approximately 50 ohms, the circuit breaker contacts are open. This reading indicates the resistance through the coil of wire that surrounds the bimetallic strip.

SAE Type 3

An SAE Type 3 circuit breaker is similar to type 1 and type 2 circuit breakers. However, type 3 breakers are manually reset. A button must be pushed to close the contacts of the breaker, to restore continuity. It is not necessary to remove power from the circuit of a SAE Type 3 circuit breaker.

The type 3 breaker is an optional breaker with only a small volume of customers specifying them for use in their trucks.

Testing Circuit Breakers

Type 1 or type 2 circuit breakers can be tested with a multimeter by setting the meter to the resistance function and touching the leads to the terminal lugs of the breaker.

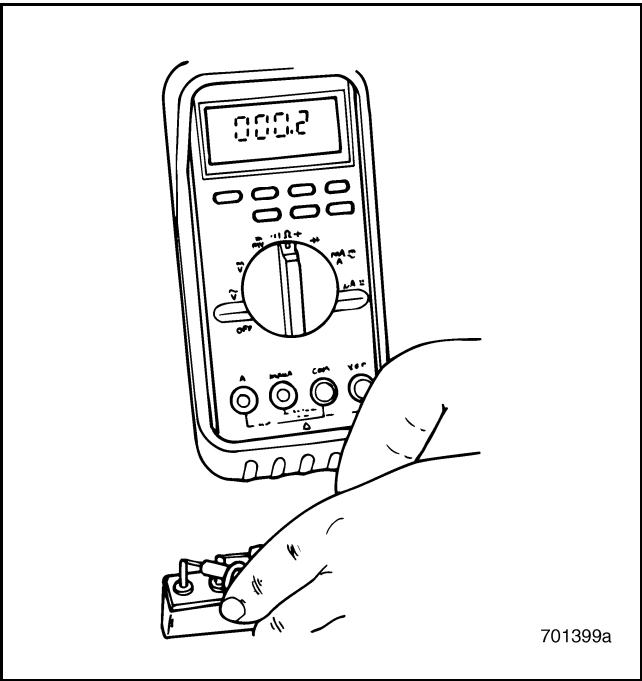


Figure 49 — Testing the Circuit Breaker

- If the circuit breaker is good, the meter indicates zero or very low resistance for type 1, type 2 and type 3 circuit breakers.
- If the circuit breaker is defective, the meter indicates infinite resistance for type 1 breakers and approximately 50 ohms resistance for type 2 breakers. Type 3 breakers will show very high to infinite resistance after a manual reset has been attempted.



DESCRIPTION AND OPERATION

WIRE SIZES

Wires used in the MACK Truck chassis electrical system are sized according to the thickness of the wire core, not the insulation. The wires are sized according to the metric wire gauge system and used in the electrical system according to the amount of current they must carry and the circuit they are in. Another method of gauging wire sizes is the American Wire Gauge (AWG) numbering system. To convert between the AWG and metric wire sizes, refer to the table below:

AWG TO METRIC WIRE SIZE CONVERSION CHART

AWG Sizes	Metric Sizes	Ohms/1000 ft — Stranded
20	0.5	10.32
18	0.8	7.24
16	1.0	4.72
14	2.0	2.99
12	3.0	1.883
10	5.0	1.166
8	8.0	0.733
6	13.0	0.377
4	19.0	0.293
2	32.0	0.178
1	40.0	0.142
0	50.0	0.112
00	62.0	0.089
000	81.0	0.070
0000	103.0	0.055

In the AWG numbering system, the higher numbered wires (such as 20), are thin, and the lower numbered wires (such as 2) are thick. The opposite is true of metric wire gauges, the lower numbered wires (such as 0.5) are thin, and the higher numbered wires (such as 50.0) are thick.

Whenever wires must be replaced, it is important that wires of the same gauge be used. Replacing a thick wire (metric gauge 13.0, or AWG 6), with a thin wire (metric gauge 0.5 or AWG 20) poses a fire hazard. If it cannot accommodate the amount of current flow needed for a particular circuit, a thinner wire may overheat and eventually burn.



DESCRIPTION AND OPERATION

WIRE IDENTIFICATION

Wires used on MACK chassis are identified by a numbering system that designates the circuit and circuit branch the wire is in, and the metric size of the wire. On V-MAC II and V-MAC III chassis, the connector pin number and module connector number are identified instead. These numbers are imprinted on each wire at intervals no greater than 30 mm. On larger wires, the numbers are

printed on two sides of the wire, 180-degrees apart, continuously along the length of the wire. The identification numbers on smaller gauge wires are imprinted on one side of the wire only, along the entire length of the wire. The electrical wiring diagrams use the same wire identification numbers that are imprinted on the wires.

Refer to the following illustrations for examples of the wire identification numbering system.

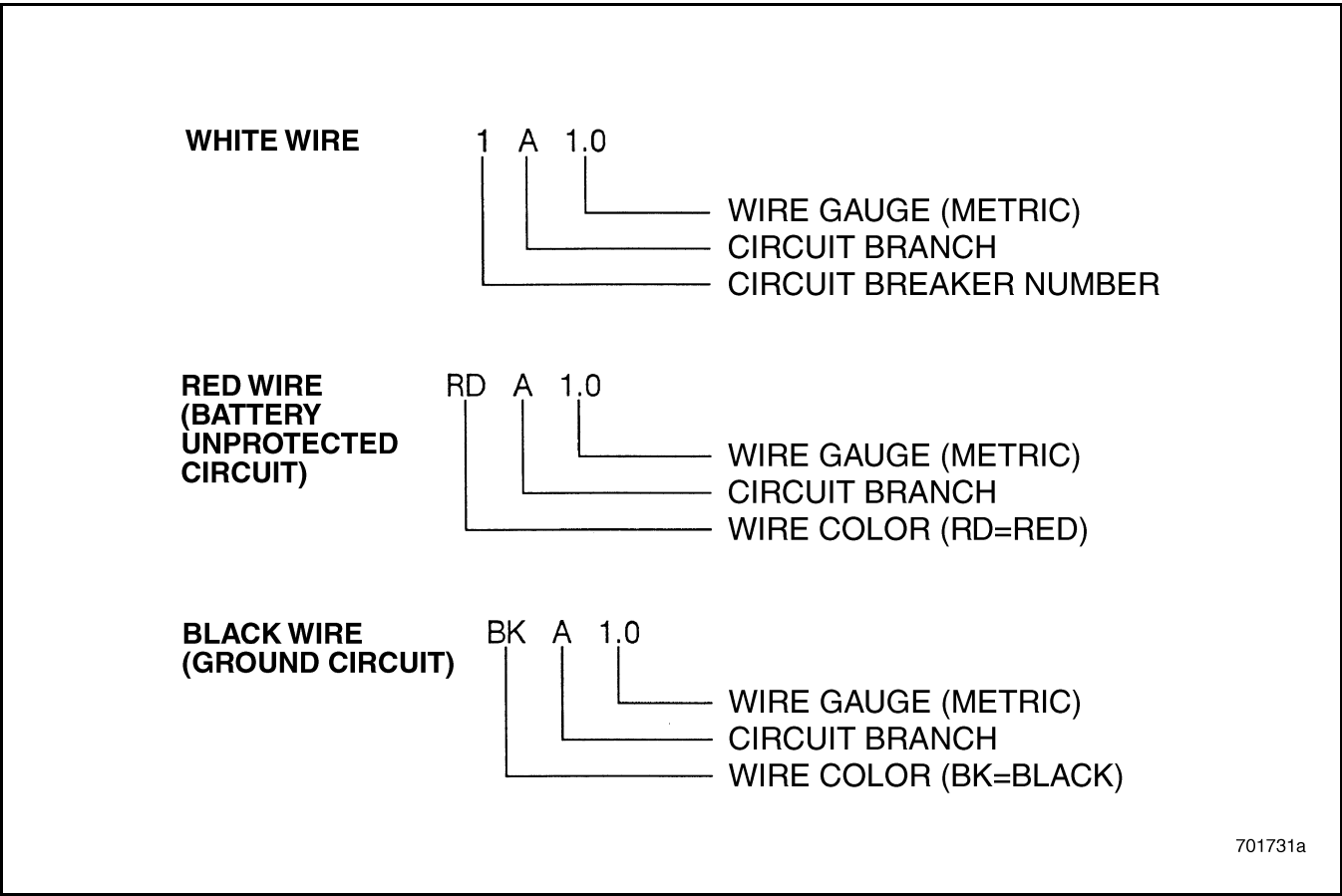


Figure 50 — Chassis Electrical Wire Identification



DESCRIPTION AND OPERATION

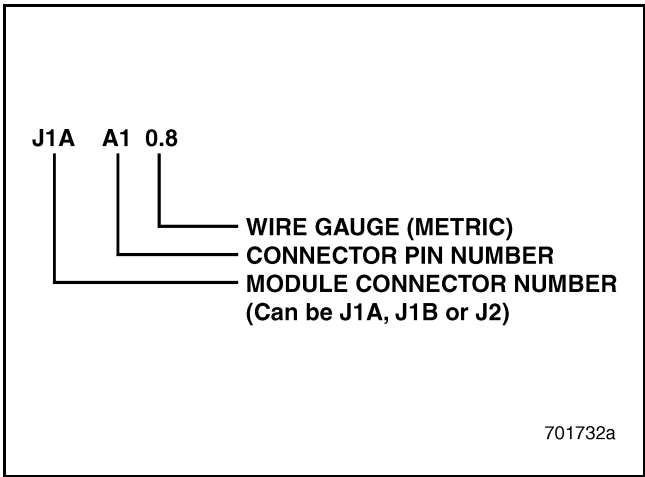


Figure 51 — V-MAC System Wire Identification

In addition to the numeric identification system, all wires used on MACK chassis are one of three colors. Wire color use is as follows:

- White — Used on all circuits that are protected by a circuit breaker.
- Red — Used on all unprotected battery circuits.
- Black — Used on all ground circuits, including the ground circuit containing the master ground circuit breaker.



DESCRIPTION AND OPERATION

BATTERIES — GENERAL INFORMATION

Batteries provide the power needed to start the engine. They also supply power for the electrical system when electrical demand exceeds what the charging system can deliver.

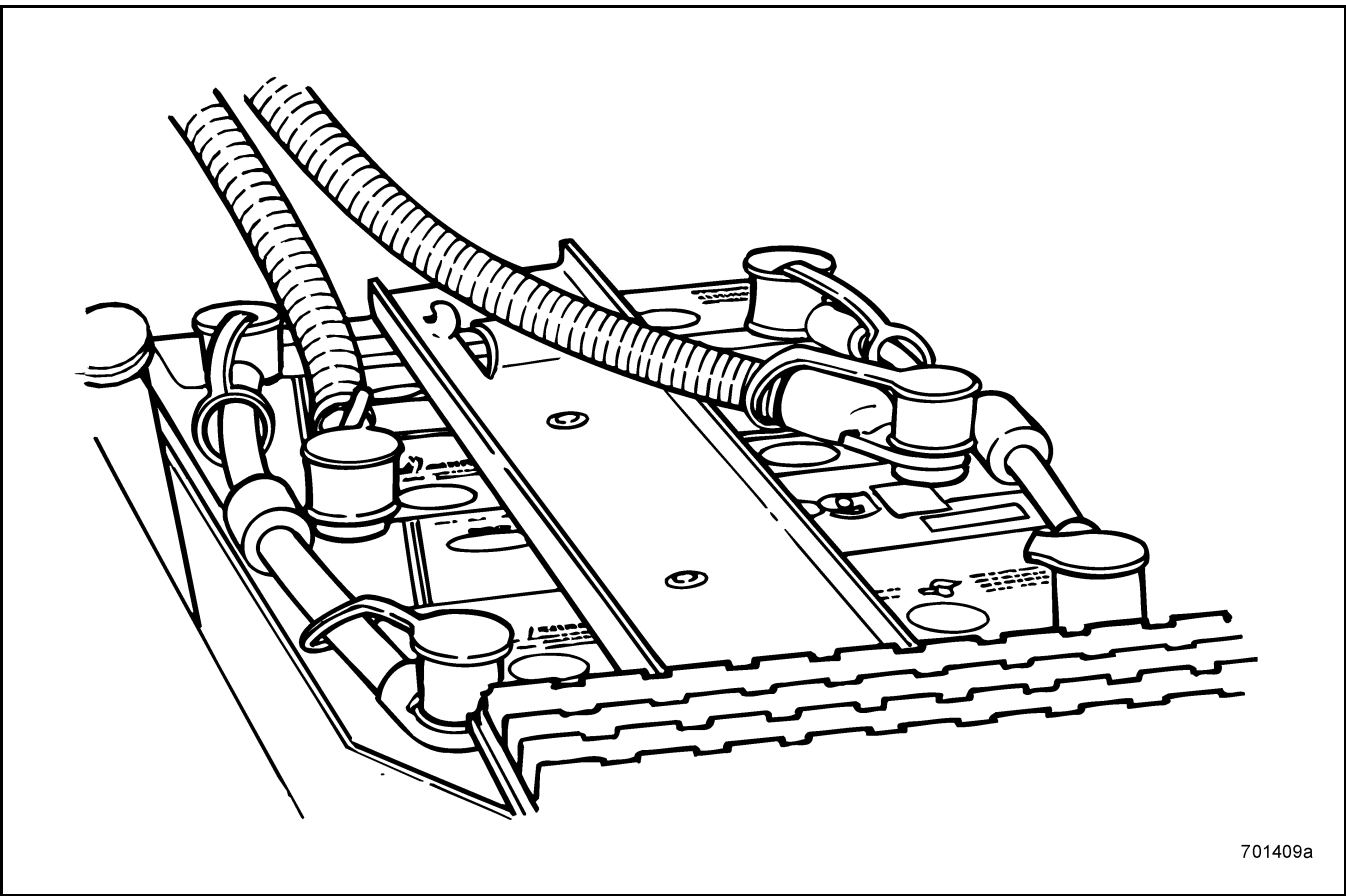


Figure 52 — Batteries

Description

Batteries produce and store electrical energy by chemical reaction. The battery contains sets of positive plates and negative plates, straps, and separators that are suspended in an electrolyte solution. The positive plates are made of lead peroxide (PbO_2), while the negative plates are made of sponge (porous) lead (Pb). The sponge lead of the negative plates includes antimony, or calcium, to increase battery performance and to decrease acid fume gassing. The electrolyte solution in the battery is a mixture of sulfuric acid (H_2SO_4) and water (approximately 35–40% acid and 60–65% water). The water optimizes voltage production and reduces the caustic effect of the acid on the internal components of the battery.

For each battery, there are a series of battery elements (cells) made from a number of positive and negative plates with separators in between. A single element or cell produces between 2–2.5 volts of electricity. A 12 volt battery would then contain 6 cells, while a 6-volt battery contains 3 cells.

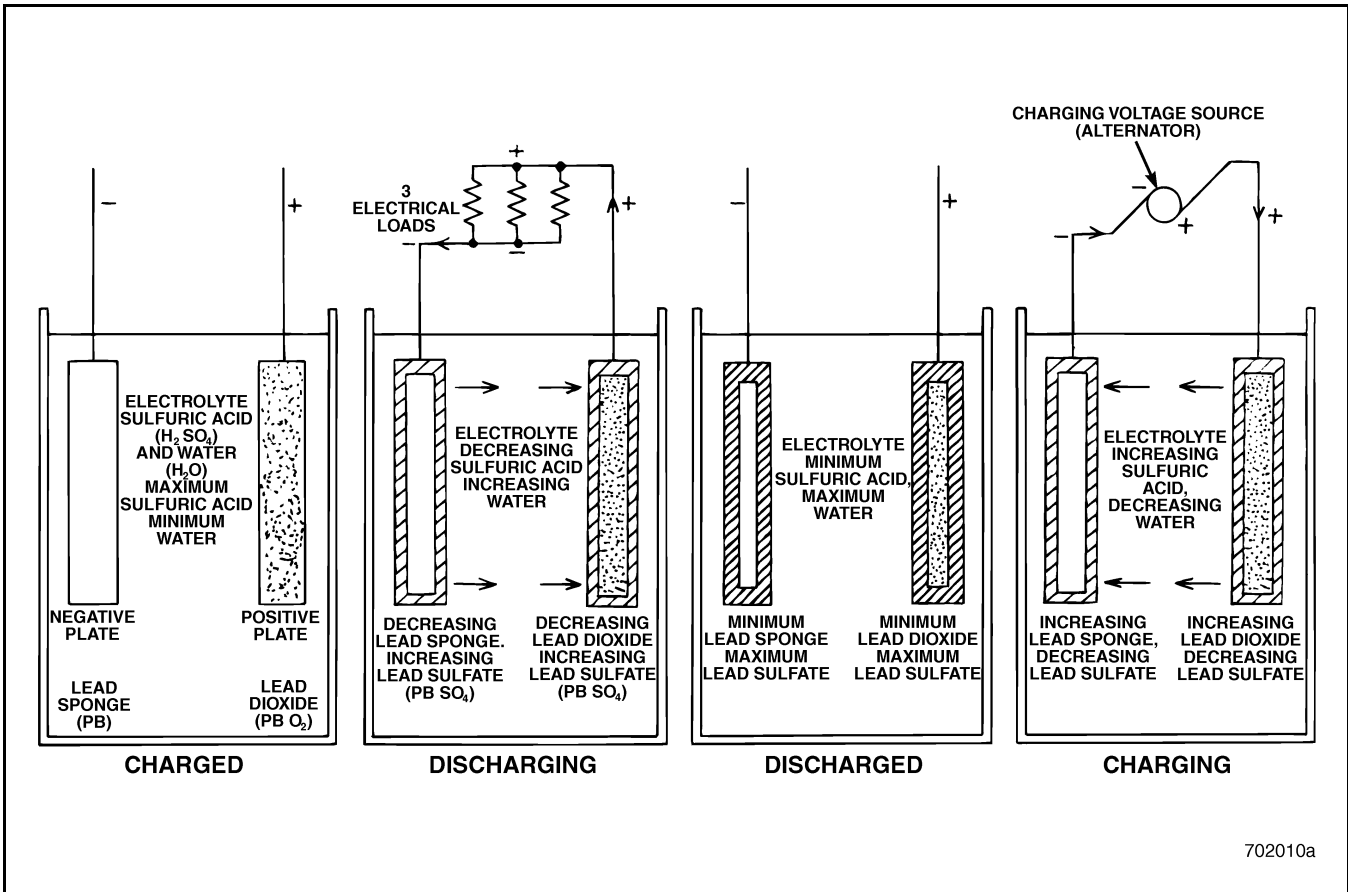


DESCRIPTION AND OPERATION

Operation

Inside the battery during the discharge cycle (using the starter, running electrical equipment), SO_4 molecules chemically separate from the sulfuric acid (H_2SO_4) and attach to the plates of

the battery. Electrical energy is released during this process. Also, oxygen atoms (O) bond with hydrogen molecules (H_2) to form water (H_2O). As the discharge cycle continues, the plates in the battery become lead sulfate (PbSO_4).



During the charging cycle, the SO_4 molecules leave the lead plates and the oxygen atoms in the water separate from the hydrogen atoms. The SO_4 bonds with the hydrogen to form H_2SO_4 . The oxygen atoms reattach to the positive plates of the battery.

The models described, represent totally charged and totally discharged batteries. The electrolyte of a totally charged battery is concentrated sulfuric acid diluted with some water. In a totally discharged state, the battery electrolyte would contain a much higher concentration of water. During normal operation, the battery would generally be fully charged to somewhat discharged.

When the electrolyte level is low, the oxygen and hydrogen in the battery has “gassed” off, leaving behind only sulfate (SO_4) molecules. Sulfate is not gassed off like the oxygen and hydrogen because the molecules are heavier. The only way a battery can loose sulfate is if the electrolyte is spilled. Never introduce premixed electrolyte into an in-service battery as an over-concentration of acid will result.



DESCRIPTION AND OPERATION

The capacity of the battery to produce electricity is directly related to the amount of lead remaining on the plates. As batteries lose lead, they lose capacity. Batteries lose lead as follows:

- Shedding (flaking) due to vibration
- Shedding due to “gassing” when “fast-charging” the battery
- Sulfation during periods of battery nonuse — The lead sulfate turns to permanent hard crystals. When this occurs, the lead is no longer suitable for chemical reaction.

All batteries are perishable, but reasonable care and maintenance can substantially extend battery life.

Types of Batteries

Basically, three different types of automotive batteries are available on the market:

- Maintenance Free — This type of battery uses a lead-acid grid construction that contains no Antimony. The battery case may be sealed so there is no provision for adding water during the service life of the battery.
- Semi-Maintenance Free — This battery is the lead-acid type with a reduced amount of antimony. These batteries require periodic addition of distilled water during battery service life.
- Filler Cap Type — This battery is also the lead-acid type, and contains a larger amount of antimony in its construction. These batteries have vented filler caps that can be removed to add distilled water. Distilled water must be added to these batteries at regular intervals to maintain service life.

Periodic Maintenance

Some periodic maintenance items include the following:

1. Inspect the battery hold-down arrangement for dirt and corrosion, and the mounting hardware for tightness. Remove, clean, repaint and reinstall the hold-down arrangement as necessary.
2. Check the state of charge indicator (if so equipped) on maintenance-free batteries. On low-maintenance type batteries with removable vent caps, check the specific gravity. Recharge as necessary.
3. Check the battery terminals for corrosion and tightness. Clean battery terminals with a wire brush, and cable connections with a solution of baking soda and water. Coat the connections with a light film of non-metallic grease.
4. Check battery cable routing and clamping. Make sure that there is no possibility of cables rubbing, chafing and/or shorting.



DESCRIPTION AND OPERATION

Battery Tests

VISUAL INSPECTION

Conduct a visual inspection of the batteries and look for obvious signs of damage that could affect their performance. Inspect each battery for the following:

- Cracks or other damage to the battery case that could allow electrolyte leakage.
- Dirt on the battery case that could allow current flow to ground and drain the battery.
- Loose or damaged terminal posts which could indicate a loose internal connection.
- Loose or corroded battery cable connections that would add unwanted high resistance to the circuit.

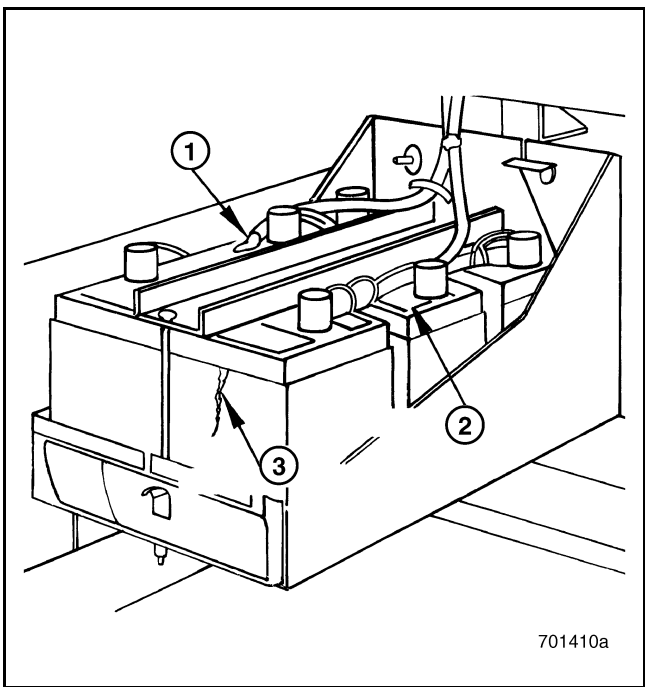


Figure 54 — Battery Inspection

1. Check Terminals & Connections	3. Check for Cracks
2. Check for Dirt	

Replace the battery if any signs of damage are evident. Then clean and tighten all the battery cable connections. If the vehicle is equipped with a low-maintenance type battery having removable vent caps, remove the caps and check the electrolyte level inside the battery. If the level is low, add enough distilled water to bring the level above the tops of the plates.

NOTE

Do not check battery state-of-charge just after distilled water has been added to the electrolyte level. A false hydrometer reading or incorrect voltage test will result. Recharge the battery, then check state-of-charge.

STATE OF CHARGE

State of charge can be determined by using a hydrometer to check the specific gravity of the electrolyte, or by performing an open-circuit voltage test. Some maintenance-free batteries have a built-in hydrometer (state-of-charge indicator) allowing quick checks of battery condition. If equipped with low-maintenance type batteries, measure the specific gravity of each cell, corrected to 80°F.

- If the specific gravity is below 1.230, or the readings of each cell vary by more than .050 between the highest and lowest cell, replace the battery.
- If the specific gravity readings of each cell are less than .050 between the highest and lowest cell, but the specific gravity is below 1.230, recharge the battery and retest. If recharging does not bring the specific gravity up to specification, replace the battery.

State of charge can also be tested with an open-circuit voltage test, using a voltmeter as follows:

NOTE

If the battery has just been recharged or has been in service, the surface charge must be removed before performing the open-circuit voltage test. Turn the lights on and leave them on for approximately 2–3 minutes (per battery or 6–12 minutes for a four-battery system). Then allow the battery to sit for 15 minutes before testing.

When using a battery load tester (with leads connected positive-to-positive and negative-to-negative), apply a 300-amp load for 15 seconds. Then allow the battery to sit for 15 minutes before testing.

1. Set the voltmeter to the VDC function.



DESCRIPTION AND OPERATION

2. Connect the positive (+) lead to the positive battery post and the negative (-) lead to the negative battery post.

NOTE

To accurately determine state of charge, disconnect the batteries from each other and test each battery individually.

3. Note the reading indicated on the meter and refer to the following table:

STATE OF CHARGE AS DETERMINED BY OPEN CIRCUIT VOLTAGE TEST

Open Circuit Voltage	State of Charge
12.6 volts or more	Fully Charged
12.4 volts	75% Charged
12.2 volts	50% Charged
12.0 volts	25% Charged
11.7 volts or less	Discharged

4. Repeat this procedure for each remaining battery.

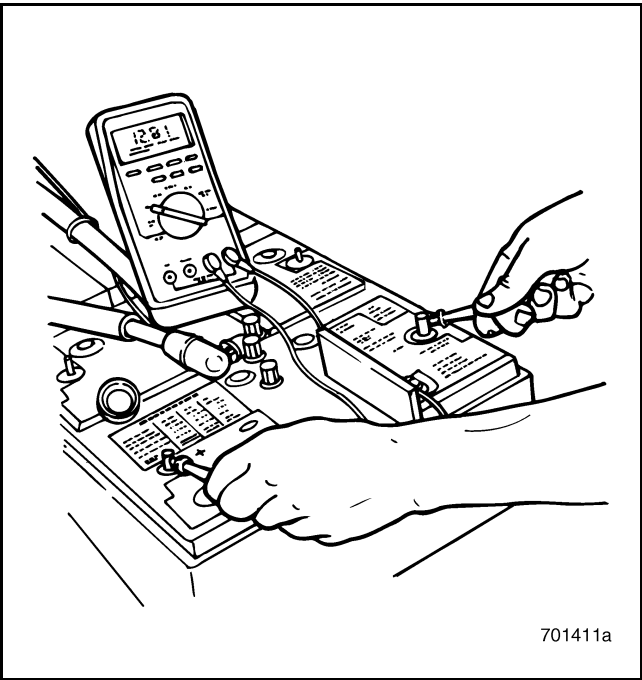


Figure 55 — Performing an Open-Circuit Voltage Test

Recharge the battery if open-circuit voltage was below 12.4 volts.

BATTERY LOAD TEST

A load test determines how well a battery functions under load. A battery tester with an adjustable carbon pile is needed to perform this test. The battery must be at, or very near, a full state of charge, and the electrolyte must be as close to 80°F (27°C) as possible. Cold batteries give a considerably lower rating. To perform the load test:

1. Disconnect the cables from all batteries. (Only one battery can be tested at a time.)

CAUTION

Always disconnect the negative battery terminal first.

NOTE

Terminal adaptors are needed for batteries with threaded stud terminals. The adapters provide an efficient attaching point for the battery tester leads.

2. Observing proper polarity, connect the battery tester to the battery terminals.
3. Remove the battery surface charge by turning the tester ON, applying a 300-amp load for 15 seconds, and then turning the tester OFF. Wait one minute before continuing.
4. Turn the tester ON and adjust the carbon pile to apply a load equal to 1/2 the battery cold cranking amps (CCA) rating (625 CCA = 313 amp load).



DESCRIPTION AND OPERATION

With the proper load applied for 15 seconds, measure and record the battery terminal voltage.

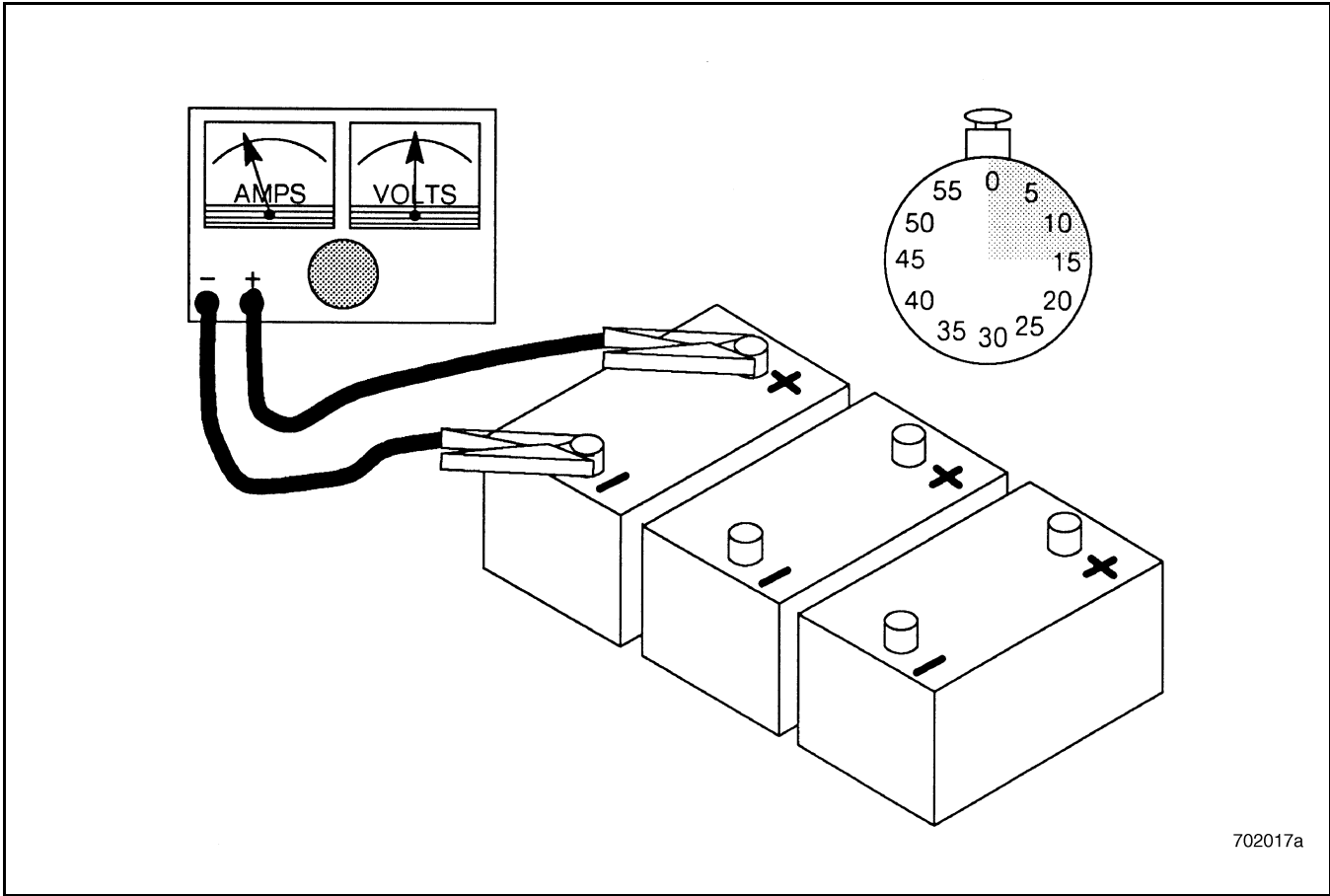


Figure 56 — Battery Load Test

5. Turn the battery tester off immediately after the 15 seconds of current draw.
6. Compare the voltage obtained from the test with the voltage values given in the following table. A 0.1 volt correction factor applies to each additional 10 degrees of battery temperature. For example, at 80°F, battery voltage would be 9.7 volts. At 90°F, battery voltage would be 9.8 volts. At 100°F, battery voltage would be 9.9 volts.

BATTERY LOAD TEST AS AFFECTED BY TEMPERATURE

Battery Temperature F° (C°)	Minimum Voltage after 15 seconds
70° (21°)	9.6 volts
60° (16°)	9.5 volts
50° (10°)	9.4 volts
40° (5°)	9.3 volts
30° (-1°)	9.1 volts
20° (-6°)	8.9 volts
10° (-12°)	8.7 volts
0° (-18°)	8.5 volts

Battery voltage should not fall below 9.6 volts at 70°F (21°C) or above. If the voltage readings exceed the specifications as shown in the table by one or more volt, the battery is supplying sufficient power. If the reading does not meet or exceed the values as listed, replace the battery.



DESCRIPTION AND OPERATION

STARTING SYSTEM

Operation

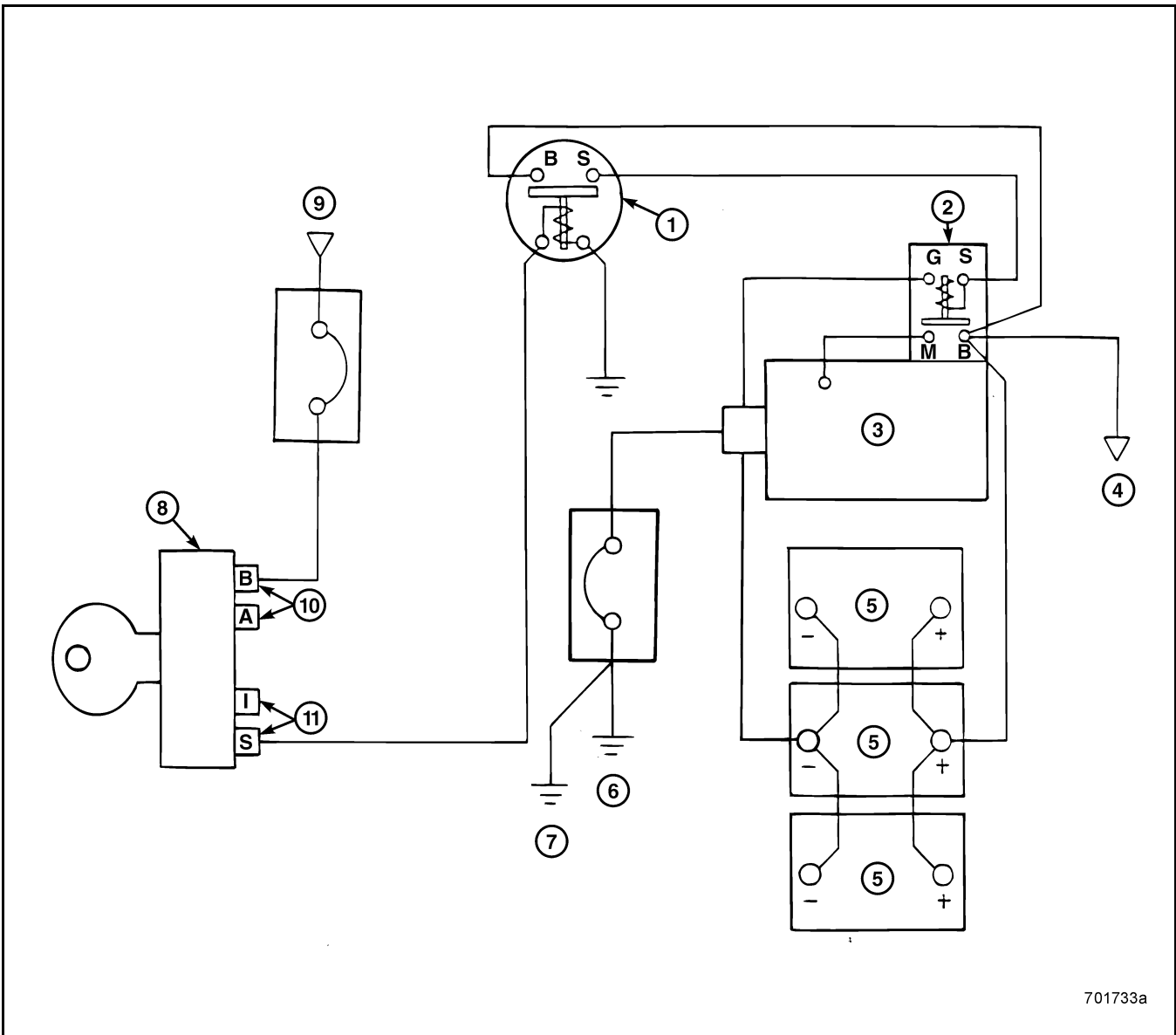


Figure 57 — Starting System Circuit

1. Starter Relay	7. Frame Ground
2. Starter Solenoid	8. Key Switch
3. Starter Motor	9. From Battery Voltage
4. To Alternator	10. B = Battery, A = Accessory
5. Battery (12 Volts)	11. I = Ignition (Run), S = Start
6. Engine Ground	



DESCRIPTION AND OPERATION

Turning the key to the start position energizes the starter relay. When the contacts of the starter relay close, battery current, originating at the starter solenoid B terminal, flows through the starter relay and back to the starter solenoid S terminal. Voltage applied to the S terminal then energizes the solenoid coil which closes the contacts and allows battery current to flow to the starter motor. At the same time, the energized starter solenoid shifts a pinion lever to move the starter pinion into contact with the flywheel ring gear, and engine cranking takes place.

Releasing the key removes voltage from the starter relay, and springs return the relay and solenoid to the released position. Pinion overrun protects the starter armature from excessive speeds when the engine starts. To prevent starter damage, the key must be released as soon as the engine starts.

Troubleshooting

The starting circuit requires a great deal of current to operate. Any added resistance in the circuit (corroded cables and connections, loose cable connectors, poor ground connections) adversely affects starter motor operation. Also, the batteries must be in good condition and fully charged for the starter motor to operate properly. The starting system can be effectively tested using the vehicle electrical system by energizing the starter. Before beginning any extensive starting system tests, always check the condition and state of charge of the batteries, and recharge as necessary. Also check for loose, damaged or corroded cables and connections. Repair as necessary.

NOTE

Starting system problems such as slow cranking or no cranking, are sometimes confused with:

- Charging system problems (e.g., faulty charging system that does not keep the batteries fully charged).
- Engine seizing, or engine oil that is not of the specified viscosity (very cold operation).

Before performing any starter tests, verify that the charging system is operating properly, and that the battery is fully charged and passes a load test.

The following tests can be used to isolate the specific cause of the condition:

- Starter voltage test
- Battery cable test
- Starter solenoid and starter relay voltage drop test
- Starter relay and key switch test

STARTER VOLTAGE TEST

Starting system problems generally appear as slow cranking speeds, or no cranking at all. To perform the starter voltage test:

1. Set the multimeter to the VDC function.
2. Connect the negative (–) lead to the negative battery terminal, and the positive (+) lead to the positive battery terminal.
3. Turn the key to the start position and energize the starter, without allowing the engine to start.

NOTE

The engine can be disabled as follows:

- On mechanical engines with a manual shutdown control, crank the engine with the stop control pulled out.
- On mechanical engines with a key switch shut-off, disconnect the fuel solenoid at the fuel injection pump.
- On electronically controlled V-MAC engines, remove power from the control modules by disconnecting the module connectors or by removing the fuses or circuit breakers powering the modules. On the V-MAC III engines (E-Tech™), remove fuse or circuit breaker No. 40. On V-MAC II engines, remove fuse or circuit breaker No. 20. On V-MAC (I) chassis, remove fuse or circuit breaker No. 31.

CAUTION

When performing any starting system test, limit cranking periods to 30 seconds or less. Allowing the starter to crank for periods longer than 30 seconds can cause the starter motor to overheat and result in starter damage.



DESCRIPTION AND OPERATION

4. Observe the voltage indicated on the meter.
Then release the key.

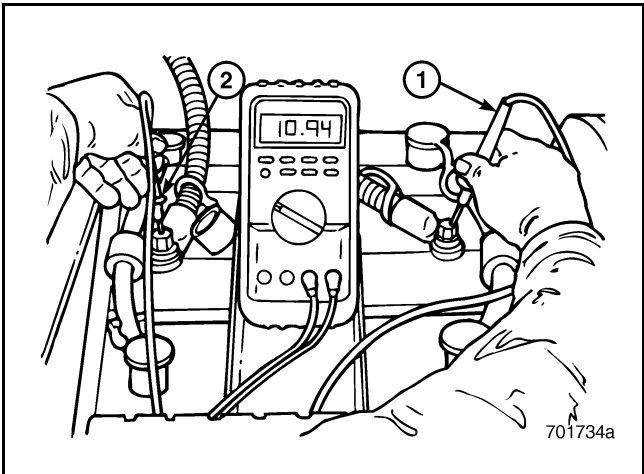


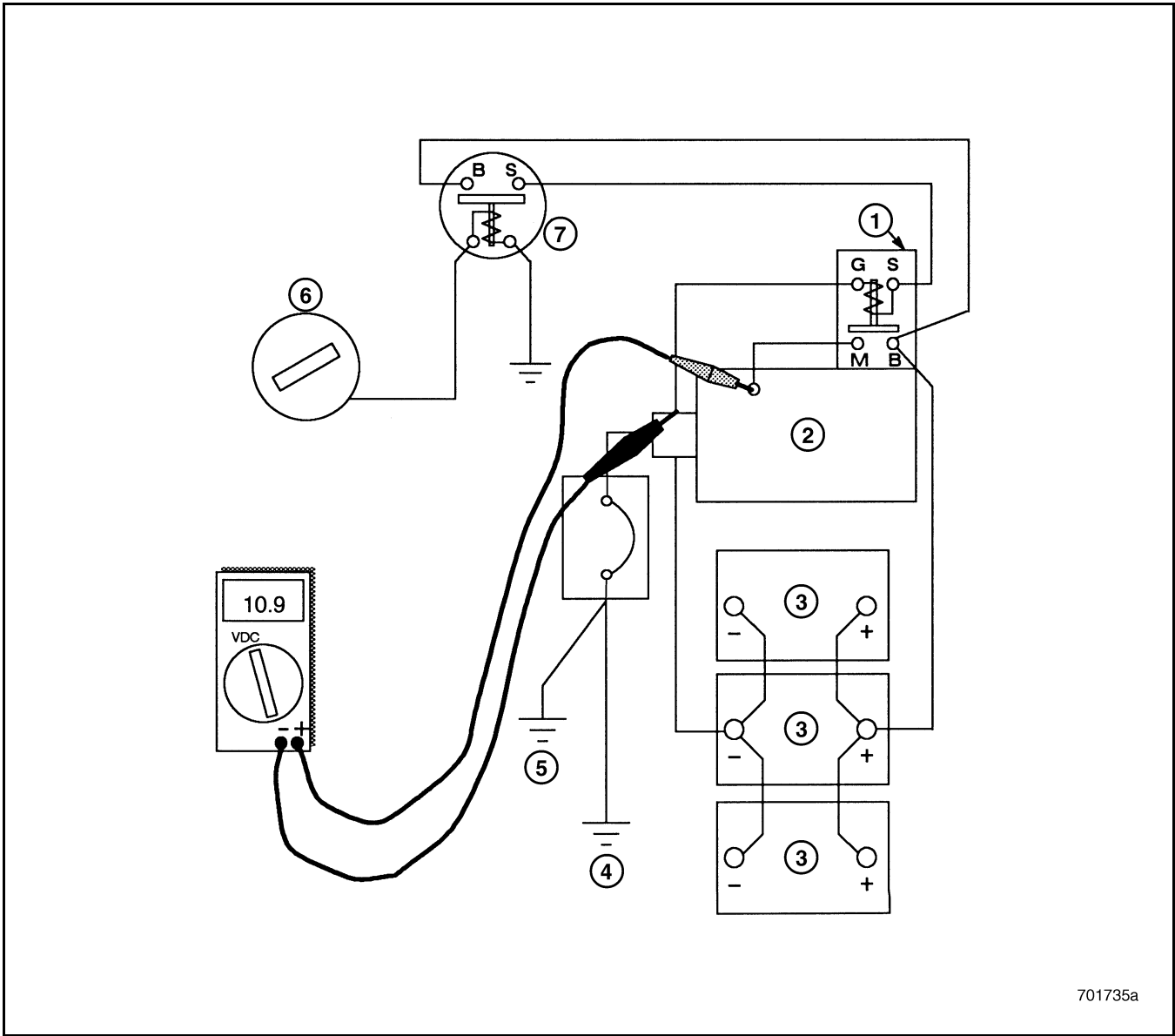
Figure 58 — Checking Starting Voltage at Batteries

1. Meter Negative Lead to Battery	2. Meter Positive Lead to Battery
-----------------------------------	-----------------------------------

5. Move the meter leads to the starter:
- Negative (–) lead on the starter ground terminal.
 - Positive (+) lead on the starter motor power terminal (connection from starter solenoid M terminal on the starter).
6. Turn the key to the start position and energize the starter.
7. Observe the voltage indicated on the meter.
Then release the key.



DESCRIPTION AND OPERATION



701735a

Figure 59 — Checking Starting Voltage at Starter

1. Starter Solenoid 2. Starter Motor 3. Battery 12 Volts 4. Engine Ground	5. Frame Ground 6. Key Switch (Turn Key to Energize Starter Motor) 7. Starter Relay
--	---

Voltage measured at the starter motor positive terminal (through solenoid) and starter motor ground terminal should be equal to voltage measured at the batteries (within 0.8 volt — approximately 0.2 volt per cable, plus approximately 0.3 volt for solenoid).

If voltage is the same at both locations, and the starter motor cranks too slowly or does not crank at all, the most probable cause is a high internal resistance within the starter motor. Remove and

repair the starter. Refer to the starter manufacturer service literature for repair and bench testing procedures.

Significantly less voltage measured at the starter motor (greater than an 0.8 volt difference between the starter and the batteries) indicates that voltage is being lost somewhere in the starter cranking circuit. Proceed by measuring voltage loss through the battery cables and the starter solenoid.



DESCRIPTION AND OPERATION

BATTERY CABLE TESTS

To perform battery cable tests and check voltage drop:

1. Set the meter to the VDC function.
2. Connect the positive (+) meter lead to the positive battery post (connect on the post and not on the clamp), and the negative (-) lead to the starter solenoid "BAT" terminal.
3. Turn the key and energize the starter without allowing the engine to start.
4. Observe the reading indicated on the meter.
5. Turn the key OFF
6. Move the negative (-) lead to the negative terminal stud on the battery, and the positive (+) lead to the starter motor ground connection.
7. Turn the key to energize the starter motor and observe the voltage indicated on the meter.

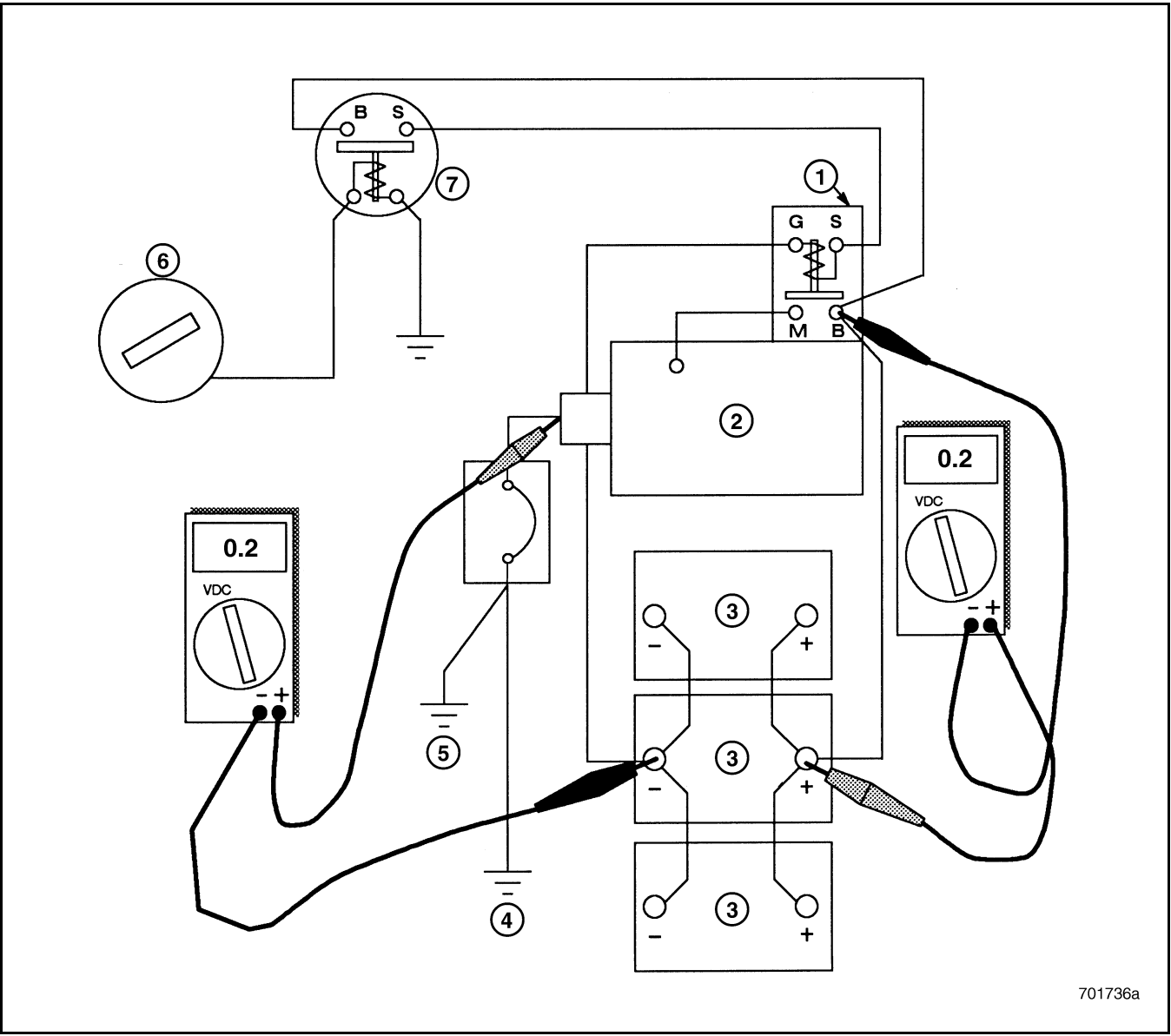


Figure 60 — Battery Cable Tests

1. Starter Solenoid	5. Frame Ground
2. Starter Motor	6. Key Switch (Turn Key to Energize Starter Motor)
3. Battery 12 Volts	7. Starter Relay
4. Engine Ground	



DESCRIPTION AND OPERATION

Voltage loss should not exceed 0.2 volt through the positive battery cable, and 0.2 volt through the negative battery cable. If an excessive loss through either cable is indicated, locate and repair the cause. Look for loose connections, corrosion and other problems.

STARTER SOLENOID AND STARTER RELAY VOLTAGE DROP

Use the following procedure to check voltage drop through the starter solenoid and the starter relay:

1. Set the multimeter to the VDC function.
2. Connect the positive (+) lead to the starter solenoid B terminal and the negative (-) lead to the starter solenoid M terminal as shown in Figure 61.
3. Turn the key to the start position and energize the starter, without allowing the engine to start.
4. Note the reading indicated on the meter.
5. Move the meter leads to the starter relay B and S terminals as shown in Figure 61.
6. Turn the key to the start position and energize the starter without allowing the engine to start.

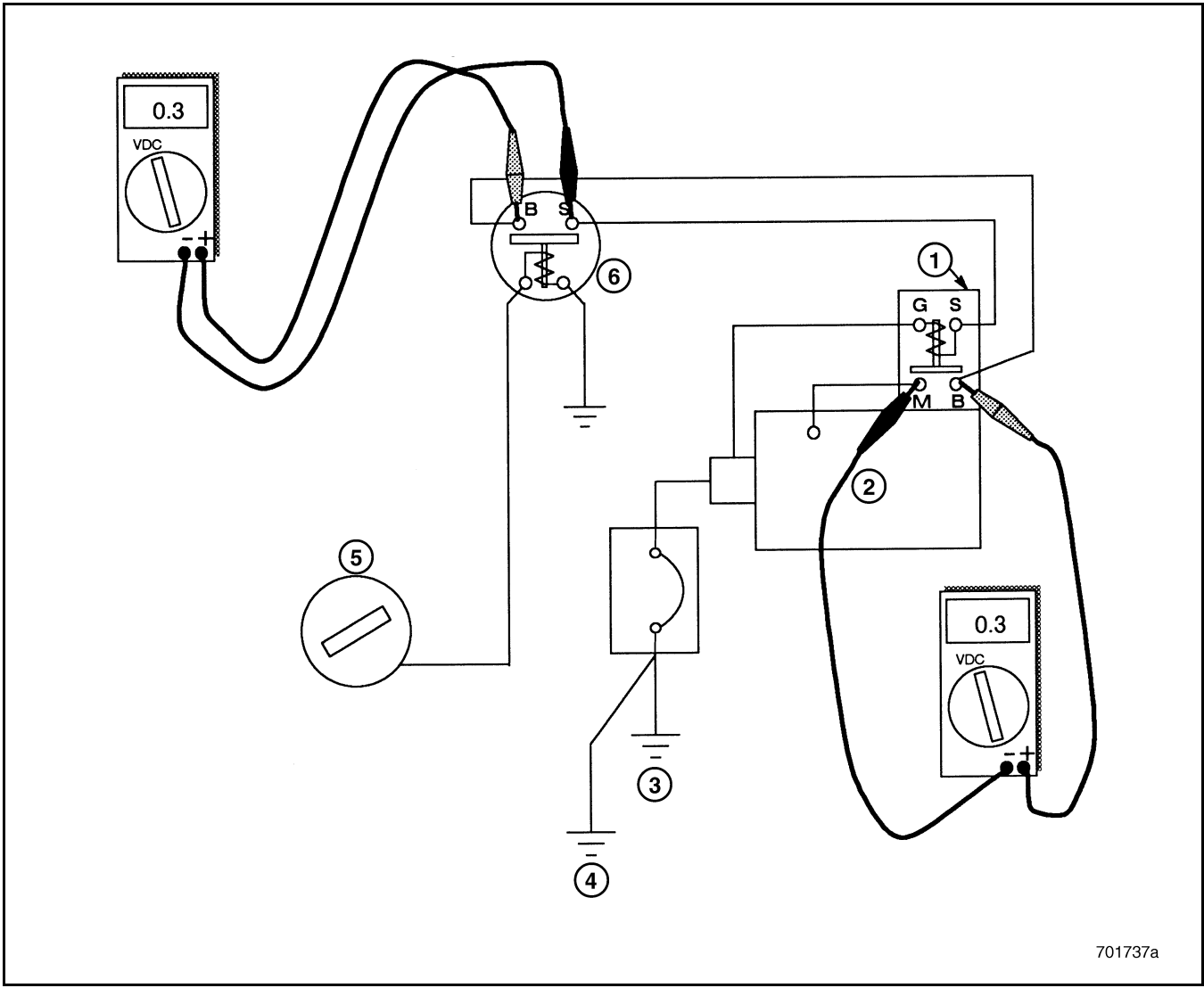


Figure 61 — Checking Voltage Drop

1. Starter Solenoid	4. Frame Ground
2. Starter Motor	5. Key Switch (Turn Key to Energize Starter Motor)
3. Engine Ground	6. Starter Relay



DESCRIPTION AND OPERATION

Note the reading indicated on the meter. Voltage drop through the solenoid or the starter relay should be 0.3 volt or less.

- A voltage drop greater than 0.3 volt indicates a high resistance inside the component. Replace the faulty component.
- If the voltage drop is 0.3 volt or less, voltage drop through the battery cables may be excessive. Refer to Battery Cable Tests.

STARTER RELAY AND KEY SWITCH

If the starter does not energize when the key is turned to the start position, begin the troubleshooting procedure by testing voltage at the starter relay, use the following procedure:

NOTE

Disconnect the wire from the starter solenoid S terminal before performing the following tests.

NOTE

An audible click should be heard coming from the starter relay when the key is turned ON. If not, the switch is most likely defective. This can be checked quickly by disconnecting the wires from the two smaller terminals and using the multimeter to measure the resistance through the coil wires. There should be a small resistance through the coil. If the meter indicates a very high resistance, or infinite resistance, the starter relay is defective.

1. Set the multimeter to the VDC function.
2. Connect the meter leads across the starter relay coil windings (two small terminals on the starter relay):
 - Negative (–) lead to the starter relay ground connection.
 - Positive (+) lead to the starter relay key switch connection.
3. Turn the key to the start position. Observe the voltage indicated on the meter, then release the key.

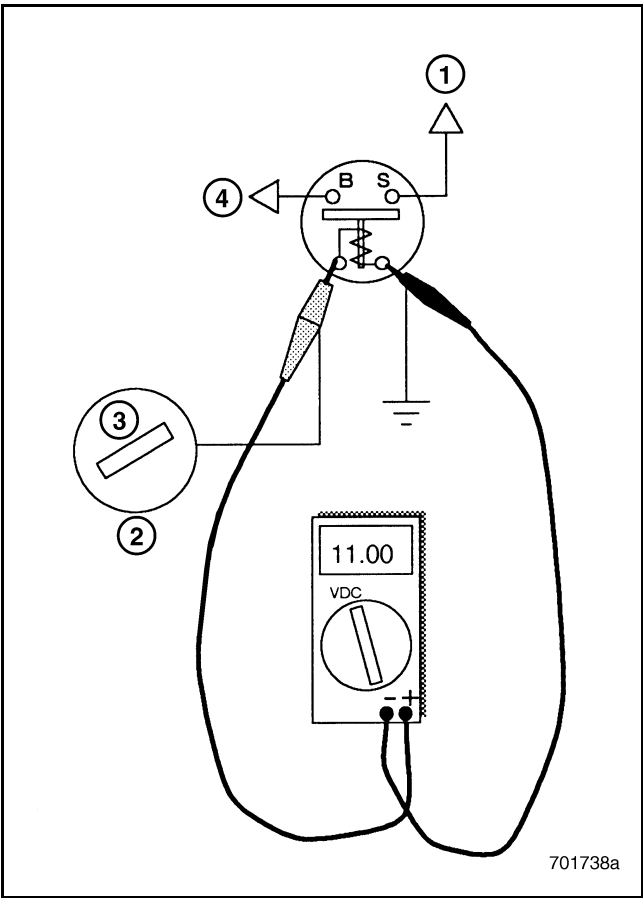


Figure 62 — Testing Voltage at Starter Relay

- | | |
|-------------------------------------|--------------------------------------|
| 1. To Starter Solenoid "S" Terminal | 3. Turn Key to Energize Start Switch |
| 2. Key Switch | 4. To Starter Solenoid "B" Terminal |

A voltage reading of 0 volts indicates an open circuit between the key switch and the starter relay. Check for disengaged connectors, broken or damaged wires or a faulty key switch. Repair or replace as necessary.

A voltage reading of less than 11.0 volts indicates a high-resistance condition in the starter control circuit. Check for loose or corroded connections and damaged wires. Repair or replace as necessary. If voltage is still less than 11.0 volts after repairs have been made, replace the starter relay.



DESCRIPTION AND OPERATION

CHARGING SYSTEM

Operation

The charging system consists of the alternator, voltage regulator, batteries and any associated wiring connected between the alternator, batteries and ground connections. The alternator keeps the batteries fully charged, and powers the various chassis and cab electrical components.

Typically, a fully charged, 12-volt battery has approximately 12.6 volts available when measured across its terminals. Electrical system use draws current from the batteries, causing the voltage to drop. When battery voltage drops to a preset level, the voltage regulator energizes the alternator to replenish battery voltage. Alternator output should be approximately 14.0 volts to bring the battery voltage back up to 12.6 volts. The voltage regulator cycles the alternator on and off up to 700 times per minute. When electrical demands are high, the alternator remains energized for longer periods of time. When demand is low, the alternator is de-energized and provides no output voltage.

Alternators generate alternating current (AC), but truck electrical systems operate on direct current (DC). Rectifier diodes are used to convert the AC voltage into DC voltage. The typical alternator used on a MACK chassis is a brush type that features an internal voltage regulator.

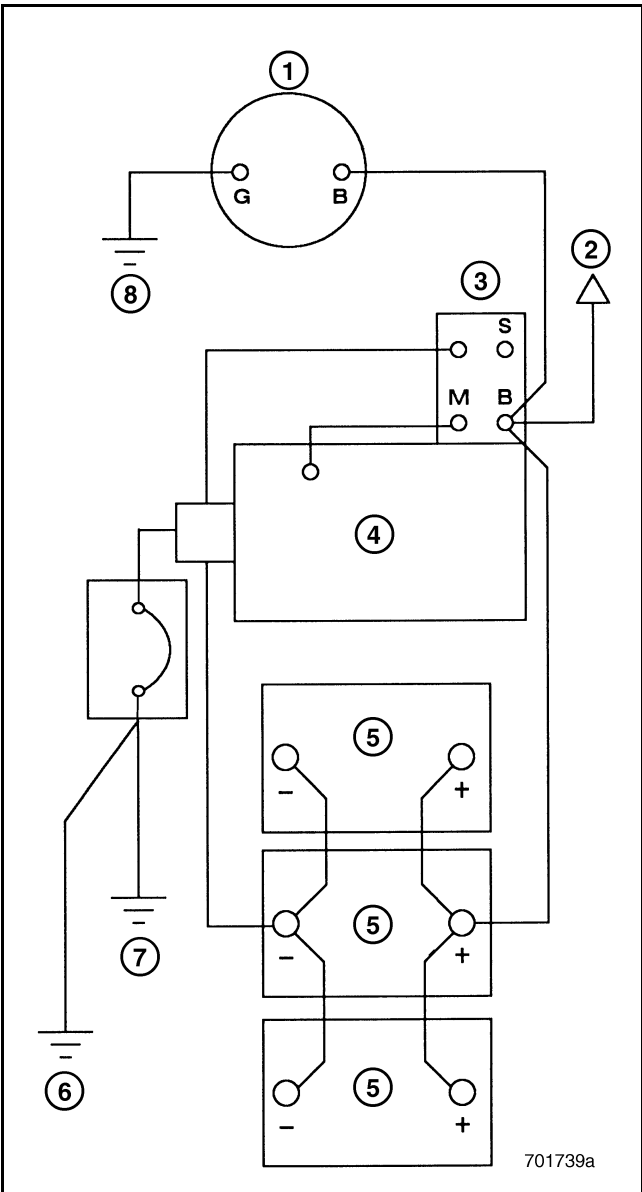


Figure 63 — Charging System Circuit

1. Alternator	5. Battery
2. To Breaker Panel	6. Frame Ground
3. Starter Solenoid	7. Engine Ground
4. Starter Motor	8. Alternator Ground



DESCRIPTION AND OPERATION

Charging System Tests

Charging system faults can be categorized as undercharging, overcharging or no charging. The alternator output tests will help determine the various faults that can be encountered.

Before investigating an undercharge condition, check the following:

- Determine that the undercharge condition is not caused by electrical devices (lights, radios, etc.) that were turned on for an extended period of time.
- Check the alternator drive belt for proper tension.
- Check battery condition, state-of-charge and capacity.
- Inspect for defective wires, and check all connections (including all battery terminals) for tightness and cleanliness.

Alternator output must reach the batteries and the chassis electrical components with a minimum amount of voltage loss. Voltage loss prevents the batteries from recharging at an adequate rate, and in some instances, the chassis electrical components will not operate at full potential. The voltage regulator controls maximum system voltage, which should be available at the alternator output terminal. If voltage is lost somewhere in the wiring, the voltage that reaches the batteries and components is less than maximum. The greatest voltage loss occurs when charging system output is at its maximum regulated amperage.

ALTERNATOR OUTPUT (UNLOADED)

To quickly test alternator output, use the following procedure:

NOTE

Before proceeding, make sure the batteries are in good condition and are fully charged and the connections are clean and tight.

1. Set the meter to the VDC function.
2. Start the engine. Connect the positive (+) meter lead to the alternator "BAT" terminal, and the negative (-) lead to a good ground.

3. With all electrical accessories turned off, increase engine speed as necessary to obtain a maximum voltage reading. Note the voltage indicated on the meter.

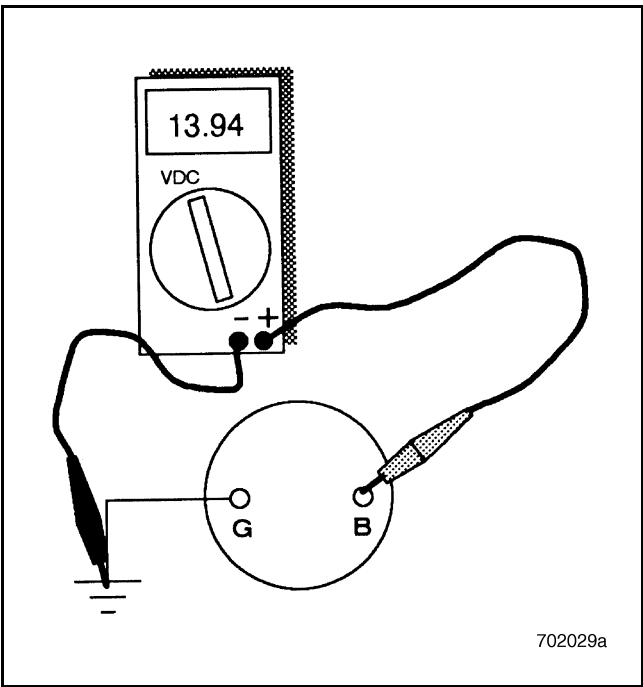


Figure 64 — Checking Alternator Output at the Alternator

4. With the engine running at the same speed, measure the voltage across the positive and negative battery terminals.

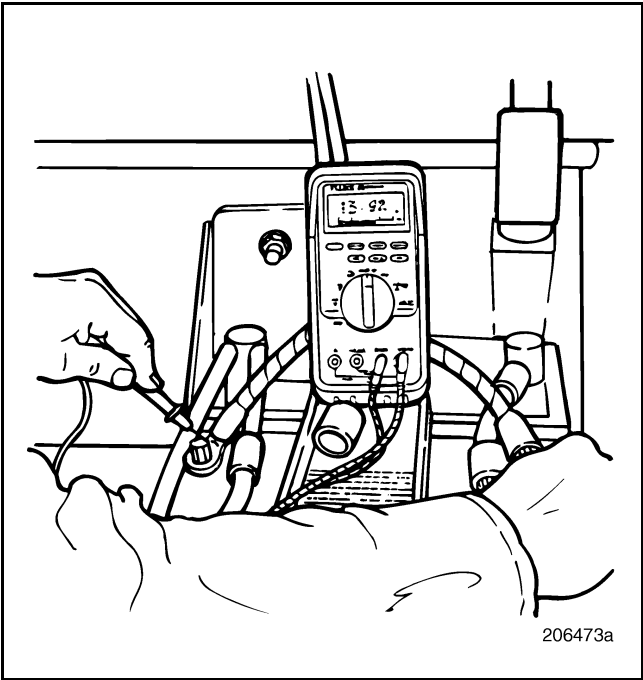


Figure 65 — Measuring Alternator Output at Batteries



DESCRIPTION AND OPERATION

Normal alternator output voltage should be 13.0 to 15.0 volts, and the same amount of voltage should be shown at the battery terminals. If alternator output is greater than 15.0 volts, refer to the alternator manufacturer service literature for voltage regulator adjustment procedures. If alternator output is satisfactory, but less voltage is indicated at the batteries, perform the following test:

With the engine running, and as many electrical components turned ON as possible, check the voltage loss at the following Test locations (refer to Figure 66).

TEST 1. From alternator G terminal to alternator ground (on engine).

TEST 2. From battery negative terminal to starter ground (on frame).

TEST 3. From positive battery terminal to starter solenoid B terminal.

TEST 4. From starter solenoid B terminal to alternator B terminal.

Voltage loss should not exceed 0.1 volt through any cable. If voltage loss is excessive, look for loose or corroded connections or damaged cables. Repair as necessary. If however, voltage loss through the cables was within specifications, the alternator is faulty and must be removed for repair. Refer to the alternator manufacturer's service literature for repair procedures.

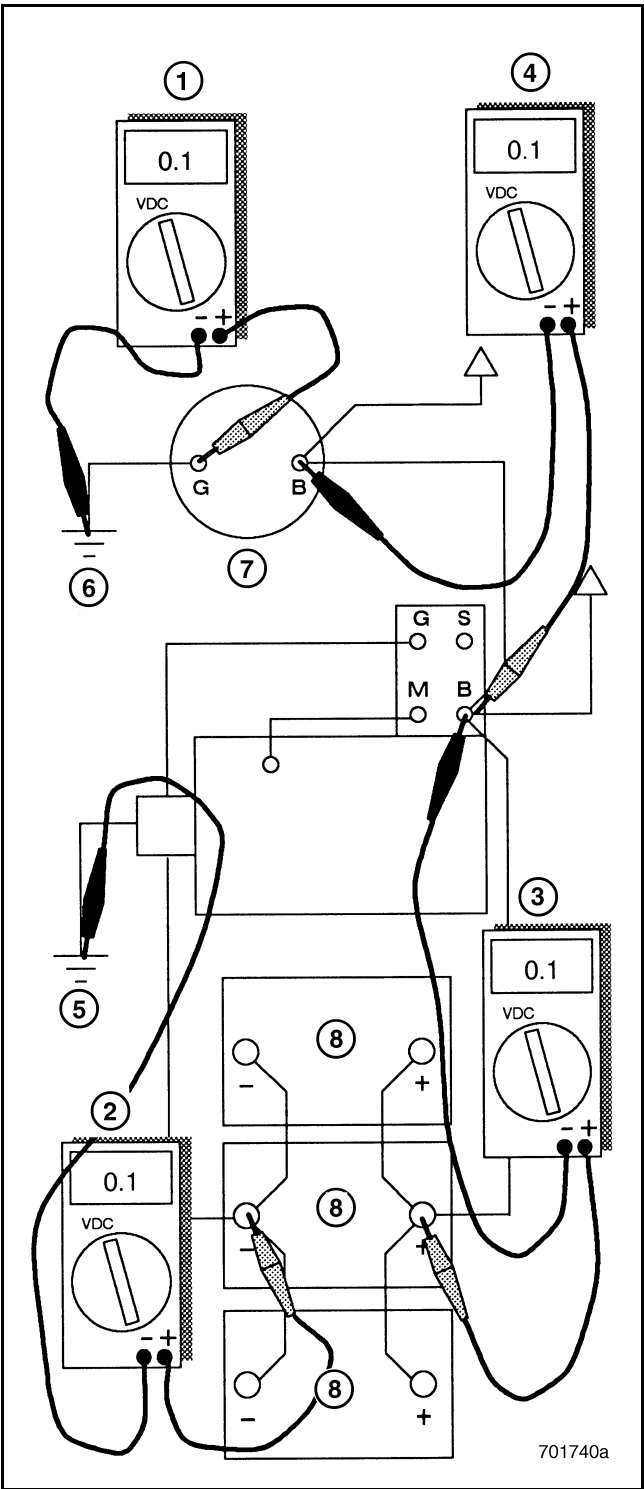


Figure 66 — Alternator Testing

1. Test 1	5. Ground on Frame
2. Test 2	6. Ground on Engine
3. Test 3	7. Alternator
4. Test 4	8. Battery



DESCRIPTION AND OPERATION

MISCELLANEOUS CIRCUITS — DESCRIPTION/FUNCTION

Lighting

MACK vehicles are equipped with daytime running lights. This system functions to illuminate the headlights (at less power) for daytime operation, and operates when the keyswitch is turned ON and the parking brakes released. When the daytime running light circuit is activated, the headlights are controlled by the Daytime Running Light (DRL) module which is located on the electrical equipment panel.

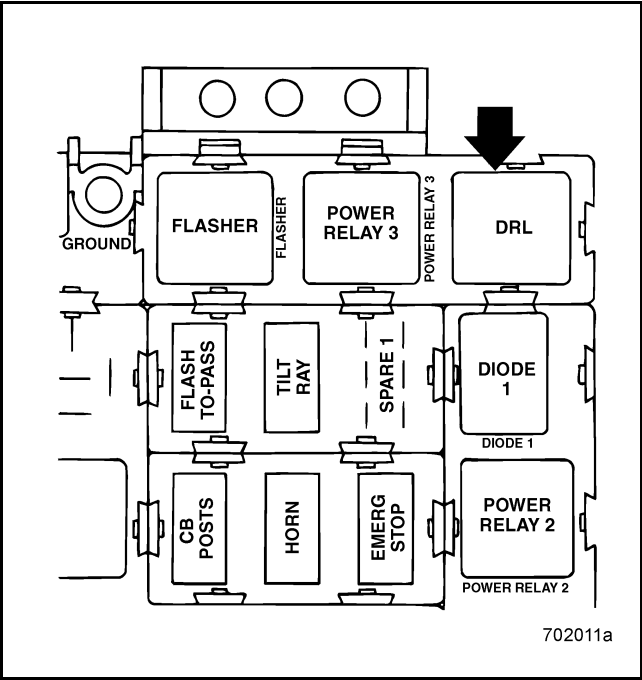


Figure 67 — Daytime Running Light (DRL) Module

The DRL module is a solid state device that cycles the headlights on and off a specific number of times per second (a frequency of approximately 115 cycles per second). When the headlights are cycled so rapidly, they are illuminated at less power (approximately 79%) than when illuminated normally through the headlight switch. To turn the daytime running lights ON, a normally closed pressure switch located in the parking brake air circuit signals the DRL module when the parking brakes are released. The DRL module is bypassed when the headlight switch is turned ON, allowing the headlights to illuminate at full power.

Other components in the lighting circuit include the tilt-ray relay which functions with the headlight dimmer switch to cycle the headlights between high and low beams, and the flash-to-pass relay which functions with the flash-to-pass switch to momentarily flash the headlights. On most MACK vehicles, both the dimmer switch and the flash-to-pass switch are an integral part of the turn signal switch. Refer to Figure 68 for a partial illustration of the lighting circuits.

When troubleshooting any faults that may occur with the lighting circuits, standard electrical tests are used. When a fault with the daytime running lights is experienced, and all other electrical tests of the circuits indicate the fault exists with the DRL module, the easiest method of troubleshooting the system is by removing the DRL module and replacing it with a module that is known to be functioning properly.



DESCRIPTION AND OPERATION

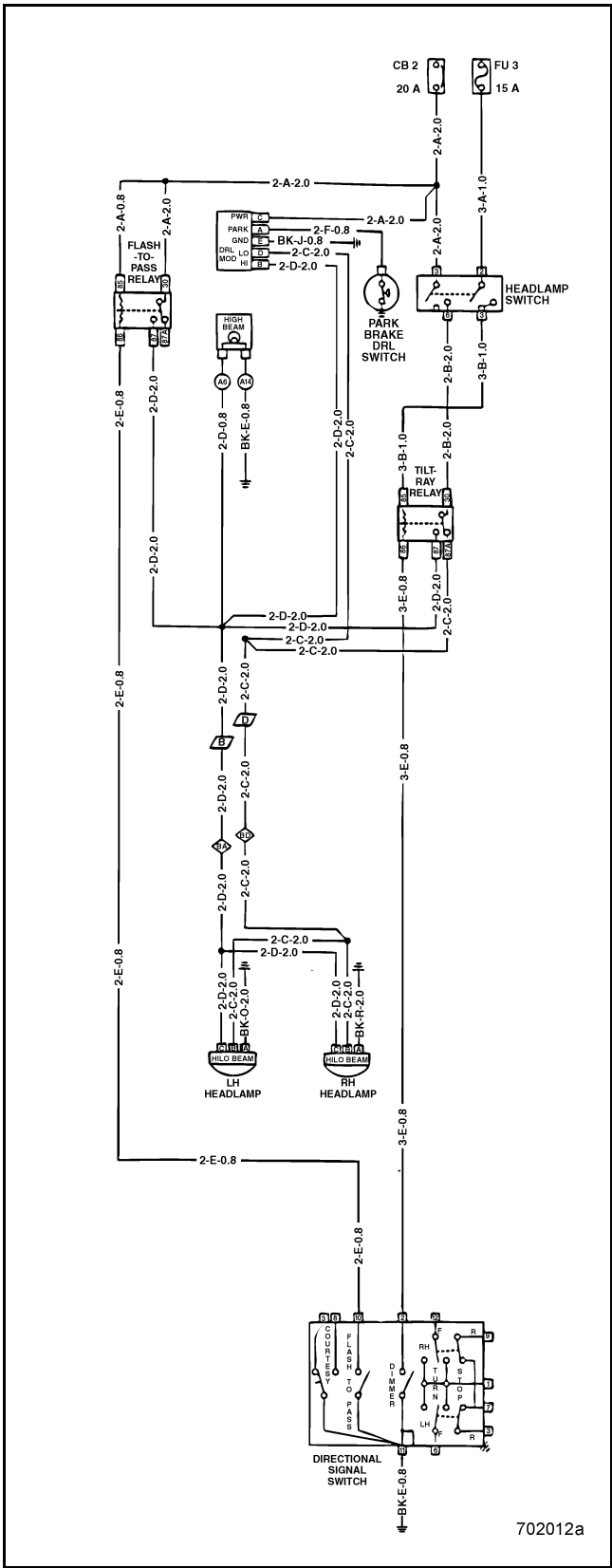


Figure 68 — Lighting Circuits

Gauges

Gauges that receive an electrical signal from a sending unit, with the exception of the engine oil pressure gauge (except CX models) and air system pressure gauge, are electrically operated units that function when current (signal from sending unit) passes through the gauge coils. The sending unit controls the amount of current flowing through the gauge coils, which then causes the gauge needle to register a reading. Variable-resistance sending units, thermistors, etc. are connected in series with the gauges.

GAUGE CONNECTIONS (EXCEPT VOLTMETER)

On printed circuit board type instrument clusters, the instrument cluster gauges are simply pushed into position and secured by the front cover bezel and pinch connectors on the circuit board. The fastening posts and nuts of the past have been eliminated from this type of cluster.

Push-in type pin terminals on the gauge, provide the electrical connection between the gauge and the instrument cluster. Each gauge has three terminal pins on the back of the gauge body. The gauge receives power at the ignition terminal (lower pin on gauge) and connects to ground at the ground terminal (right pin on gauge). Signal voltage from the sending unit is transmitted through the signal terminal (left pin on gauge). A locating tab on the lower portion of the gauge holder prevents incorrect gauge installation. Refer to Figure 70. R, MR, LE model vehicles have individual gauges that are secured in the dash with clamps, wires are connected with terminal lugs.



DESCRIPTION AND OPERATION

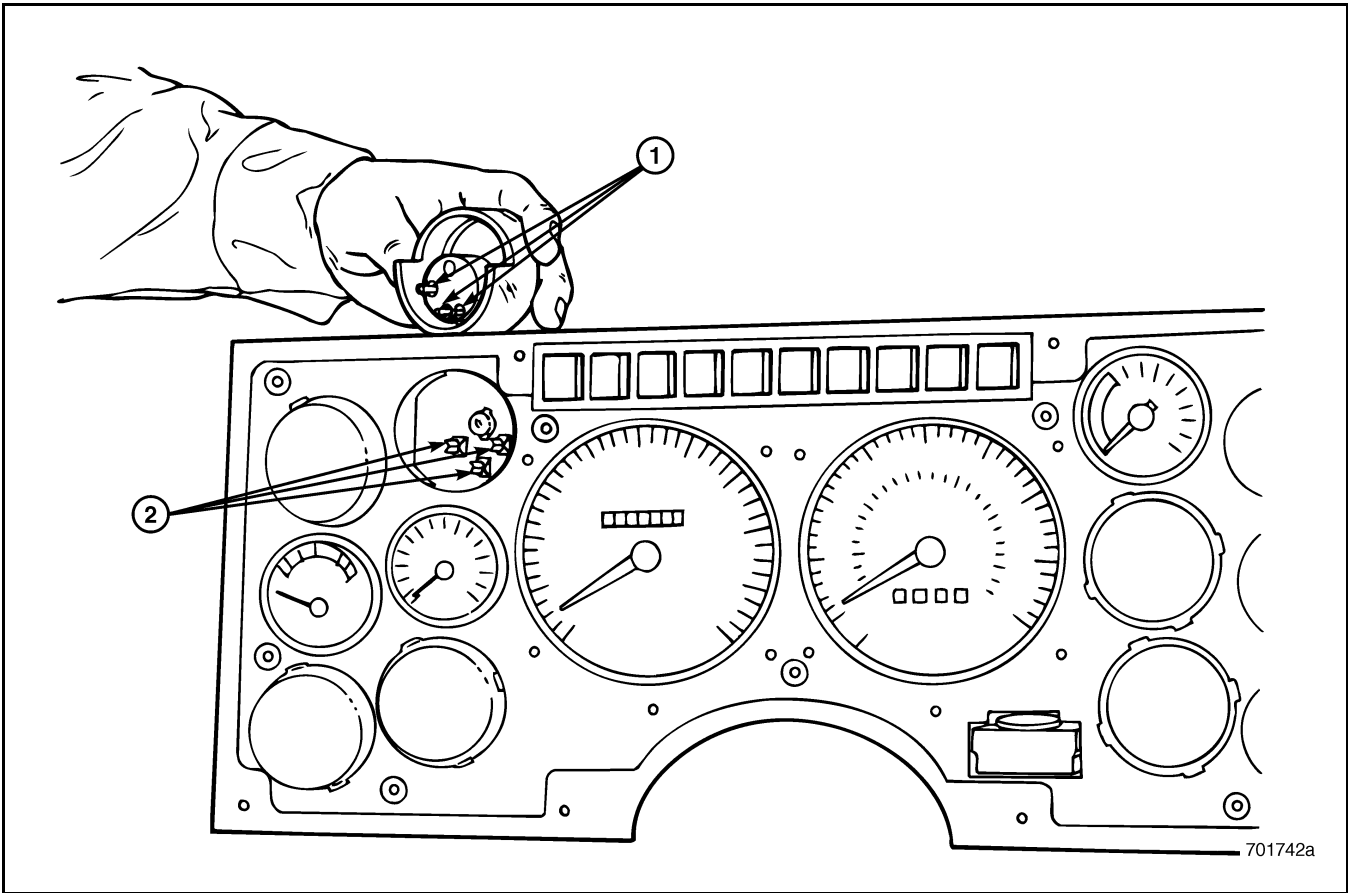


Figure 69 — Gauge Pin Terminals and Instrument Cluster Pinch Connectors (CH and CL Shown)

1. Gauge Pin Terminals	2. Instrument Cluster Pinch Connectors
------------------------	--

On CH and CL models, three pinch connectors soldered into the instrument cluster, provide the gauge electrical connections. The instrument cluster chassis provides an opening or gauge socket to locate each gauge. A locator slot is positioned at the lower portion of the gauge opening. A push-in type lamp is used to illuminate the gauge. Refer to Figure 71.

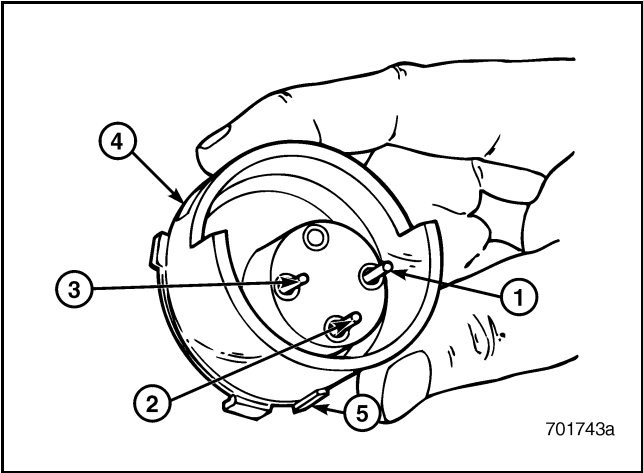


Figure 70 — Gauge Pin Terminals

1. Ground Terminal	4. Instrument Cluster Gauge
2. Ignition Terminal	5. Gauge Holder Locating Tab
3. Signal Terminal	



DESCRIPTION AND OPERATION

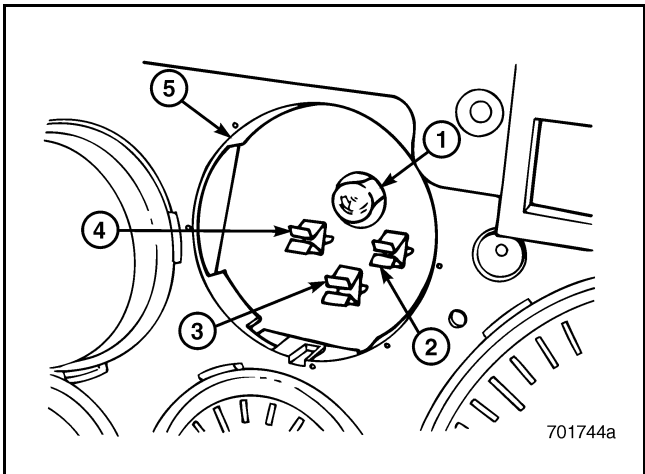


Figure 71 — Instrument Cluster Gauge Pinch Connectors

1. Lamp for Instrument Cluster Gauge	4. Ground Pinch Connector
2. Sending Unit Signal Pinch Connector	5. Instrument Gauge Socket
3. Ignition Pinch Connector	6. Gauge Locator Slot

GAUGE CONNECTIONS (VOLTMETER)

The voltmeter connections on the instrument cluster printed circuit board are similar to other instrument cluster gauges, except there are only two pin terminals on the gauge and two pinch connectors on the instrument cluster. One terminal is for ignition voltage, while the other terminal is a ground connection through the instrument cluster. Ignition voltage flows through the meter and is registered as a voltage reading on the gauge:

- With the key switch turned to the “ACC” or “RUN” position and the engine not running, the voltmeter indicates battery voltage.
- When the engine is running and the charging system is functioning, the meter indicates charging system voltage.

Sending Units

TEMPERATURE SENDING UNIT

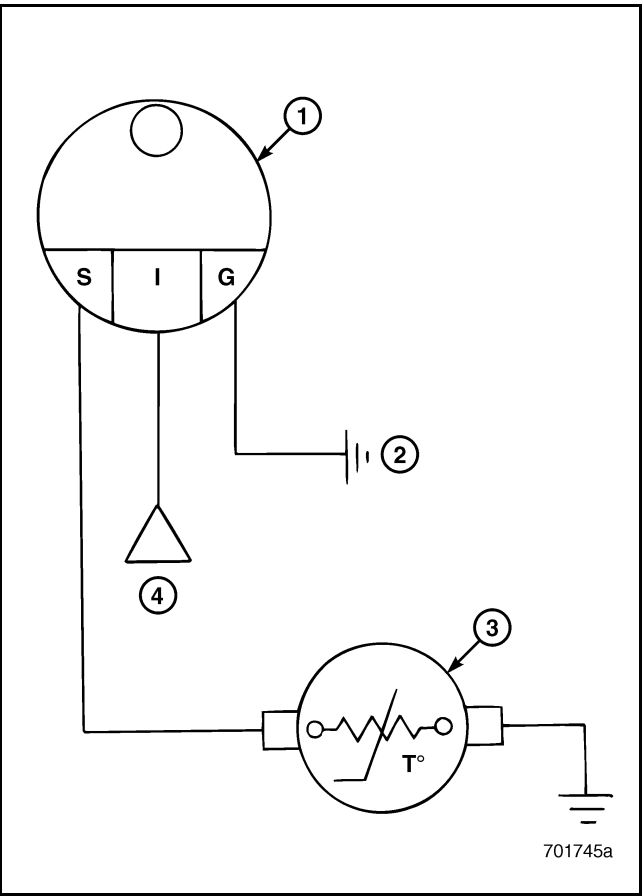


Figure 72 — Temperature Sending Unit Schematic

1. Temperature Gauge	3. Temperature Sending Unit
2. Instrument Panel Ground	4. From Key Switch (Ignition Voltage)

Signal voltage at the signal voltage terminal of the gauge is varied by the temperature sending unit. The sending unit is a thermistor that responds to changes in temperature. As temperature decreases, sending unit resistance increases. As temperature increases, sending unit resistance decreases. This variation in sending unit resistance affects current flowing through the temperature gauge coil which moves the gauge needle to register a reading on the gauge. At lower temperatures, sending unit resistance is high, causing the gauge to register a low temperature reading. As temperature increases, sending unit resistance decreases, and the gauge registers a high temperature reading.



DESCRIPTION AND OPERATION

FUEL LEVEL SENDING UNIT

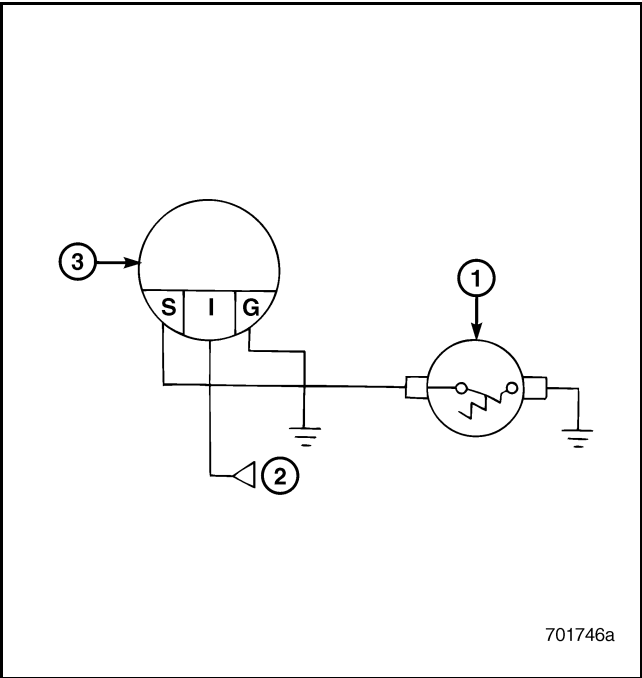


Figure 73 — Fuel Level Sending Unit Schematic

1. Fuel Level Sending Unit	3. Fuel Level Gauge
2. From Key Switch (Ignition Voltage)	

The fuel level sending unit consists of a variable resistor and a float. As fuel level inside the fuel tank changes, the float reacts up or down accordingly and moves the arm of the variable resistor. As the arm moves, sending unit resistance changes and causes a change in current flowing through the fuel gauge coil. The fuel gauge shows its lowest reading when the sending unit is at its highest resistance. The fuel gauge shows its highest reading when the sending unit is at its lowest resistance. Ignition voltage is provided to the sending unit through the fuel gauge. The fuel level sending unit resistor is grounded to the chassis.

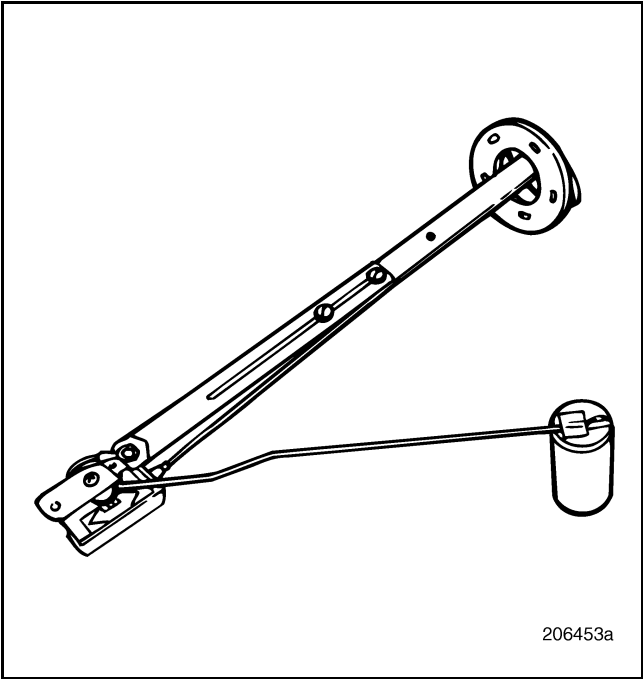


Figure 74 — Fuel Level Sending Unit



NOTES



TROUBLESHOOTING

TROUBLESHOOTING



TROUBLESHOOTING

TROUBLESHOOTING OF INSTRUMENT CLUSTER, GAUGES, SENDING UNITS, SENSORS AND HORN

This section will be troubleshooting of the following:

- Instrument Cluster
- Gauges
- Sending Units
- Sensors
- Horn

Before beginning any extensive troubleshooting, first check all connector and ground connections. Look for loose or damaged terminals, corrosion, or broken or frayed wires. Make sure all connections are tight.

NOTE

The following gauge testing information does not apply to CX model chassis. CX models have an electronic dashboard and information to the gauges is transmitted through the dashboard module.

Gauge Testing

TESTING GAUGE OPERATION

Testing gauge operation involves:

- Checking for power at the gauge.
- Checking for a good ground.
- Installing a jumper wire across the terminals of the sending unit harness connector.

To conduct a simple test of gauge operation, momentarily jumper the sending unit harness connector terminals and observe the reaction of the gauge needle:

1. Turn the key to the “ACC” or “RUN” position.
2. Install a jumper across the sending unit harness connector terminals of the suspect gauge.
3. Observe the reaction of the gauge needle.

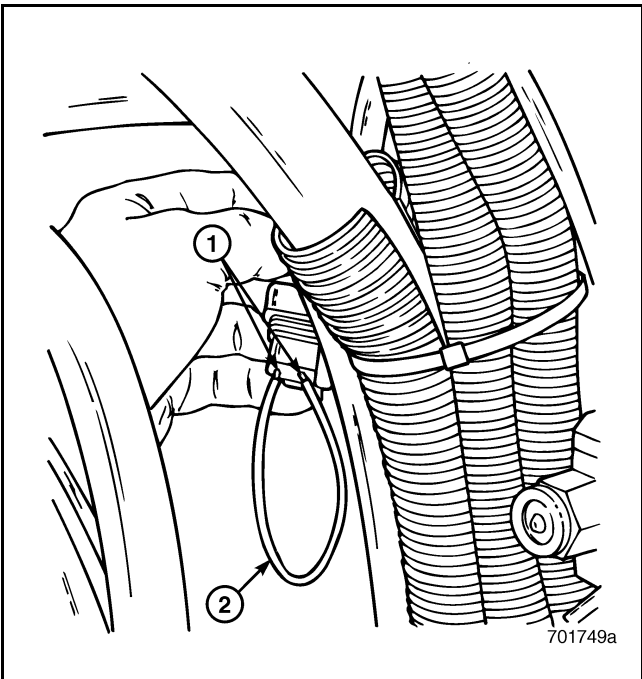


Figure 75 — Jumping Sending Unit Harness Connector

- | | |
|---|----------------|
| 1. Sending Unit Harness Connector Terminals | 2. Jumper Wire |
|---|----------------|

If the needle of the suspect gauge moves to full scale when the sending unit harness connector was jumpered, the gauge is functioning properly and the fault can most likely be isolated to the sending unit. If the gauge needle did not react, the fault can be isolated to the gauge and associated wiring circuits. When the gauge and/or circuit fault has been corrected, retest the gauge circuit operation. Refer to Checking for Voltage at the Gauge.



TROUBLESHOOTING

CHECKING FOR VOLTAGE AT THE GAUGE

For the gauge to operate, voltage must be present at the instrument cluster ignition pinch connector terminal for the suspect gauge.

- Test for voltage, using the following procedure:
1. Set the multimeter to the VDC function.
 2. Turn the key to the ACC or RUN position.
 3. Connect the negative (–) lead to a good ground (or ground connector terminal of the instrument cluster), and the positive (+) lead to the ignition connector terminal in the gauge socket of the instrument cluster.

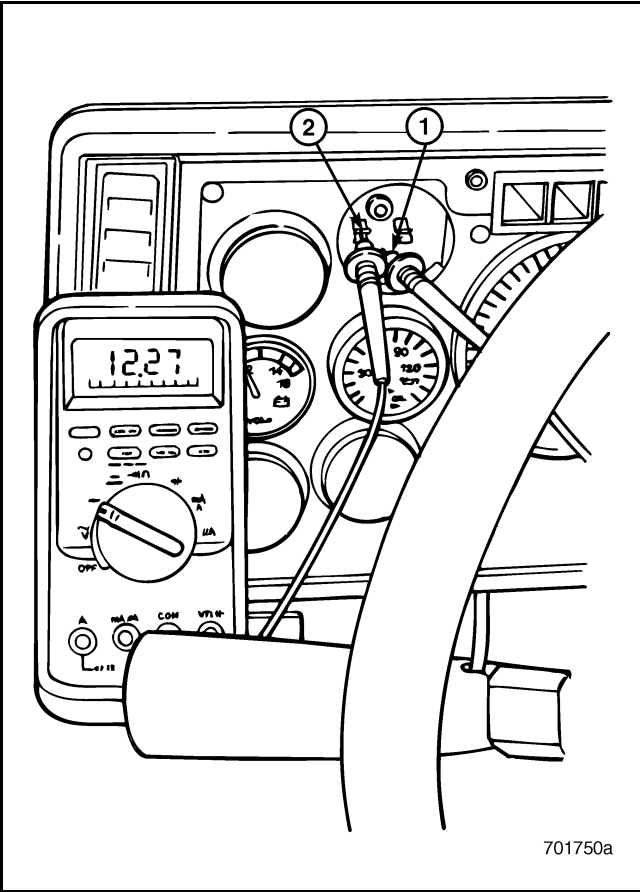


Figure 76 — Checking for Ignition Voltage at Instrument Cluster

- | | |
|--|--|
| 1. Meter Positive Lead to Instrument Cluster Ignition Terminal | 2. Meter Negative Lead to Instrument Cluster Ground Terminal |
|--|--|

The meter should indicate battery voltage. If no voltage is indicated at the ignition terminal, check to make sure the meter negative lead is attached to a known good ground, and then check for an

open in the ignition voltage circuit. If battery voltage is indicated, proceed to Checking the Ground Circuit.

CHECKING THE GROUND CIRCUIT

1. Set the multimeter to the resistance function.
2. Connect one lead to the instrument cluster ground terminal for the gauge and the other lead to the common ground stud of the dashboard.

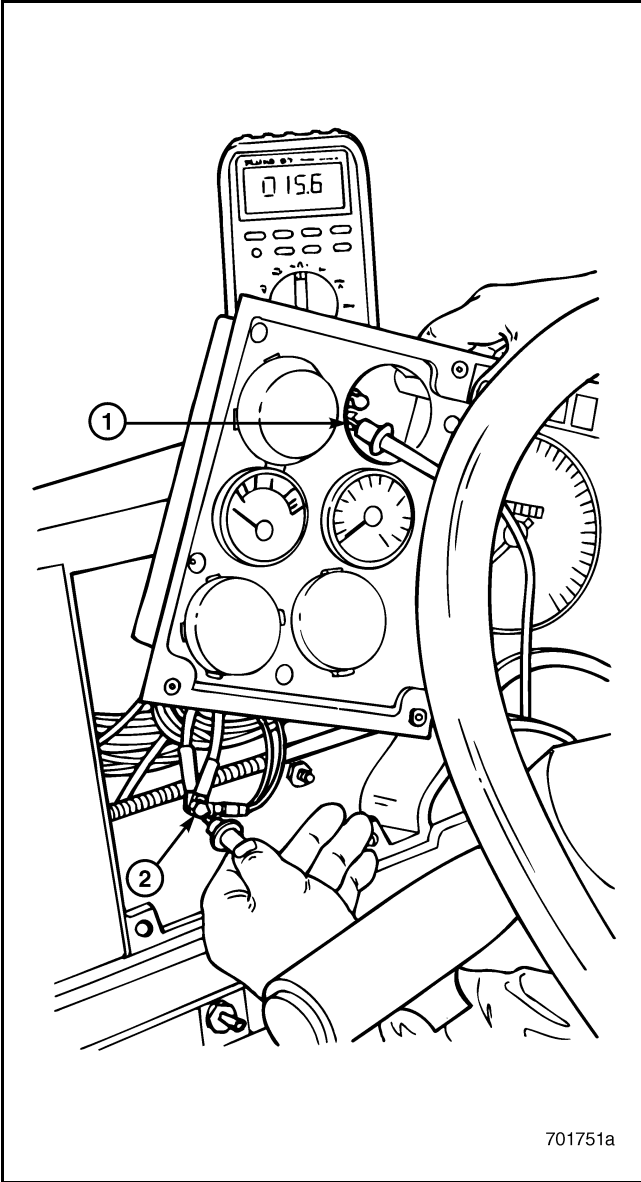


Figure 77 — Checking Ground Circuit

- | | |
|--|--|
| 1. Meter Positive Lead to Instrument Cluster Ground Terminal for Gauge | 2. Meter Negative Lead to Instrument Cluster Grounding Stud on Dashboard |
|--|--|



TROUBLESHOOTING

The meter should indicate 0 ohms, or fractions of ohms for a good ground connection. A resistance reading greater than a few ohms indicates a fault in the ground circuit. Check for loose or corroded ground connections, or damaged wires, and repair as necessary.

CHECKING SIGNAL VOLTAGE

A gauge reacts to input signals received from the sending unit. To check signal voltage at the gauge S terminal:

1. Set the multimeter to the VDC function.
2. Turn the key to the ACC or RUN position.
3. Connect the negative (–) lead to the instrument cluster ground terminal for the gauge, and the positive (+) lead to the signal terminal on the instrument cluster. Observe the reading indicated on the meter.

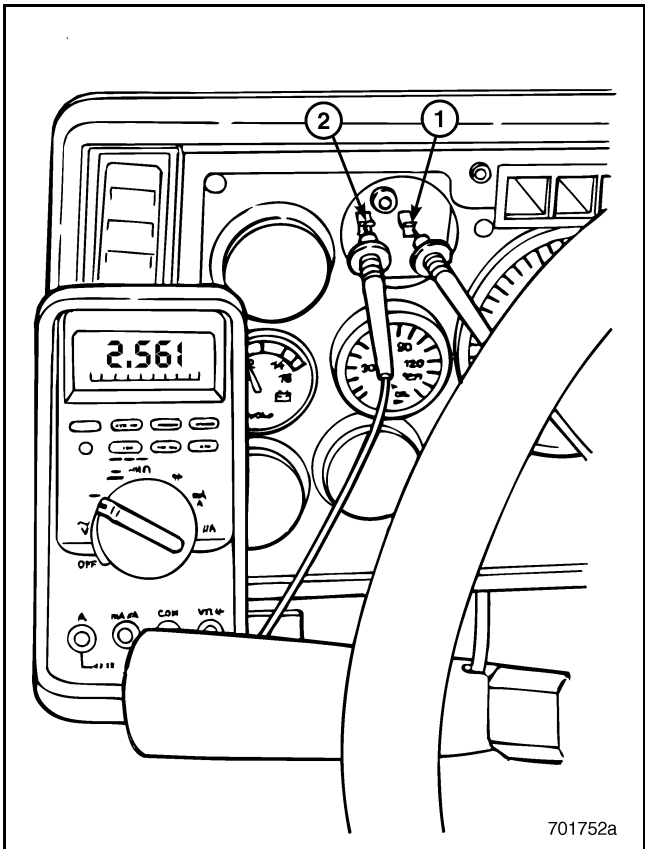


Figure 78 — Checking Signal Voltage

1. Meter Positive Lead to Instrument Cluster Signal Terminal for Gauge	2. Meter Negative Lead to Instrument Cluster Ground Terminal for Gauge
--	--

Signal voltage depends upon sending unit resistance, and the resulting voltage changes (such as changes in temperature when checking temperature gauges, or fuel level changes when checking fuel level gauges). If the multimeter is indicates full battery voltage at the signal terminal and the gauge needle is at full scale, a short most likely exists in either the sending unit or in the wiring between the signal terminal and the sending unit.

If the meter indicates 0 volts at the signal terminal and the gauge needle does not move off the lowest scale when the circuit is powered, an open may exist in either the sending unit or in the circuit between the sending unit and the signal terminal.

Specific Gauge and Sending Unit Tests

VOLTMETER

The voltmeter does not receive any signal voltage from a sending unit, but merely uses ignition voltage at the ignition terminal as the input signal. If the voltmeter is suspect, troubleshooting is only a matter of checking for power at the ignition terminal behind the gauge on the instrument cluster and making sure there is a good ground connection. To test the accuracy of the voltmeter, measure the voltage across the ignition and the ground terminals with a multimeter. Then compare the reading with the reading registered on the voltmeter.



TROUBLESHOOTING

TEMPERATURE SENDING UNITS

Temperature sending units react to changes in temperature by changing resistance. Sending units can be tested by measuring resistance through the unit at various temperatures using the following procedure:

- 1. Disconnect the harness connector from the sending unit.
- 2. Set the multimeter to the resistance function.
- 3. Connect one lead to a good ground and the other lead to the sending unit terminal.
- 4. Measure and note the resistance through the sending unit while it is still cold.
- 5. Start the engine and allow the sending unit to heat up while observing the reading indicated on the meter.

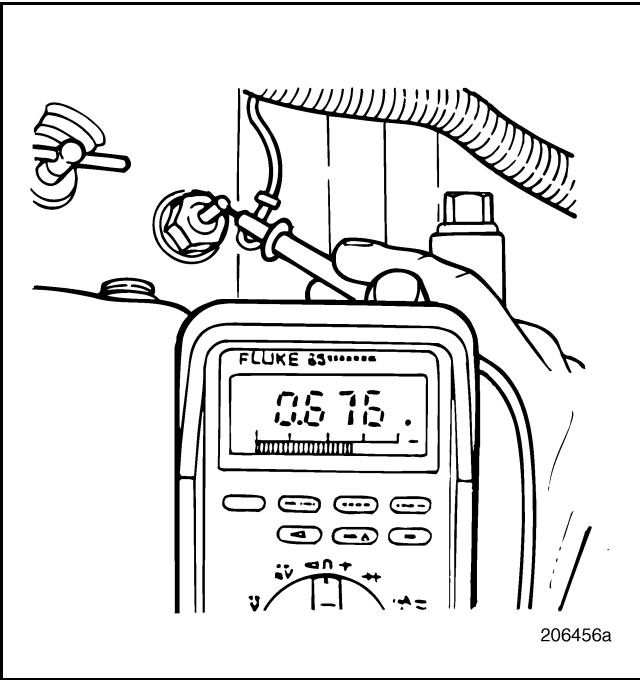


Figure 79 — Testing Temperature Sending Unit

Resistance of a cold sensor should be approximately 700 ohms. As the temperature of the sending unit increases, resistance readings should decrease. If sending unit resistance does not change, replace the sensor.

FUEL LEVEL SENDING UNIT

Checking Resistance

Resistance through the fuel level sending unit changes in response to changes in the level of fuel inside the tank. The resistance reading will be low if the fuel level is low, and will increase with more fuel in the tank. To check the sending unit:

- 1. Disconnect the wires from the fuel level sending unit terminal studs at the fuel tank.
- 2. Set the multimeter to the resistance function.
- 3. Connect the leads to the terminal studs of the sending unit.

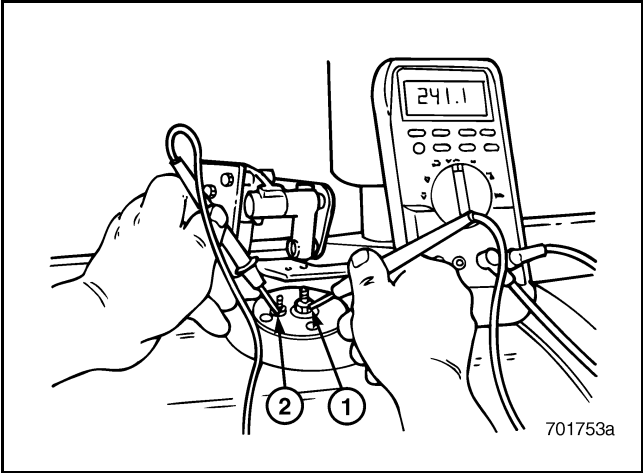


Figure 80 — Checking Sending Unit Resistance

1. Negative Lead to Grounding Terminal	2. Positive Lead to Signal Terminal
--	-------------------------------------



TROUBLESHOOTING

If the sending unit is suspect, it can be removed from the tank and checked by connecting the meter leads to the two terminal studs of the sending unit. Move the float arm through a full swing. Resistance through the sending unit should increase as the float arm is being moved from the lowest to the highest position.

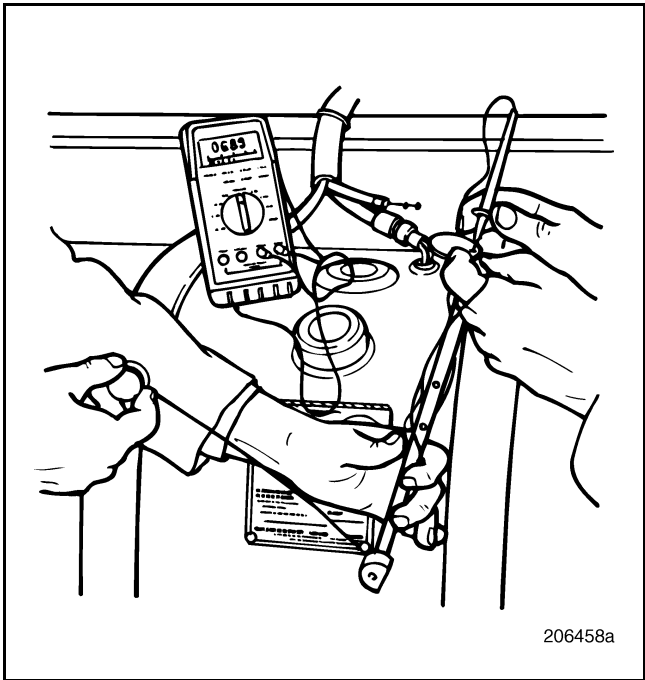
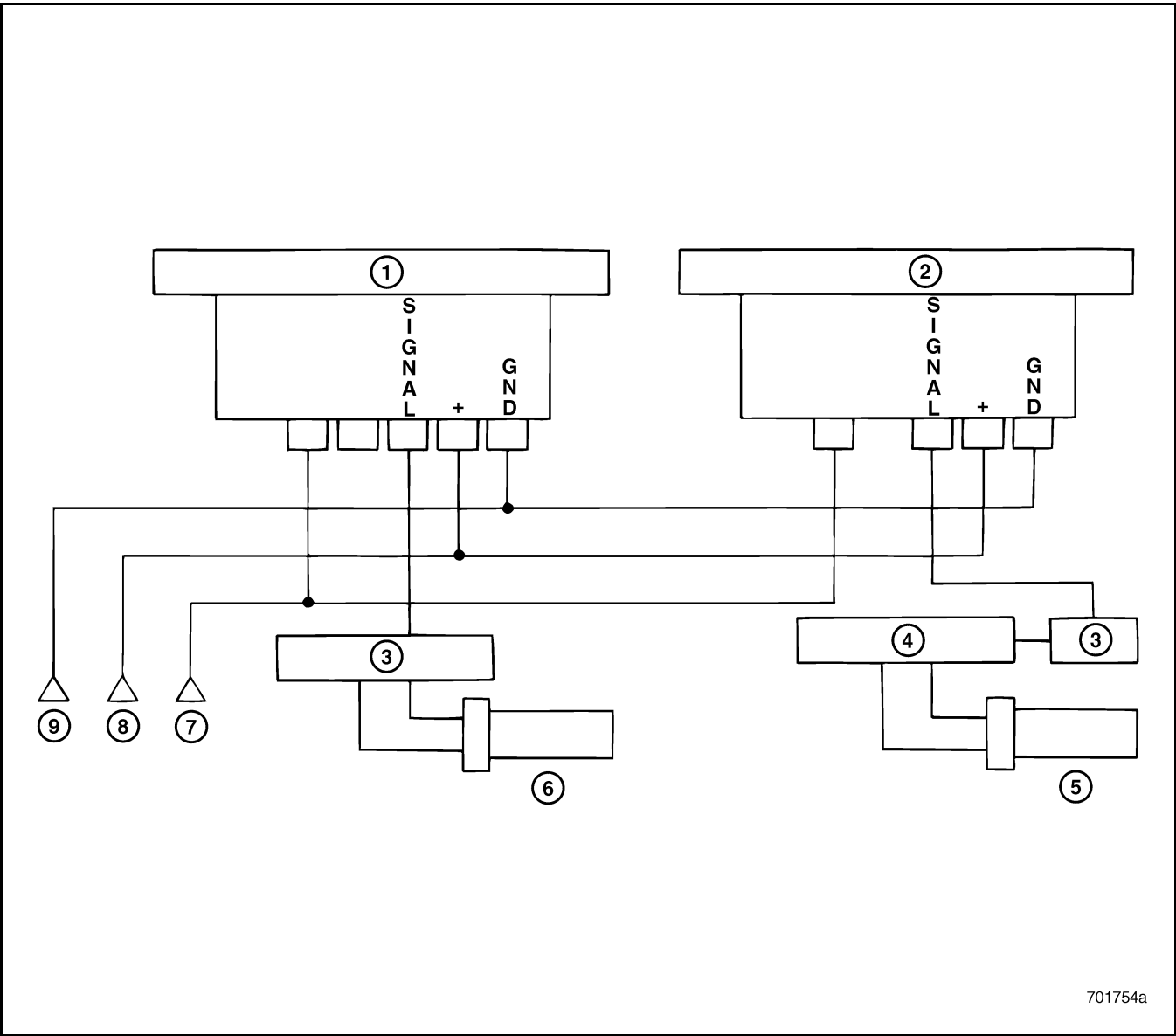


Figure 81 — Testing Sending Unit Resistance



TROUBLESHOOTING

SPEEDOMETER AND TACHOMETER



701754a

Figure 82 — Speedometer and Tachometer Circuits

1. Speedometer 2. Tachometer 3. Vehicle Electronic Control Unit (VECU) 4. Engine Electronic Control Unit (EECU) 5. Tachometer Sensor	6. Speedometer Sensor 7. Gauge Lamp Circuit 8. Ignition Circuit 9. Instrument Panel Ground
--	---

The speedometer and tachometer are electronically operated units that translate input signal voltages into engine speed and vehicle road speed.



TROUBLESHOOTING

Both instruments are powered when the key is turned to the RUN position. The speedometer and tachometer are both grounded through the instrument panel ground circuit. The speedometer and tachometer receive input signals from their respective speed sensors through either the Engine Electronic Control Unit (EECU) and/or the Vehicle Electronic Control Unit (VECU) on V-MAC systems.

- On V-MAC III vehicles, the tachometer signal is sent first to the EECU from the sensor, then to the VECU, then to the tachometer.
- On V-MAC III vehicles, the speedometer (mph) signal is from the sensor, through the VECU to the speedometer.
- On V-MAC II vehicles, there is only one module and only the tachometer signal is sent through the module.
- On V-MAC I vehicles, the tachometer signal is through the module to the tachometer.

Speed sensors use the principle of induction to generate pulses of alternating current. The sensor contains a permanent magnet and is mounted in close proximity to a metallic toothed gear. As the toothed gear passes in front of the sensor, the magnetic field is broken and a pulse of AC voltage is generated. The pulses are registered as vehicle road speed on the speedometer, and engine revolutions per minute on the tachometer.

Diagnosing speedometer or tachometer problems requires checking for:

- Ignition voltage.
- A good ground.
- Signal input voltage.
- Speed sensor operation.

Check for voltage, ground and signal with the speedometer or tachometer removed from the instrument cluster, and harness connector engaged into the back of the gauge.

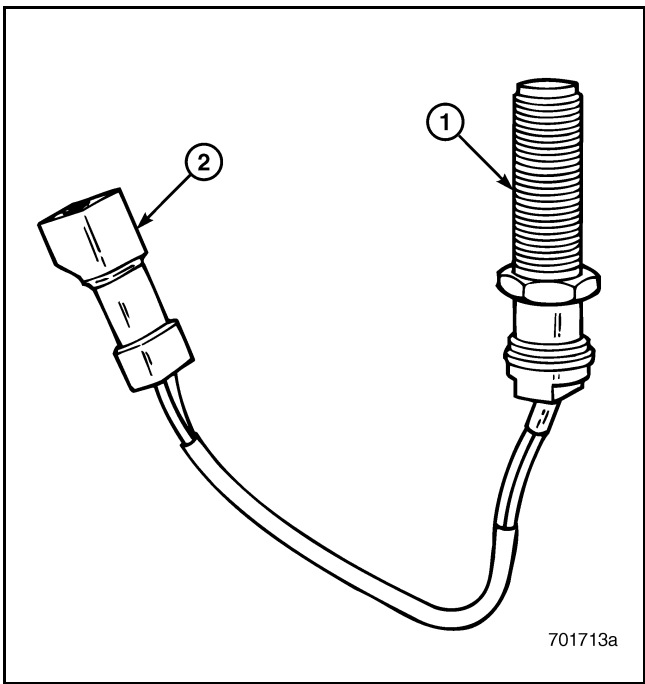


Figure 83 — Speed Sensor

1. Speed Sensor	2. Speed Sensor Connector (Integral)
-----------------	--------------------------------------



TROUBLESHOOTING

Testing for Ignition Voltage

- 1. Set the multimeter to the VDC function.
- 2. Turn the key to the RUN position.
- 3. Working from the back of the connector, insert the negative (–) meter lead into the ground terminal (black wire) and the positive (+) meter lead into the ignition terminal.

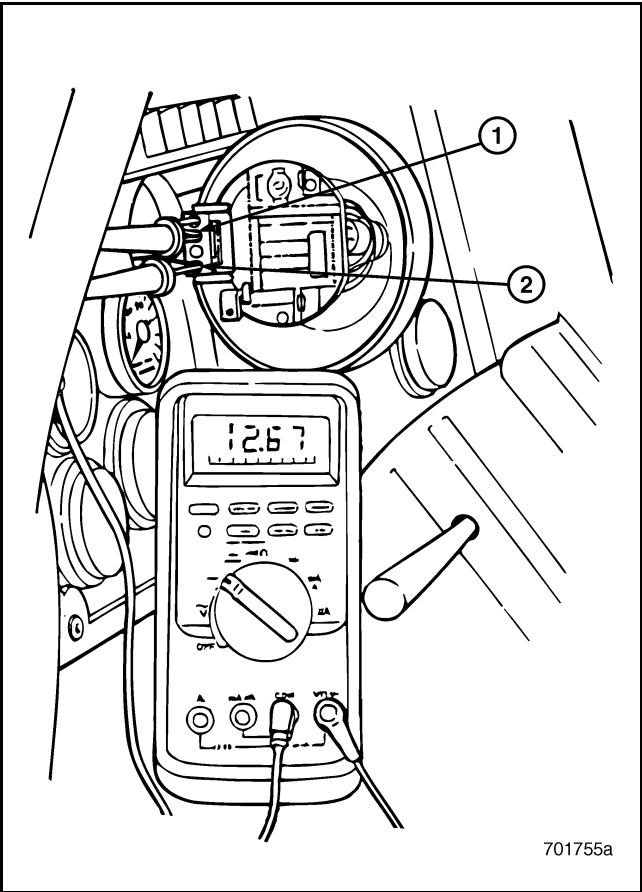


Figure 84 — Testing for Ignition Voltage (Back of Tachometer Shown)

1. Positive Meter Lead in Ignition Cavity of Connector	2. Negative Meter Lead in Ground Cavity of Connector
--	--

Ignition voltage should be present on the back of the gauge. If meter indicates 0 volts, or less than ignition voltage, check for an open, or a source of high resistance (such as a loose wire or corroded connection) in the ignition voltage circuit. Proceed to TESTING THE GROUND, to verify that the ground circuit is good.

Testing the Ground

- 1. Make sure the key switch is turned OFF.
- 2. Set the meter to the resistance function.
- 3. With gauge connector attached, insert one lead of the meter into the ground terminal (black wire) at the back of the harness connector, and the other lead to a good ground in the cab.

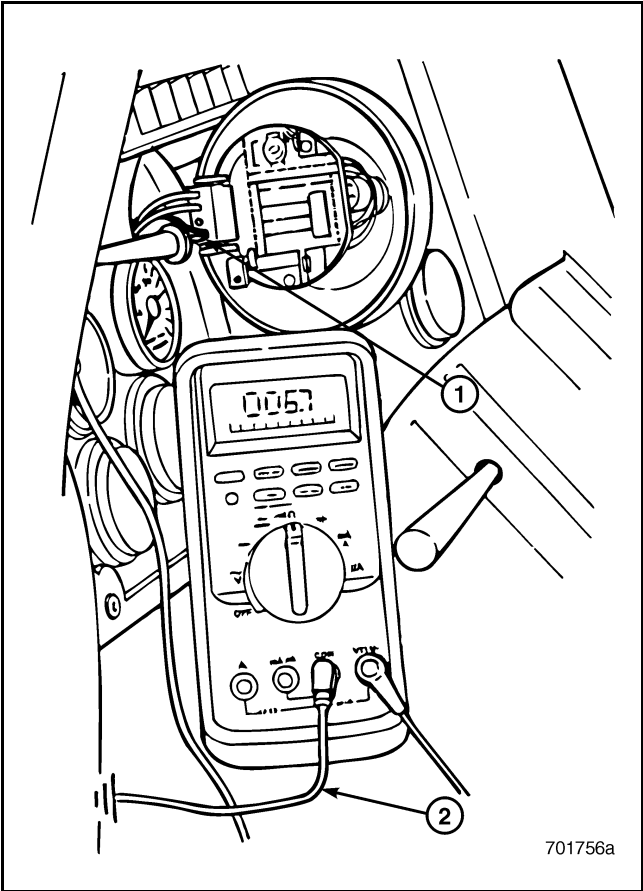


Figure 85 — Testing Ground (Back of Tachometer Shown)

1. Positive Meter Lead in Ground Cavity of Connector	2. Negative Meter Lead to a Good Ground
--	---

The meter should show zero or fractions of ohms resistance. Higher resistance readings indicate a poor ground connection. If a poor ground connection is indicated, look for loose or damaged connections, and broken or otherwise damaged wires.



TROUBLESHOOTING

TESTING SPEEDOMETER INPUT SIGNAL

1. Block the front wheels to prevent the vehicle from moving.
2. Raise the rear wheels off the ground and support the weight of the vehicle on suitable jack stands.

CAUTION

DO NOT rely on hydraulic jacks to support the weight of the vehicle. Jacks can fail unexpectedly, causing serious personal injury, property damage or death.

3. With the key switch turned OFF, disconnect the harness connector from the back of the speedometer.
4. Set the multimeter to the VAC function.
5. Insert the positive (+) meter lead into the signal terminal of the harness connector, at the back of the gauge. Connect the negative (–) meter lead into the ground terminal of the harness connector, at the back of the gauge (or a good ground in the cab).

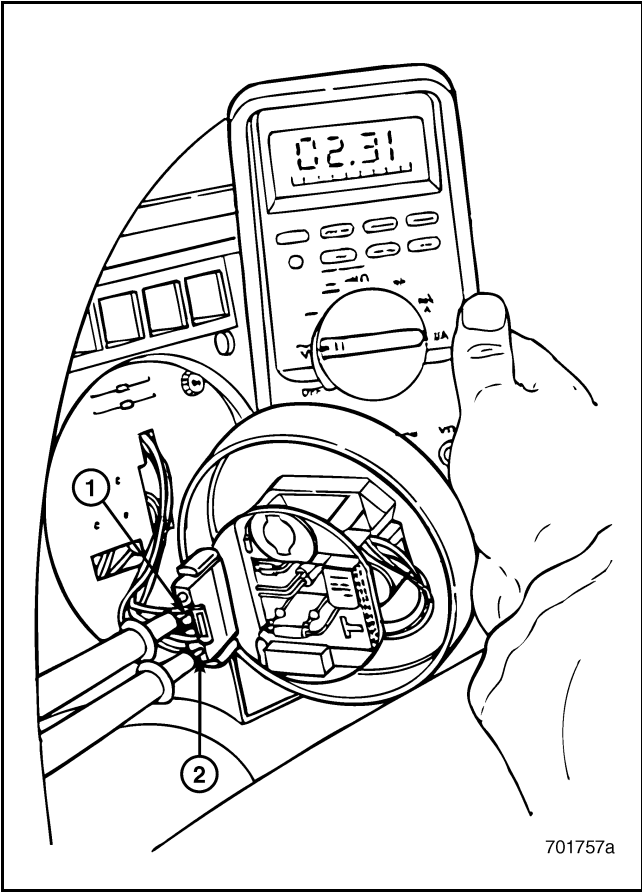


Figure 86 — Checking Signal Voltage at the Speedometer Connector

- | | |
|--|---|
| 1. Positive Meter Lead in Signal Cavity of Connector | 2. Negative Meter Lead in Ground Cavity of Connector (or Good Cab Ground) |
|--|---|

6. Start and run the engine.
7. Shift the transmission into the highest gear, release the park brake and allow to run at an idle (approximate vehicle speed above 10 mph).

WARNING

Proper precautions must be taken to prevent the vehicle from moving while performing this test. Make sure the front wheels are blocked, the rear axles are suitably supported and the front drive axle (if equipped) is disengaged. Failure to take proper precautions can result in serious personal injury, property damage or death.



TROUBLESHOOTING

8. With the engine running at an idle (vehicle speed approximately 10 mph), note the AC voltage indicated on the meter.

Signal voltage should be approximately 1.75 to 3.25 volts AC. If there is no or low input voltage, adjust the sensor and recheck. Also check for an open in the wires connecting the speed sensor to the V-MAC III Vehicle Control Unit (VCU), and the wires connecting the VCU to the speedometer. Refer to the V-MAC III Service Manual (8-211) for specific sensor, sensor circuit and module testing. If readjustment does not bring input voltage within range, and the circuit between the sensor, VCU and speedometer connector is good, replace the speed sensor.

NOTE

AC voltage is being measured when checking input signal voltage of both the speedometer and the tachometer.

TESTING TACHOMETER INPUT SIGNAL

1. Block the front wheels to prevent the vehicle from moving.
2. With the key switch turned OFF, disconnect the harness connector from the back of the tachometer.
3. Set the meter to the VAC function.
4. Insert the positive (+) meter lead into the to the signal terminal of the harness connector at the back of the gauge. Connect the negative (-) meter lead into the ground terminal of the harness connector at the back of the gauge (or a good ground in the cab).
5. Set the parking brake, shift the transmission into neutral and start the engine.
6. Allow the engine to run at an idle and observe the voltage reading indicated on the multimeter.

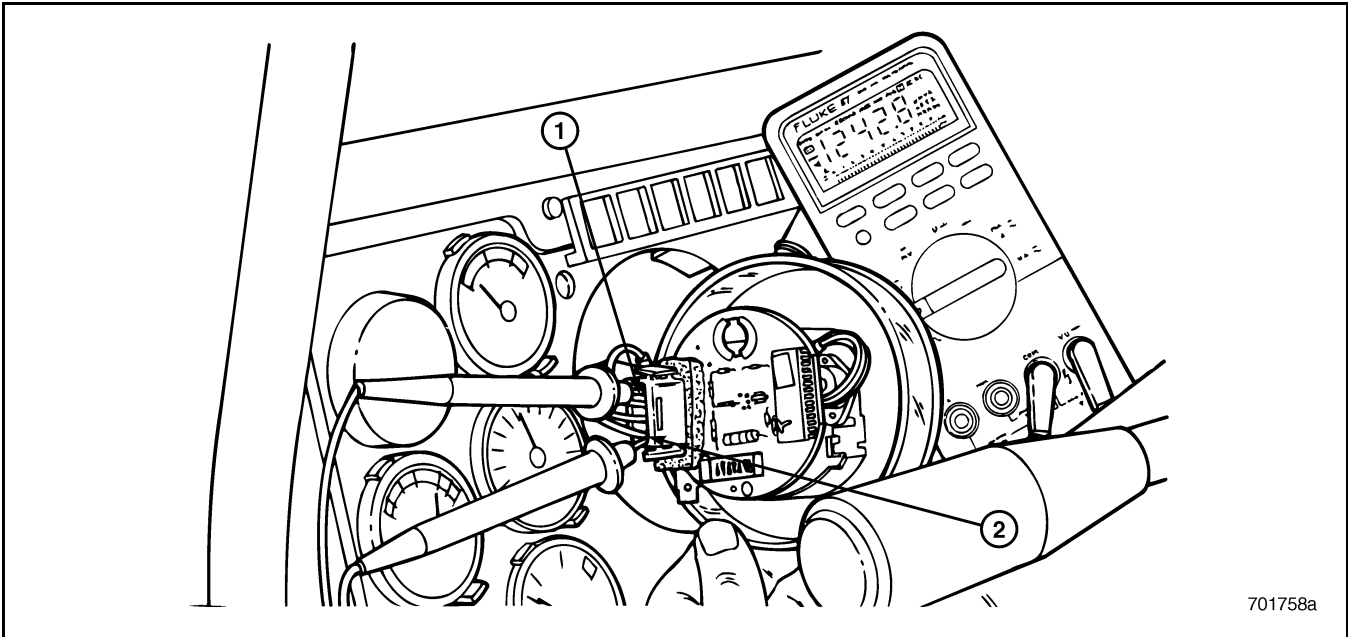


Figure 87 — Checking Input Signal at Tachometer Connector

1. Positive Meter Lead in Signal Cavity of Connector

2. Negative Meter Lead in Ground Cavity of Connector (or Good Cab Ground)

Signal voltage should be approximately 1.75 to 3.25 volts AC. If there is no or low input voltage, adjust the sensor and recheck. Also check for an open in the wires connecting the speed sensor to the V-MAC III Engine Control Unit (ECU), and the wires connecting the ECU to the tachometer.

Refer to the V-MAC III Service Manual (8-211) for specific sensor, sensor circuit and module testing. If readjustment does not bring the input voltage within range, and the circuit between the sensor and tachometer connector is good, replace the sensor.



TROUBLESHOOTING

Speed Sensors

MEASURING SPEED SENSOR RESISTANCE

NOTE

Speed sensors must be adjusted correctly to function properly. Before testing the speed sensors, make sure they are properly adjusted. If the sensor is adjusted with an excessive gap, less voltage is produced. If the sensor is adjusted with too little gap, more voltage is produced. Refer to SENSOR ADJUSTMENT in this section.

To measure sensor resistance:

1. Disconnect the wires from the sensor (when sensor is left in vehicle).
2. Set the multimeter to the resistance function.
3. Connect the meter leads to the sensor terminals and note the resistance reading indicated on the meter.

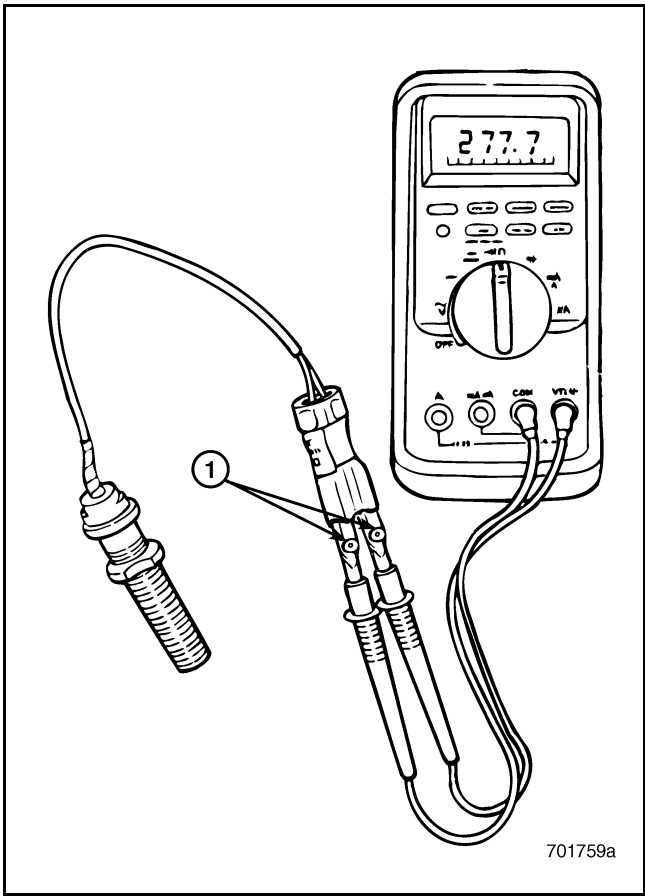


Figure 88 — Checking Sensor Resistance

1. Meter Leads Connected to Sensor Terminals

If the resistance indicated on the meter is not within range, replace and adjust the sensor. For specific sensor resistance values, refer to the V-MAC III Service Manual 8-211.

TESTING SPEED SENSOR FUNCTION (OUTPUT VOLTAGE)

To test speed sensors remove them from the vehicle and follow the steps below:

1. With the key switch turned off, disconnect the wires from the sensor.
2. Loosen the jam nut. Then unscrew the sensor to remove.
3. Connect the meter leads to both terminals of the sensor.
4. Set the meter to the VAC function.
5. Pass a metallic object, such as a wrench or similar metal object, in front of the sensor, approximately .5 inch away from the surface.
6. Observe if a voltage reading is indicated on the meter when the object passes in front of the sensor.

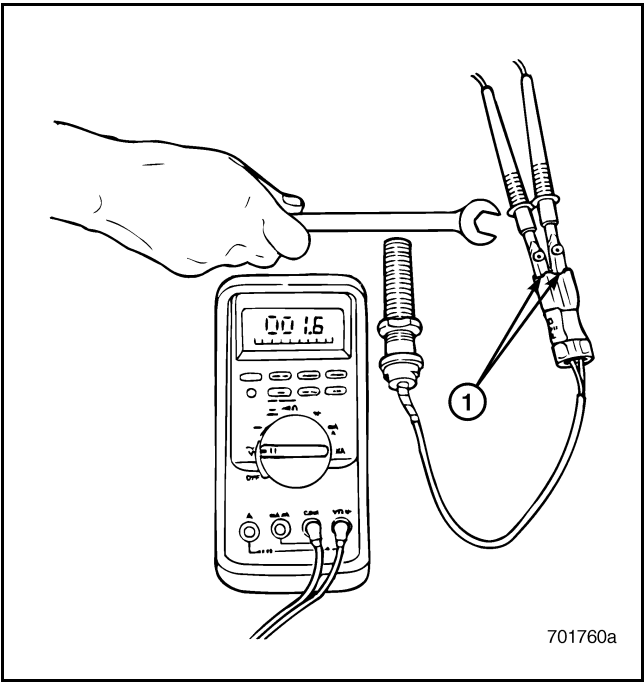


Figure 89 — Testing Sensor Output

1. Meter Leads Connected to Sensor Terminals



TROUBLESHOOTING

When the metal object passes in front of the sensor, a pulse of AC voltage should be generated and indicated on the meter. If the meter does not react, replace the sensor and then adjust it.

SENSOR ADJUSTMENT

Proper adjustment is essential for the sensors to operate correctly. For specific sensor adjustment procedures, refer to the V-MAC III Service Manual 8-211 for the vehicle speed sensor or the E-Tech™ Service Manual 5-106 for the engine speed sensor. To adjust a typical sensor:

- 1. Install the sensor and turn by hand until it bottoms (contacts the tone wheel).
- 2. Back the sensor out one full turn.
- 3. Tighten the jam nut to 15 lb-ft torque.

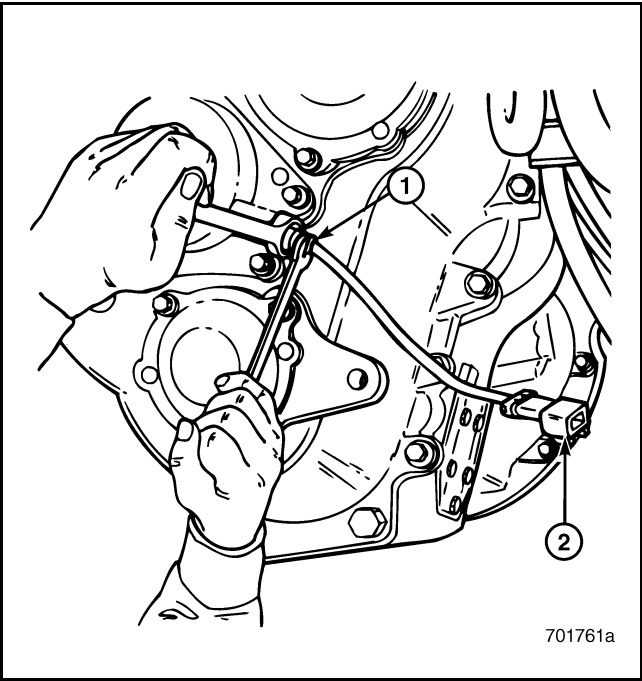


Figure 90 — Adjusting Vehicle Speed Sensor

1. Vehicle Speed Sensor	2. Speed Sensor Connector
-------------------------	---------------------------



TROUBLESHOOTING

Horn

The electric horn is powered through a circuit breaker that is at battery voltage. This allows the horn to operate with the key switch turned ON or OFF. The horn circuit includes the horn, horn relay and the horn button. The horn button is located in the center of the steering wheel. The horn operates when the button is depressed, and a circuit to ground through the horn relay is completed. When current flows through the horn relay coil, the relay contacts close and the horn operates.

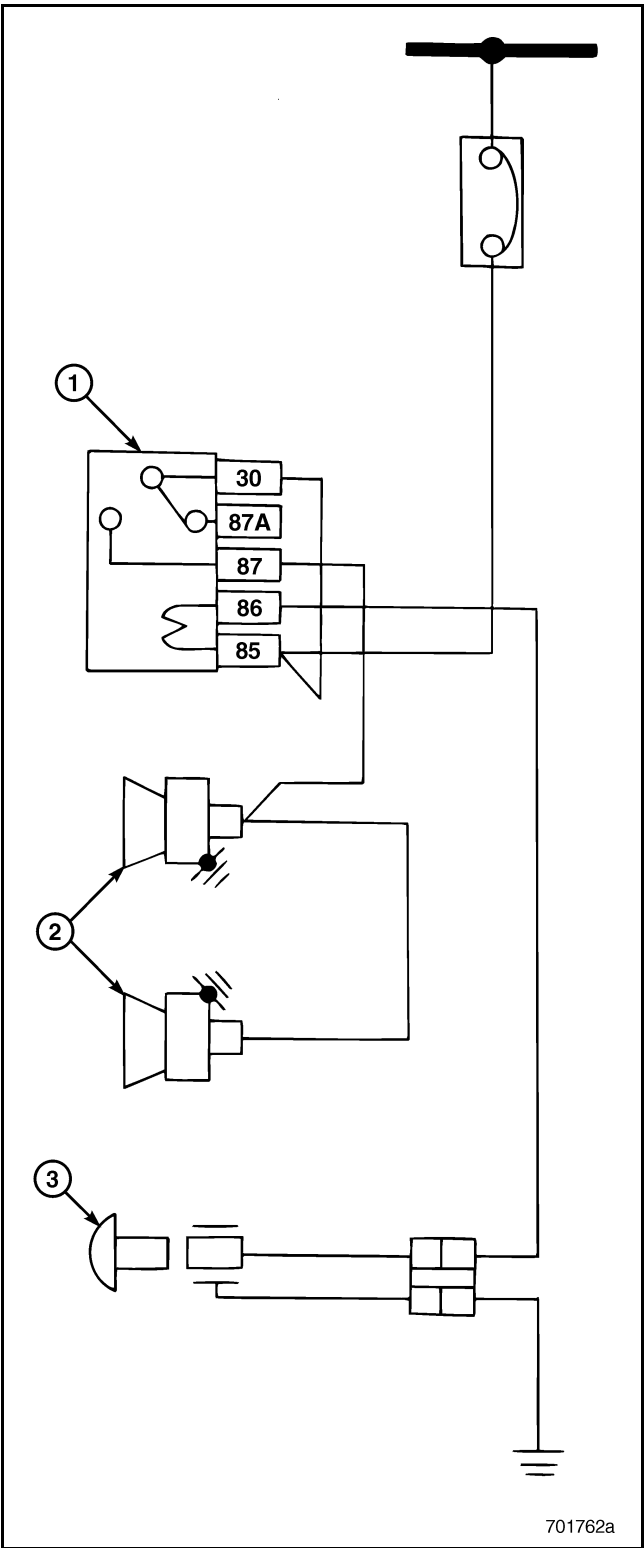


Figure 91 — Horn Circuit

1. Horn Relay	3. Horn Button
2. Horns	



TROUBLESHOOTING

Circuit breaker battery voltage is connected to the horn relay cavity terminal 85. The horn button is connected to the horn relay cavity terminal 86. When the horn relay is energized by depressing

the horn button, the circuit breaker powers each horn through cavity 87. The horns are grounded to the cab by the mounting brackets.

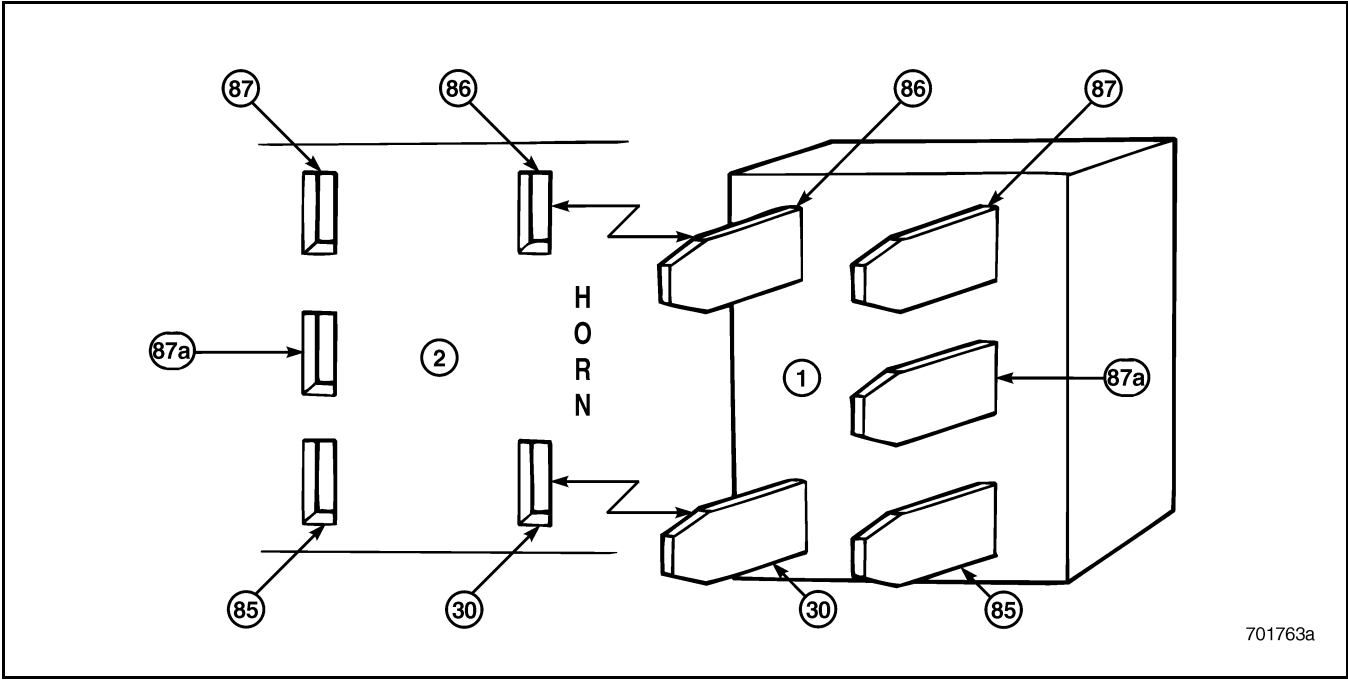


Figure 92 — Horn Relay Configuration

1. Horn Relay (With Five Pins as Marked)	2. Electrical Equipment Panel Horn Relay Socket (With Five Cavities as Marked)
--	--

CHECKING THE HORN BUTTON/HORN RELAY CIRCUIT

To quickly check an inoperative horn, install a jumper across the horn relay cavities 30 (or 85) and 87 in the equipment panel. If the horn operates when the terminals are jumped, a problem exists with either the horn relay, or the horn button and circuits.

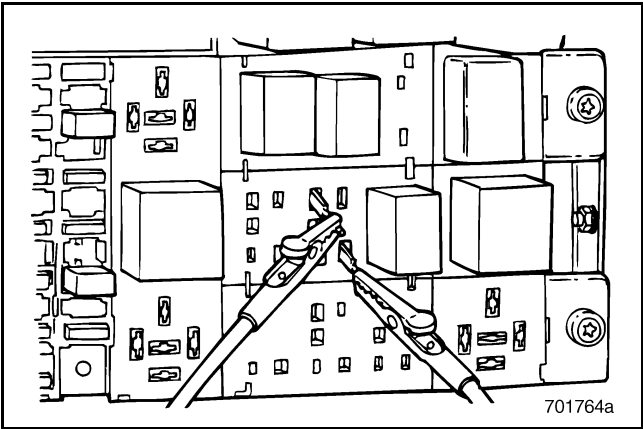


Figure 93 — Jumping Electrical Panel Horn Relay Circuits



TROUBLESHOOTING

ISOLATING HORN BUTTON MALFUNCTION

To isolate the specific area of the problem, install a multimeter between the horn relay cavity 86, in the electrical panel, and a good ground. Set the multimeter to check continuity or ohms resistance.

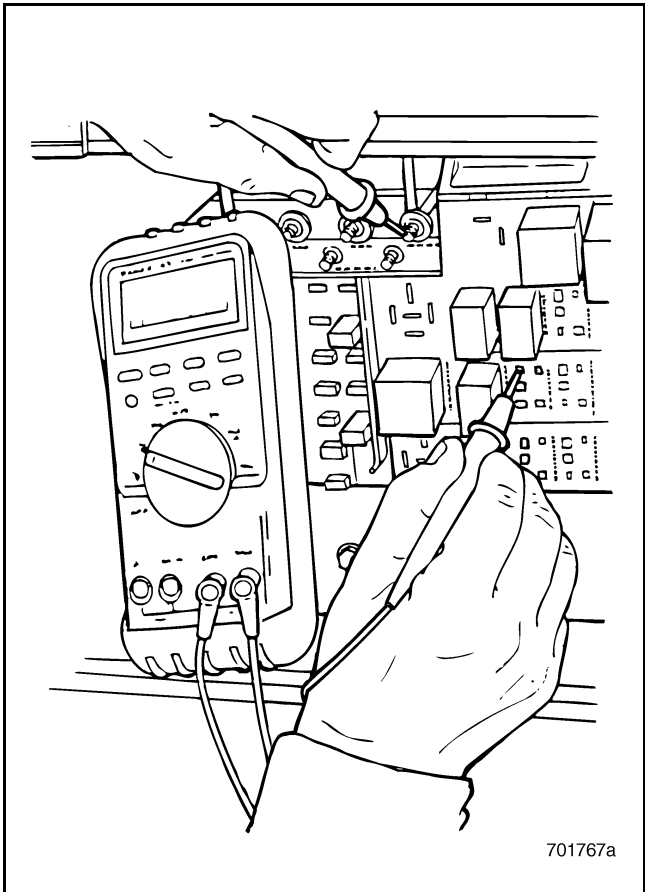


Figure 94 — Checking Horn Relay Coil Ground Circuit

Operate the horn button and note the meter reading. There should be very low resistance in the circuit when the horn button is pressed. There should be infinite resistance when the horn button is released.

- If OK, replace the relay.
- If not OK, repair the horn button circuit.

CHECKING VOLTAGE AT THE HORN RELAY

If the horn failed to operate in the first test, check voltage at horn relay cavities 30 and 85 to determine the cause.

To test for voltage at the electrical panel horn relay cavity 30:

1. Set the multimeter to the VDC function.
2. Connect the positive (+) lead to the electrical panel horn relay cavity 30, and the negative (-) lead to a good ground (use ground lug on panel).
3. Observe the voltage indicated on the meter.

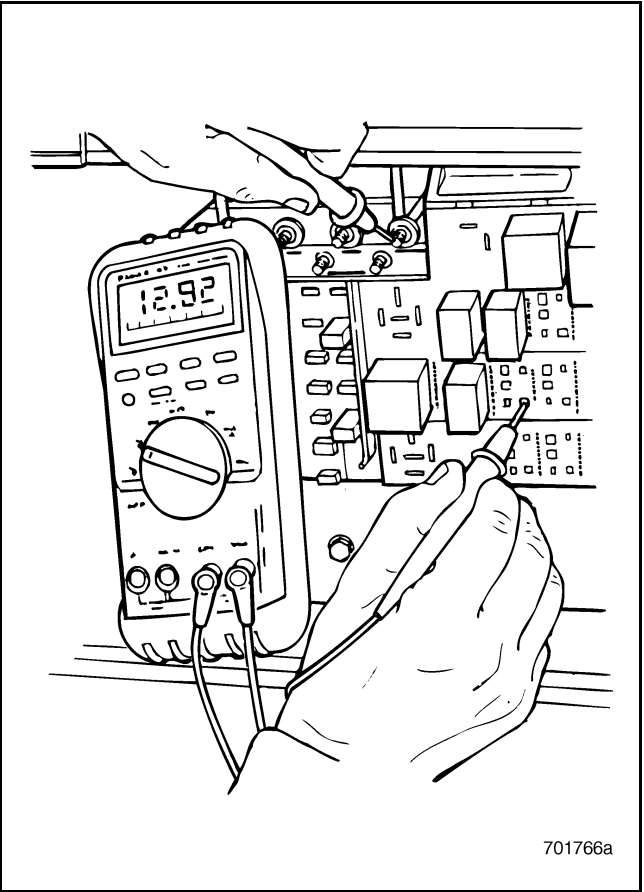


Figure 95 — Checking Voltage at Electrical Panel Horn Relay Cavity 30

Battery voltage should be present at the panel horn relay cavity 30. If no voltage is indicated, check for an open in the circuit between cavity 30 and cavity 85. Also check the fuse (or circuit breaker) and circuit that supplies power to the relay for opens. Check for loose connections, broken or frayed wires, or other problems.



TROUBLESHOOTING

To test for voltage at the electrical panel horn relay cavity 85:

1. Set the multimeter to the VDC function.
2. Connect the positive (+) lead to the electrical panel horn relay cavity 85, and the negative (-) lead to a good ground (use ground lug on panel).
3. Depress the horn button to energize the horn relay.
4. Observe the voltage indicated on the meter when the relay is energized.

Voltage should be available at the panel horn relay cavity 85. If no voltage is indicated, inspect the fuse (or circuit breaker) and circuit, that supplies power to the relay, for opens. Check for loose connections, broken or frayed wires, or other problems.

If voltage is available at the relay location on the panel, inspect the horn button, the horn and the ground circuit.

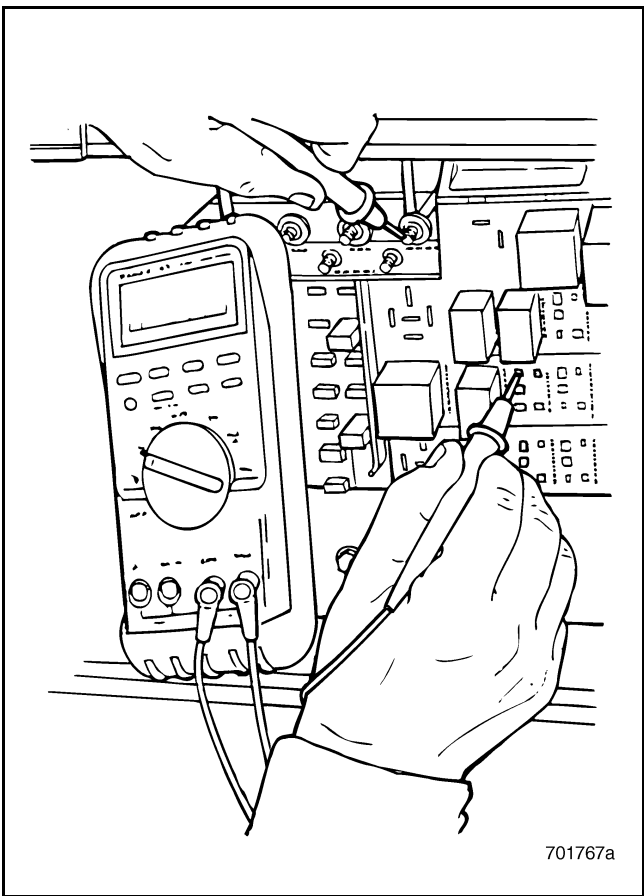


Figure 96 — Checking Voltage at Electrical Panel Horn Relay Cavity 85



NOTES



REPAIR PROCEDURES

REPAIR PROCEDURES



REPAIR PROCEDURES

COMMON ELECTRICAL PROCEDURES

Correct Use of Tie Wraps

The correct use of tie wraps to secure electrical wires on a MACK chassis is very important. Whenever a tie wrap is removed, a **new** tie wrap must be installed before the job can be considered finished. In addition to replacing tie wraps removed during servicing, technicians may need to reroute wires or secure two harnesses together.

Proper use of tie wraps helps to reduce the likelihood of problems while the truck is in service. A properly installed tie wrap minimizes wire movement and chafing and holds a wire harness away from other objects. They also provide protection from the vibrations that occur during the life of a heavy-duty vehicle.

To ensure proper installation tension of tie wraps, Mack Trucks Inc. recommends using a tool such as a Panduit #GS4H, a Snap-On #YA317, or equivalent. These tools cut off the excess length of the tie wrap, leaving the end smooth and flush.

CAUTION

If the recommended tool is not used, the cut-off end of the tie wrap may have sharp edges that can cause injury. Be sure to remove any sharp edges on all tie wraps.

JOINING TWO HARNESSES TOGETHER

Whenever two wiring harnesses must be joined together or split to travel in two directions (especially at the point where the harnesses separate from each other), special attention must be given to ensure that the joint is properly supported. To obtain the greatest support, follow the steps illustrated below:

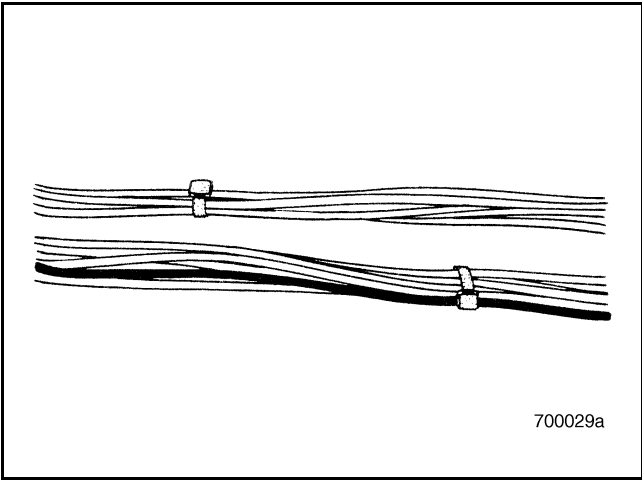


Figure 97 — Joining Two Harnesses

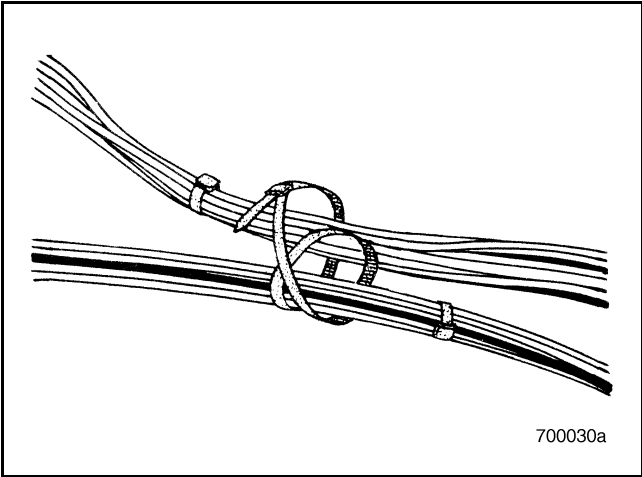


Figure 98 — Installing Tie Wrap Around Both Harnesses



REPAIR PROCEDURES

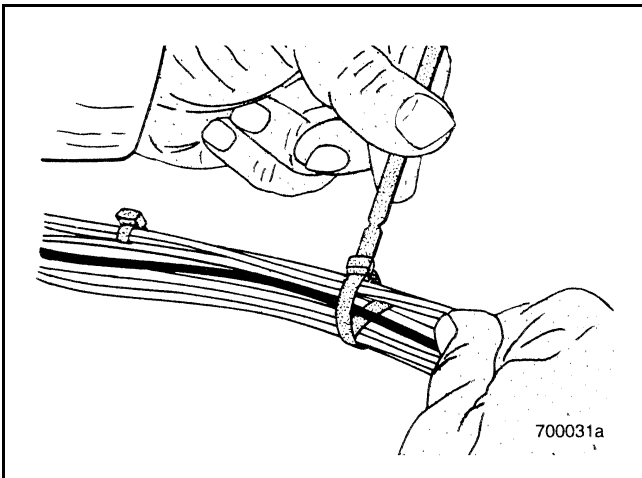


Figure 99 — Hand Tightening

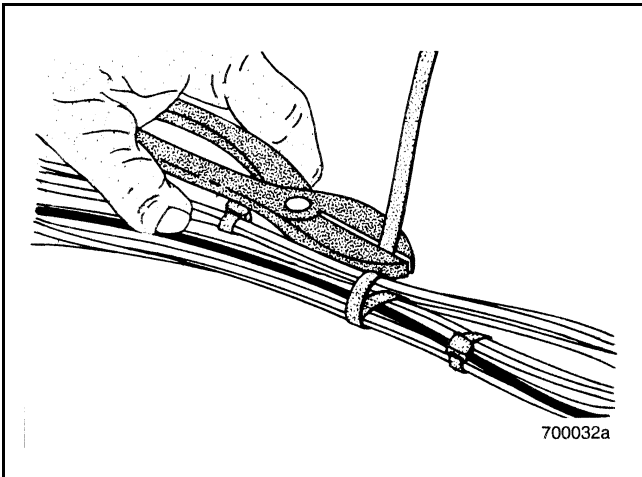


Figure 100 — Use Proper Tool to Cut Off Excess Length of Tie Wrap

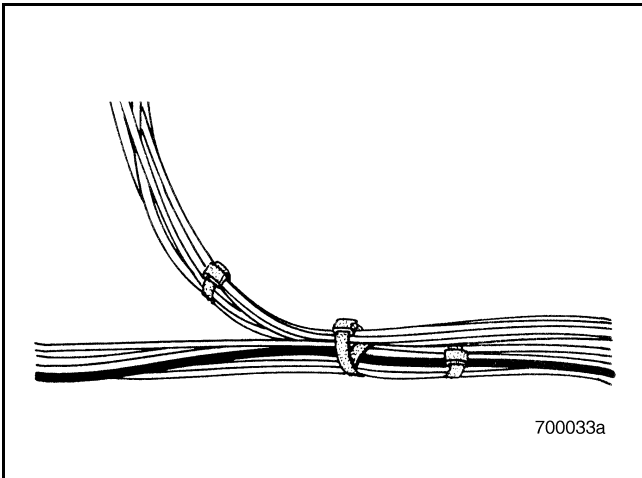


Figure 101 — Completed Joint

CREATING A TEE CONNECTION

Whenever two wiring harnesses must be joined together or split to create a tee connection, special attention must be given to ensure that the joint is properly supported and that the joint remains in the desired location. To provide the greatest security of the joint, follow the steps illustrated below.

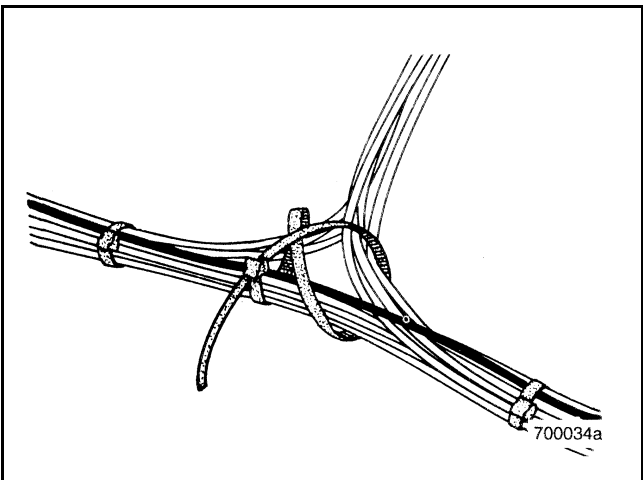


Figure 102 — Installing Tie Wrap Around the Tee

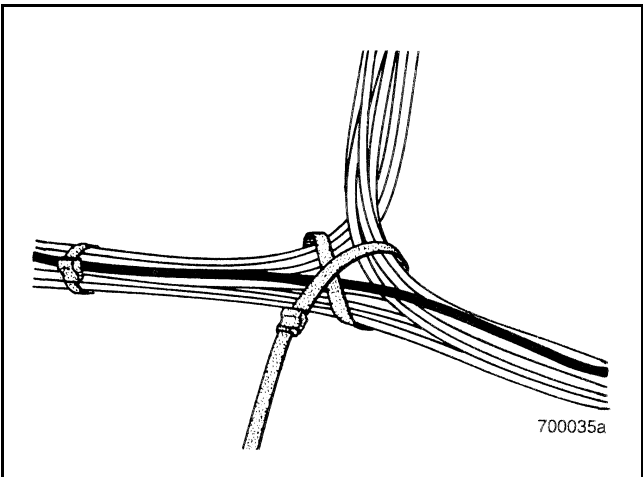


Figure 103 — Partially Tightened



REPAIR PROCEDURES

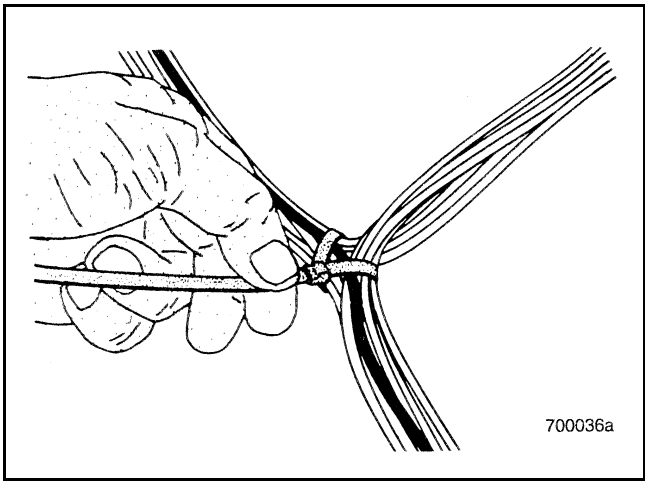


Figure 104 — Hand Tighten Tie Wrap

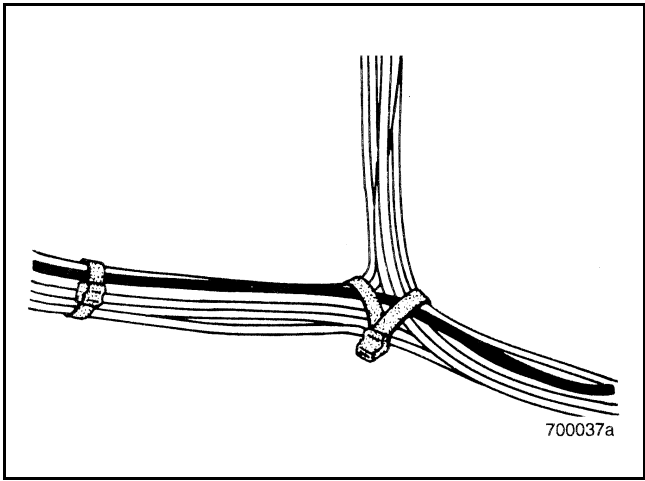


Figure 105 — Completed Tee Connection

ADDING A WIRE TO A TEE

When adding a wire to a tee, secure it to the existing harness in a manner that provides support and prevents it from being snagged. Secure the wire close to the joint.

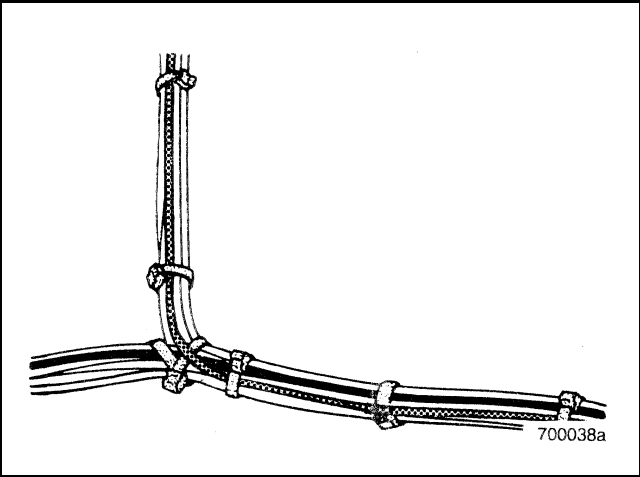


Figure 106 — Correct Way to Attach a Wire to a Tee

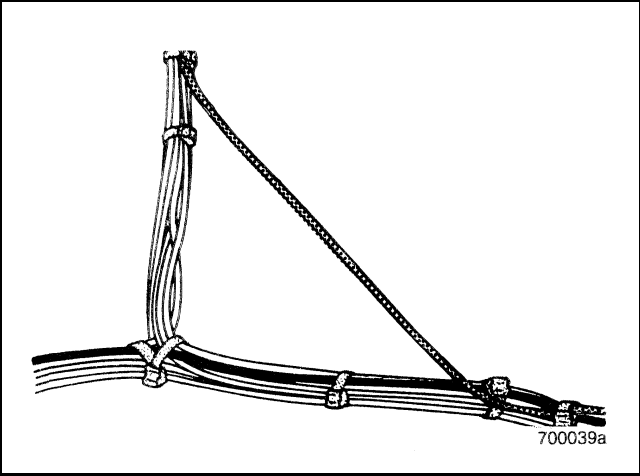


Figure 107 — Incorrect Way to Attach a Wire to a Tee.
DO NOT USE THIS METHOD.



REPAIR PROCEDURES

Typical Connectors

Use the procedures in this section to repair the various connectors found on a MACK truck chassis.

DEUTSCH CONNECTORS

Typical uses for this connector are:

- Bulkhead Connector
- Serial Communication Port
- Transmission Harness Connector

Contact Removal

1. Slide pin removal tool J 34513, tapered end first, onto the damaged wire.

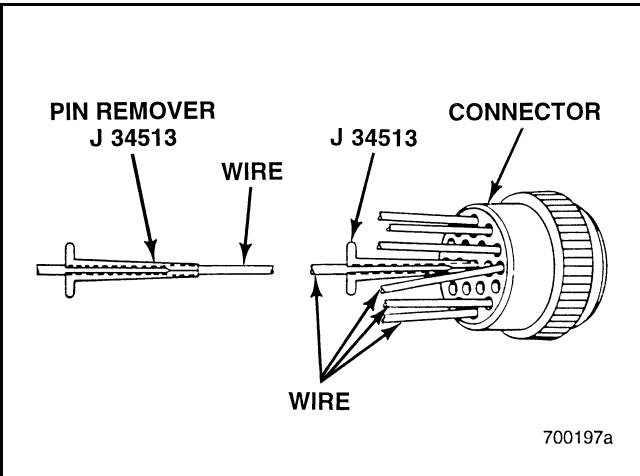


Figure 108 — Pin Removal Tool

2. Work tool along wire into the insert cavity until it engages the contact and resistance is felt. Do not twist or insert tool at an angle.

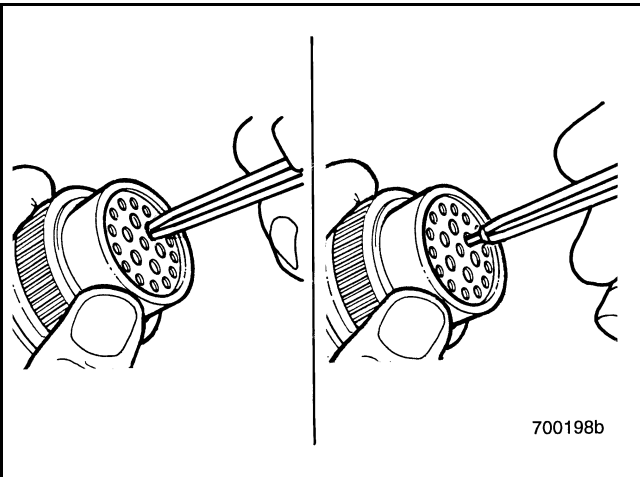


Figure 109 — Release Pin with Removal Tool

3. Pull the removal tool, terminal and wire from the connector socket.

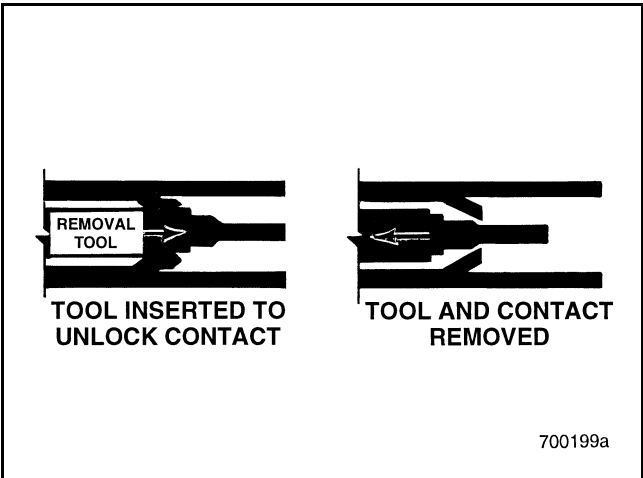


Figure 110 — Contact Removal

4. Repeat the removal steps for each of the damaged wires or contacts.
5. Cut the wire as close to the contact as possible to minimize wire loss.

Contact Replacement

1. Strip 0.24 to 0.32 inch (6 to 8 mm) of insulation from the wire.
2. Set the wire size indicator on crimping tool J 34182 by matching the gauge wire being used. Remove the lock clip, raise the wire gauge selector and rotate the knob to the number matching the correct gauge wire. Lower the selector and insert the lock clip.

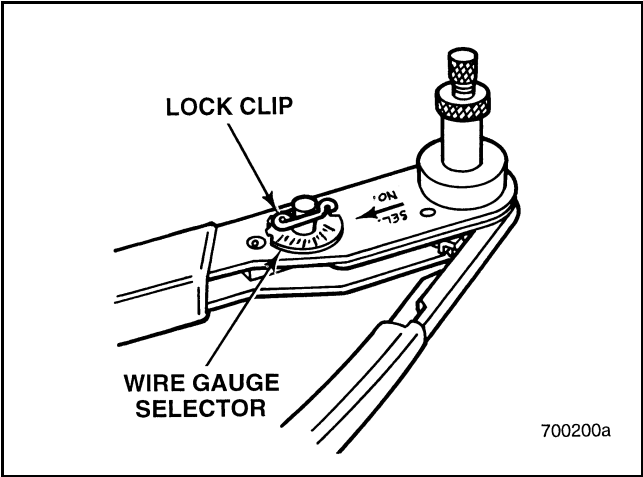


Figure 111 — Hand Crimp Tool



REPAIR PROCEDURES

3. Insert the contact, long end first, into tool J 34182. Close the crimping tool just enough to hold the contact. Back off the locking nut so the adjusting nut is free. Turn the contact depth adjustment screw until the top of the contact is above the crimping hole. Tighten the locking nut against the crimping tool.

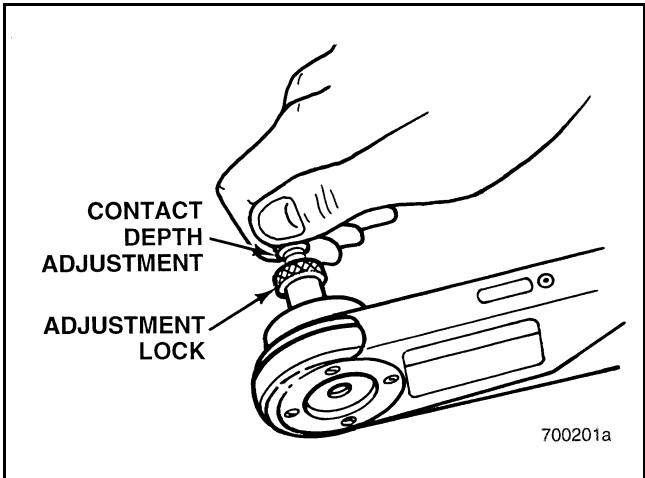


Figure 112 — Adjusting Crimp Tool

4. Insert the stripped end of the wire into the crimp barrel and contact. Be sure the wire is fully inserted. Squeeze the crimping tool handles together until the ratchet in the crimping tool releases. Release the handles and remove the wire and contact from the crimping tool.

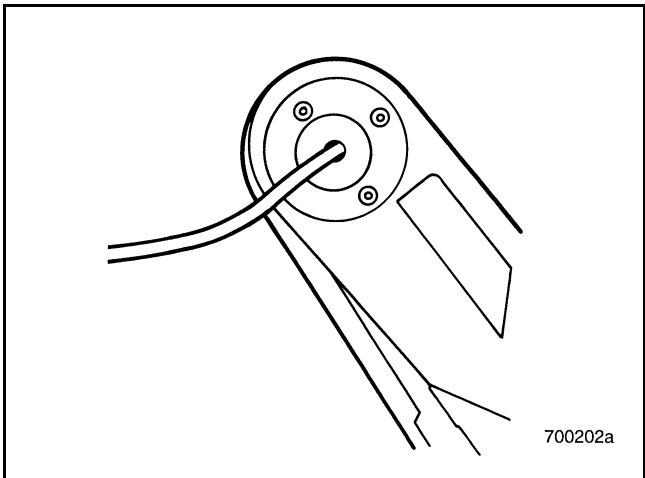


Figure 113 — Crimping Contact

5. Inspect the terminal for a proper crimp. Make sure that all strands are in the crimp barrel and that the wire is visible in the terminal inspection hole.

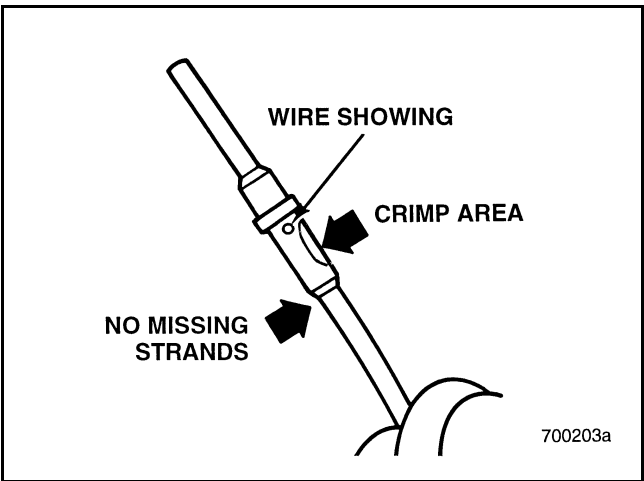


Figure 114 — Inspecting for Proper Crimp

Contact Insertion

1. Grasp contact approximately 1 inch (25.4 mm) behind the contact crimp barrel.

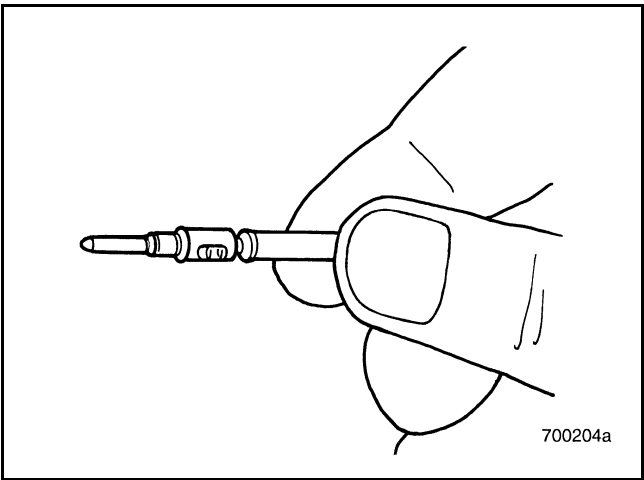


Figure 115 — Contact



REPAIR PROCEDURES

2. Hold connector with rear grommet facing contact and wire.

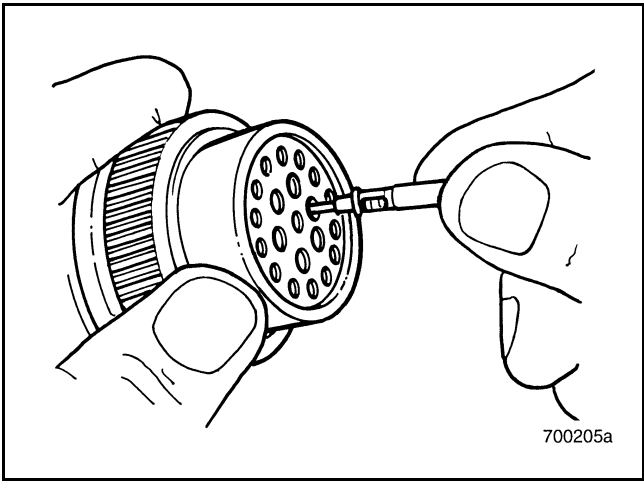


Figure 116 — Contact Insertion

3. Push contact straight into connector grommet until a positive stop is felt. Tug slightly to confirm that it is properly locked in place.

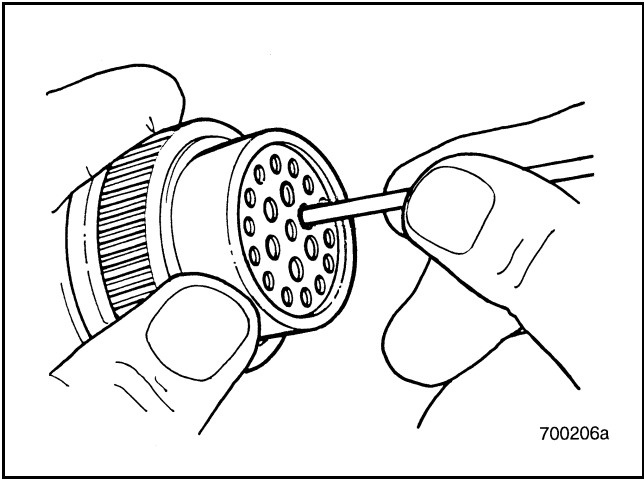


Figure 117 — Contact Installed

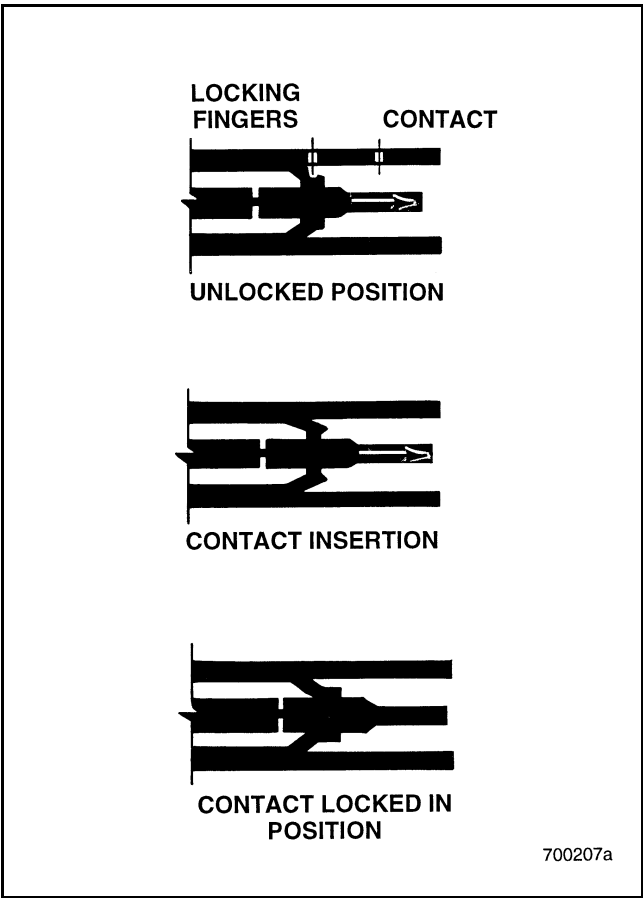


Figure 118 — Contact Insertion Sequence



REPAIR PROCEDURES

WEATHER PACK CONNECTORS

Typical uses for this connector are:

- Throttle Position Sensor
- Switch Connector

To remove the terminals on these two-part connectors, first unlatch and open the secondary lock on the connector. Removal is the same for both halves of the connector.

Terminal Removal

1. Firmly grasp the connector body. Push the terminal forward in the connector as far as possible. Locate the terminal lock tab in the connector. Insert remover tool J 28742-A in the front of the connector, over the terminal. Push the tool over the terminal and pull the terminal out of the back of the connector.

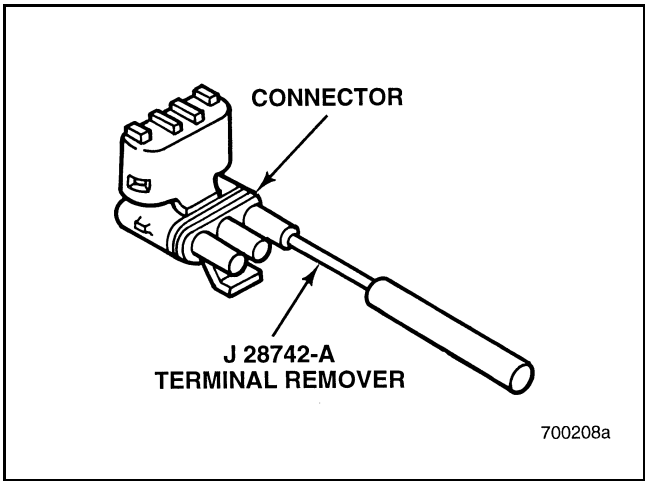


Figure 119 — Terminal Removal

2. Cut the damaged terminal from the wire as close as possible to the terminal end of the wire. If the wire has a rubber seal, remove it.

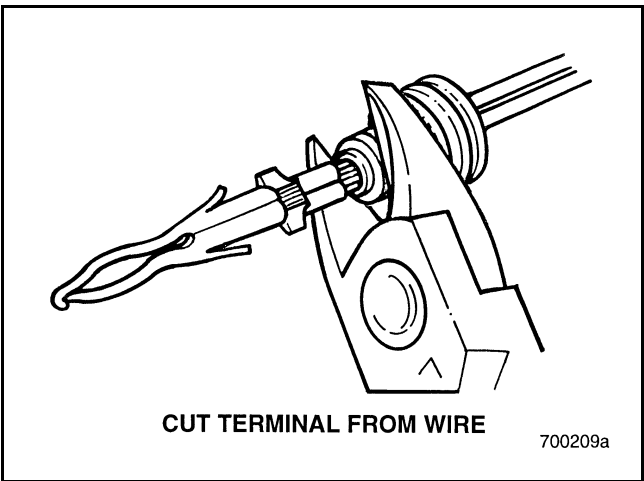


Figure 120 — Cut Terminal from Wire

Terminal Replacement

1. If the wire originally had a rubber seal, install a **new** one. Strip 0.23 to 0.25 inch (5.75 to 6.26 mm) of insulation from the wire. Be careful not to cut through any strands of wire.
2. Align the edge of the rubber seal with the edge of the wire insulation.

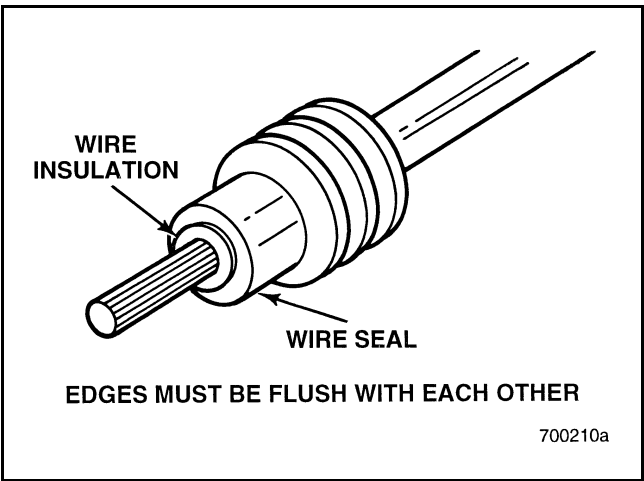


Figure 121 — Align Seal



REPAIR PROCEDURES

- Using crimping tool J 35606, squeeze the handles together until the ratchet automatically opens. Hold the tool so the gauge numbers are facing the user.
- Insert the terminal into the terminal holder until the insulation wings are flush with the anvil on the crimp tool. Make sure the core wings and the insulation wings of the terminal are pointing toward the smooth, concave side of the crimping jaw anvil.

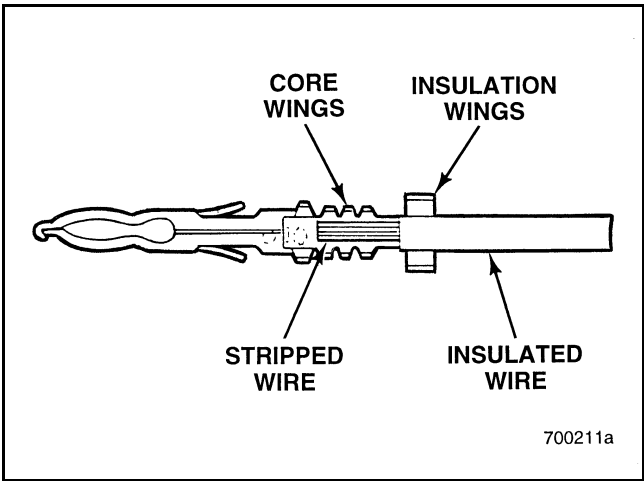


Figure 122 — Terminal Crimp Locations

- Place the wire and seal (if equipped), into the terminal until the first rib of the seal is flush against the crimper.

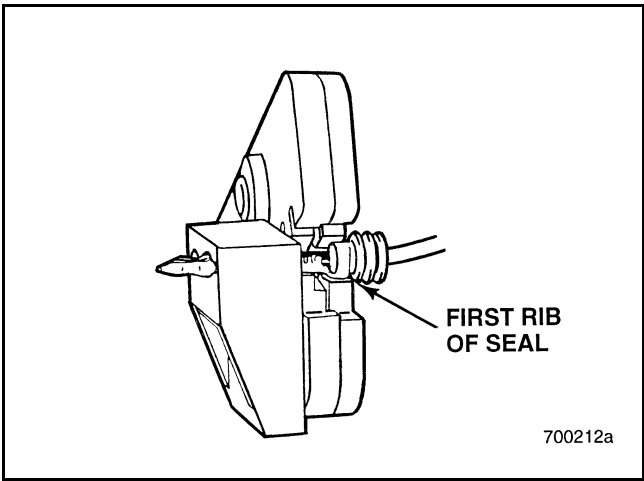


Figure 123 — Position Crimper

- Cradle one handle of the crimper on a workbench so that only one hand is necessary to operate the tool. This allows faster, more efficient operation. The anvil should be on the bottom when crimping.

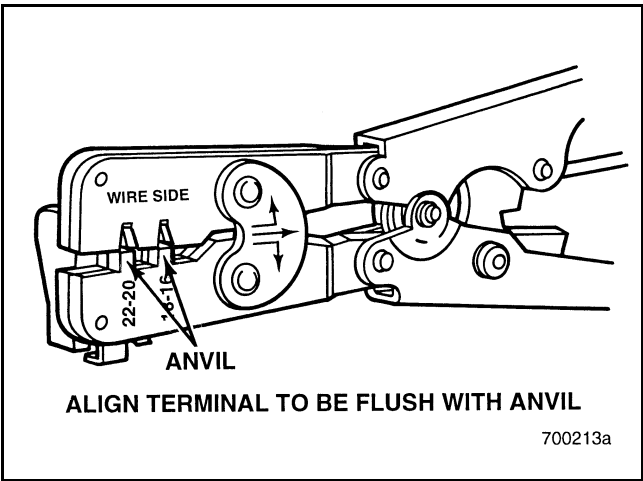


Figure 124 — Anvil Position

- Compress the handles until the ratchet automatically releases and the crimp is complete. Be careful not to crimp the first rib of the seal.

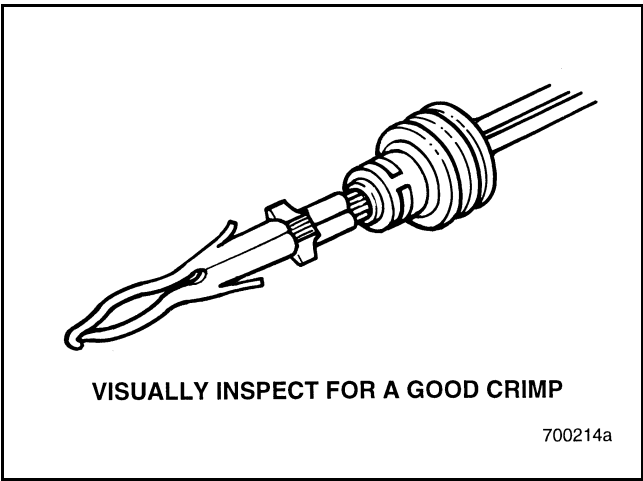


Figure 125 — Inspect Crimp



REPAIR PROCEDURES

DELPHI-PACKARD 56 SERIES CONNECTORS

Typical uses for this connector are:

- Bolt-Down Solenoid Connector
- Pressure Switch Connector

Terminal Removal

1. Lift the secondary lock from the back end of the connector. Insert a small screwdriver in either slot of the secondary lock to release.

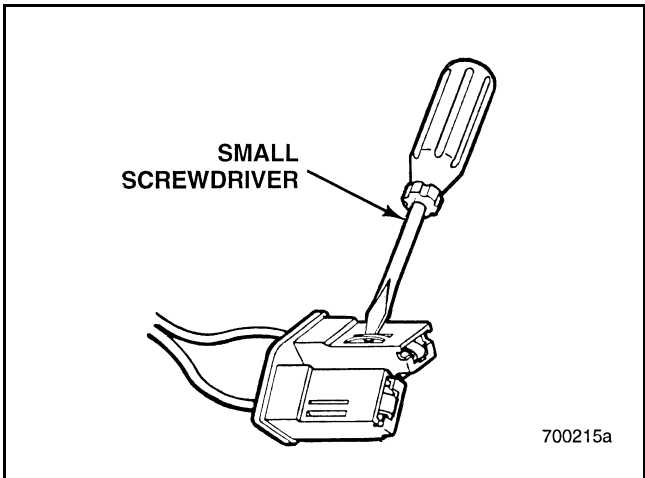


Figure 126 — Connector Secondary Lock

2. Insert remover tool J 33095 into the front of the connector.

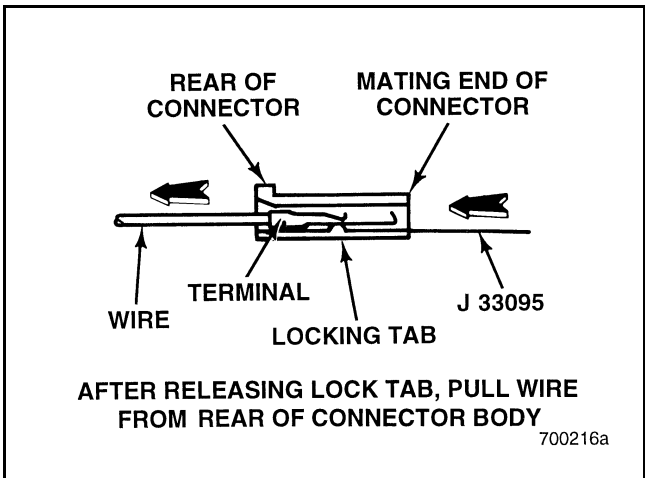


Figure 127 — Releasing Lock Tab

3. Push the terminal-holding prong straight in, and pull the wire and terminal out the back end of the connector.

NOTE

The connector on the forward pressure switch does not allow access to the secondary lock slots. This connector cannot be serviced and must be replaced.

Terminal Replacement

1. Remove the terminal by cutting the wire as close to the terminal as possible. This minimizes the amount of wire loss during the repair.
2. Strip 0.23 to 0.25 inch (5.75 to 6.25 mm) of insulation from the wire.
3. Insert the terminal into crimping tool J 25563.

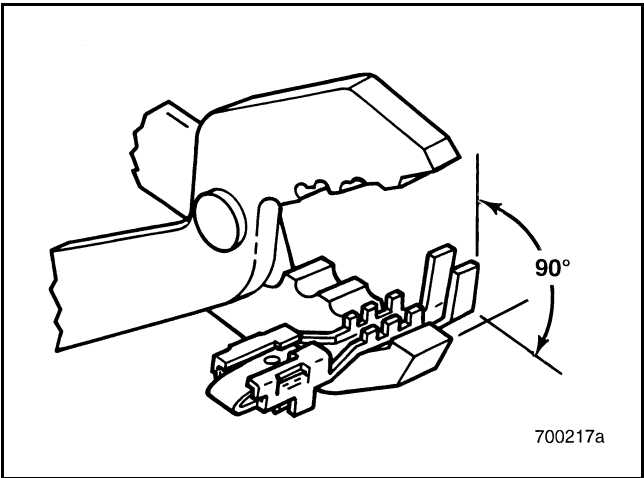


Figure 128 — Terminal Crimping

4. The u-shaped portion of the tool should hold the flat area of the terminal. The m-shaped portion of the tool should close around the open edge of the terminal.
5. Slightly close the crimping tool to hold the terminal steady.
6. Insert the wire so that the stripped portion is in the area to be crimped and the insulated portion is in the other crimping area.



REPAIR PROCEDURES

7. Crimp the stripped section of wire.

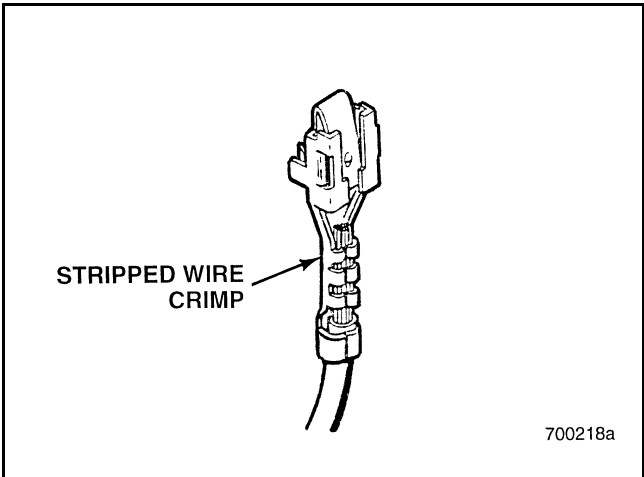


Figure 129 — Crimp Terminal

8. Remove the terminal from the crimping tool.
9. Use a pair of needlenose pliers to start the bend on the terminal area, that crimps around the insulation.
10. Using the area behind the crimping tool pivot, crimp the insulated section of wire.

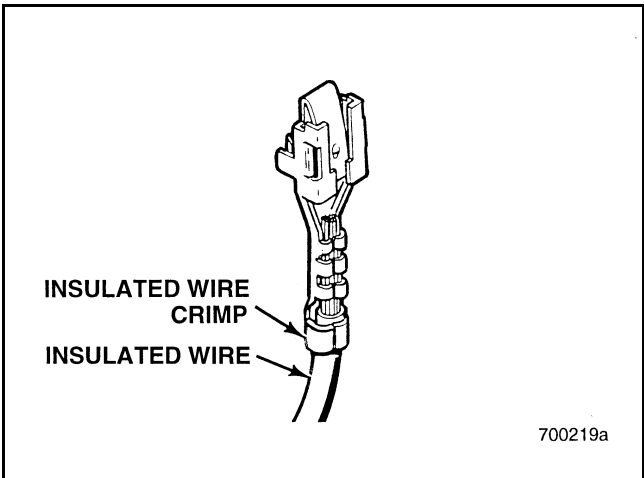


Figure 130 — Crimp Insulation Section

11. Remove the terminal from the crimping tool.
12. Pull on the terminal to ensure a tight fit.
13. Insert the terminal into the connector with the holding prong facing toward the connector.
14. The terminal should click in place and not pull out.

DELPHI-PACKARD 150 SERIES (PULL-TO-SEAT) CONNECTORS

Typical uses for this connector are:

- Automatic Transmission Shift Selector

Terminal Removal

1. Grasp the connector body firmly. Pull the terminal toward the rear of the connector as far as possible.
2. Insert needle end of terminal remover J 35689-A into the small notch in the cavity of the terminal being removed. Move the holding prong toward the terminal.

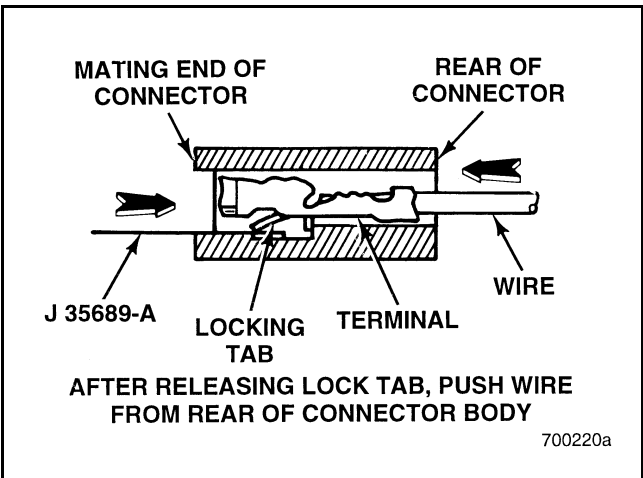


Figure 131 — Terminal Release

3. After releasing the tab, push the wire and terminal from the rear through the front of the connector (this type of terminal is pulled into position from the front of the connector body, to seat).

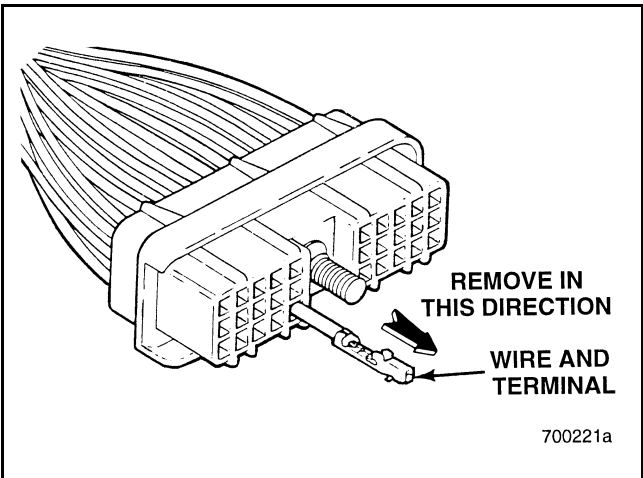


Figure 132 — Terminal Removal



REPAIR PROCEDURES

4. Pull the terminal as far as necessary from the connector. This is limited by the number of wires inserted into the connector and by the distance between the back side of the connector and the beginning of the harness covering.
5. Remove the terminal by cutting the wire as close to the terminal as possible to minimize wire loss during the repair.

Terminal Replacement

1. Before stripping, push the wire through the proper hole in the seal and out the other side of the connector.
2. Strip 0.15 to 0.17 inch (3.75 to 4.25 mm) insulation from the wire.
3. Push open the terminal holder on the crimping tool J 35123 and insert a terminal into the appropriate sized opening for the wire being used. Position the terminal so that the crimp ends point up. Release the terminal holder.

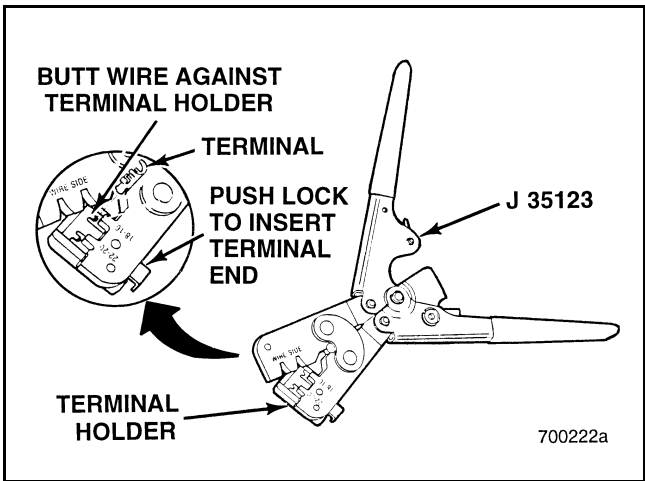


Figure 133 — Position the Terminal

4. Slightly close the crimping tool until a click is heard. Do not start to crimp the terminal. Orient the terminal so it is in the same position as it will be when pulled back into the connector.
5. Insert the wire into the terminal until the wire hits the holder. This positions the wire and insulation for the crimp.
6. Squeeze the crimper fully until it opens when released.

7. Open the terminal holder and remove the wire and terminal from the crimping tool.

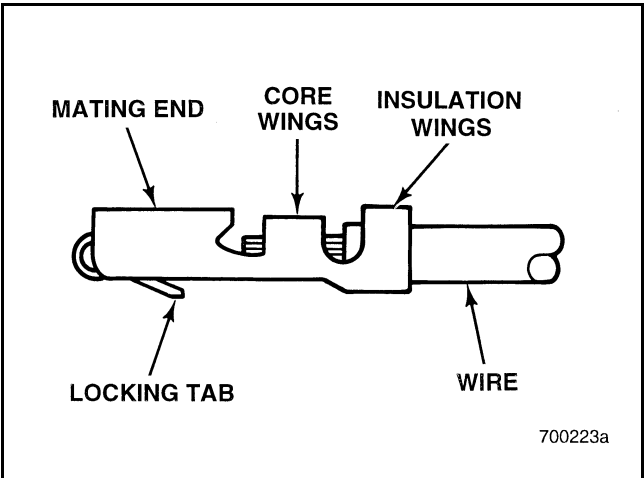


Figure 134 — Correctly Crimped Terminal

8. Pull on the terminal to ensure the crimp is tight.
9. Position the terminal so that the holding prong aligns with the appropriate notch in the connector cavity.
10. Pull the wire and terminal completely into the cavity. A click should be heard and the terminal should stay in place if the wire is pushed.

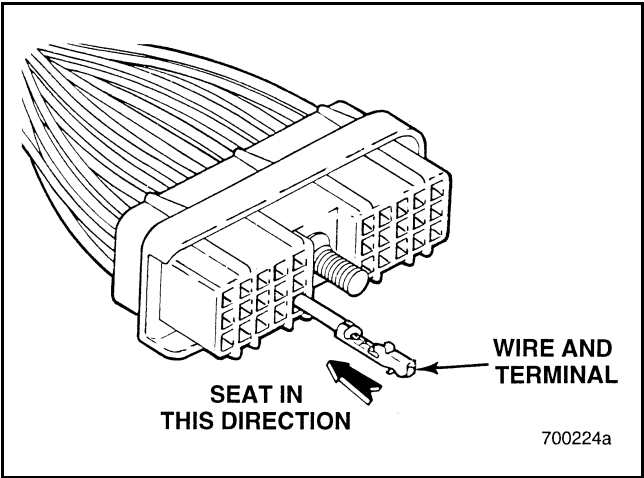


Figure 135 — Terminal Installation

11. Plug unused openings in the wire seal with sealing plugs.



REPAIR PROCEDURES

DELPHI MICRO-PACK 100W (RECTANGULAR) CONNECTORS

Typical uses for this connector are:

- Transmission ECU Connector

Use the procedures in this section to repair these connectors.

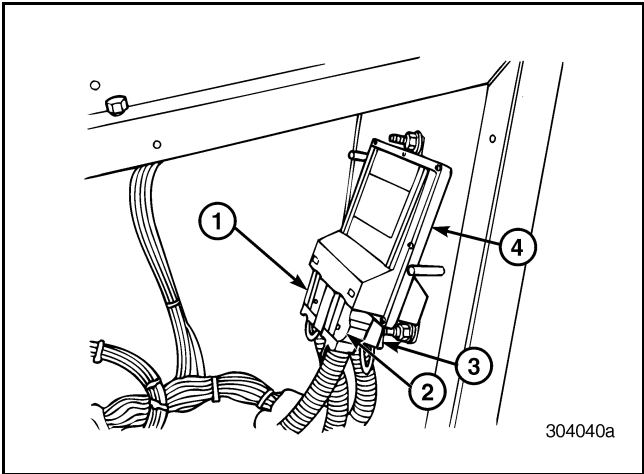


Figure 136 — Typical Transmission ECU Connectors

1. Black Connector	3. Blue Connector
2. Gray Connector	4. Transmission ECU

Terminal Removal

1. Use a small-bladed screwdriver to gently release the lock tabs at the splitline of the strain relief.

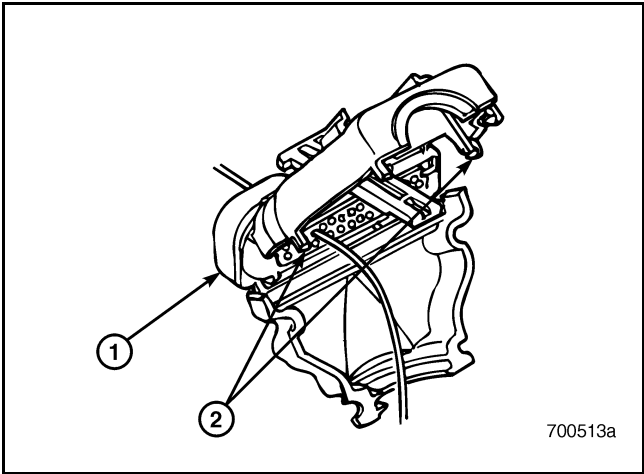


Figure 137 — ECU Harness Connector

1. Strain Relief	2. Lock Tabs
------------------	--------------

2. Spread the connector strain relief open.
3. Remove the retainer from the connector by using a small-bladed screwdriver to depress the lock tabs on the side of the connector.

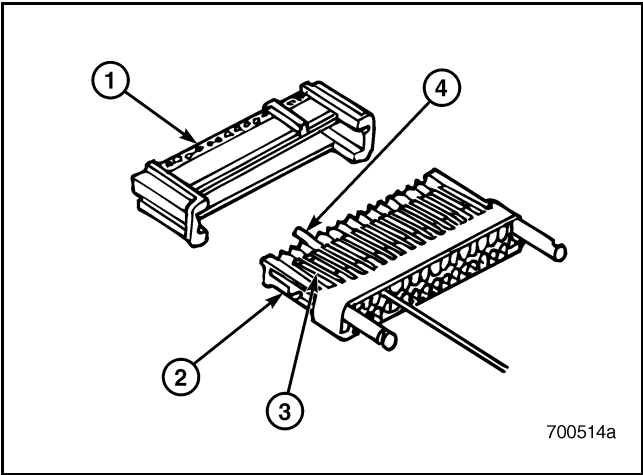


Figure 138 — ECU Connector Retainer

1. Retainer	3. Terminal Locking Finger
2. Lock Tab (Secures Retainer)	4. Socket Terminal (Female)

4. Remove a selected terminal by pushing forward on the wire, or by lifting the locking finger and pulling the wire and terminal rearward out of the connector.
5. Cut the damaged terminal from the wire as close as possible to the terminal end of the wire.



REPAIR PROCEDURES

Terminal Replacement

- 1. Carefully strip insulation to leave 5.0 mm ± 0.5 mm of bare wire showing.
- 2. Insert the **new** terminal to be crimped in the J 42215 crimping tool. A spring-loaded terminal positioner at the front of the tool holds the terminal in place. Squeeze the crimper handles for a few clicks to start the crimping process, but leave room to insert the bare wire end.

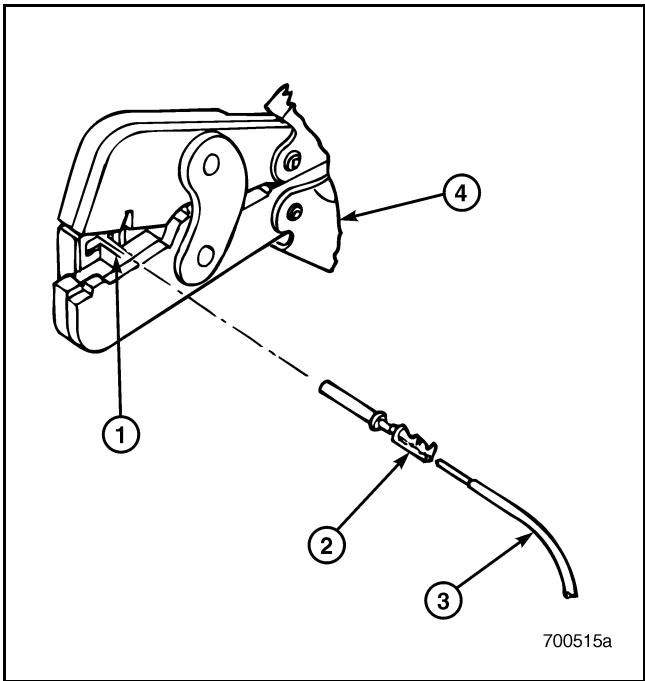


Figure 139 — Terminal Positioning

1. Lock Terminal in Tool	3. Stripped Wire
2. Socket Terminal	4. Crimping Tool J 42215

- 3. Insert the bare wire end into the terminal. Squeeze the crimper handles until the crimper handles open when released. Remove the terminal/wire assembly from the crimping tool J 42215.

Terminal Installation

- 1. Align the locking posts on the connector with the seal and push the locking posts through the seal into the mating holes in the strain relief (if the connector was removed from the strain relief).

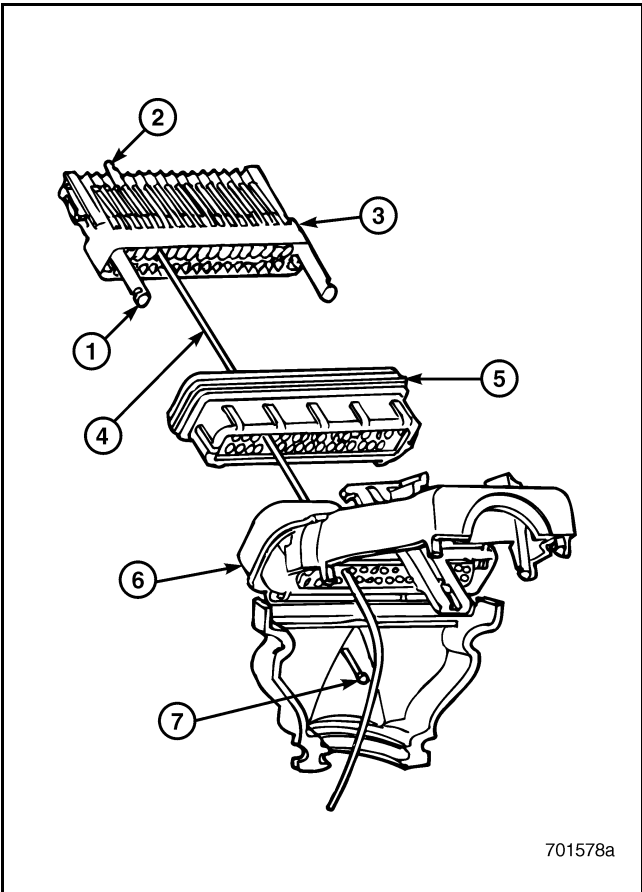


Figure 140 — Connector Alignment

1. Locking Post	5. Connector Seal
2. Socket Terminal (Female)	6. Strain Relief
3. Connector	7. Connector Cavity Plug
4. Typical Wire	



REPAIR PROCEDURES

2. Push the terminal/wire assembly through the proper hole in the back of the seal. Push the wire in until the terminal clicks into position.

NOTE

All terminals must be properly positioned in the seal to install the retainer.

3. Install the retainer on the connector body to lock the terminals in position. Pull rearward on the wire to be sure that the terminal is fully seated. Install cavity plugs as needed to fill any open cavities.

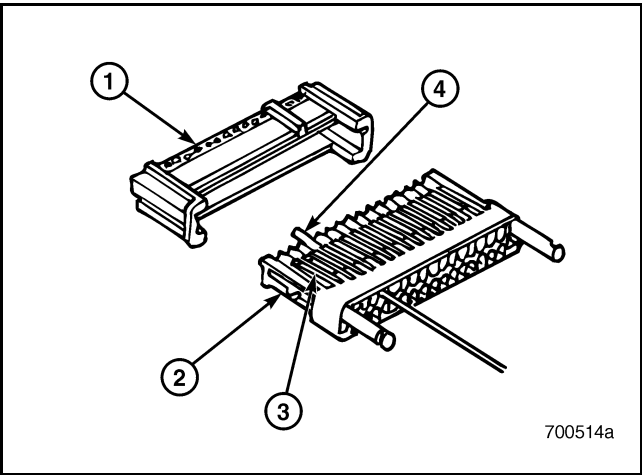


Figure 141 — Connector Retainer Installation

1. Retainer	3. Terminal Locking Finger
2. Lock Tab (Secures Retainer)	4. Socket Terminal (Female)

4. Position the conduit inside the strain relief and snap the strain relief halves together.

DELPHI MICRO-PAK 100W (CIRCULAR) CONNECTOR

Typical uses for this connector are:

- Transmission Shift Selector Harness Connector
- Body Builder Interface Connector

Terminal Removal

To repair these connectors, use the following procedure.

1. Carefully insert a small screwdriver blade between the connector body and the secondary lock. Twist/pry the secondary lock to remove it from the connector body.

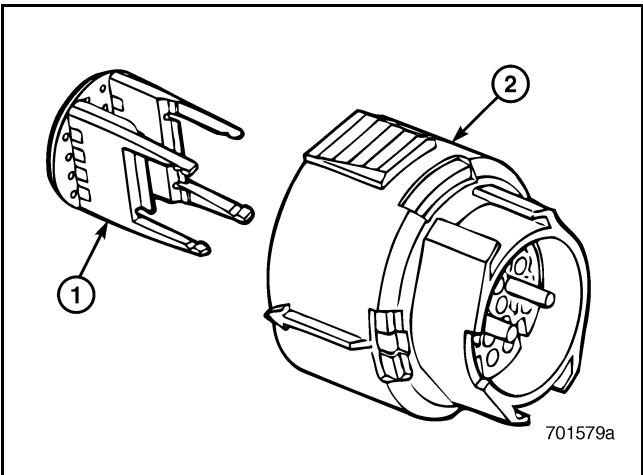


Figure 142 — Connector Secondary Lock Removal

1. Secondary Lock	2. Mating Connector with Female (Socket) Terminals
-------------------	--



REPAIR PROCEDURES

2. Open the conduit clip on the back of the connector after lifting the lock tabs on each side. Slide the clip back to release it from the connector.

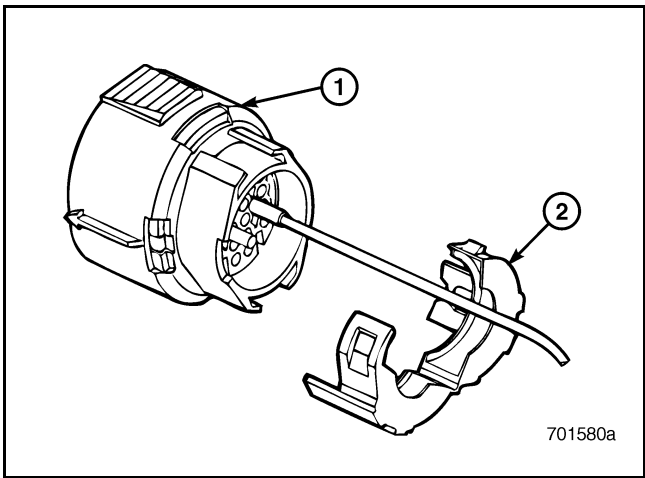


Figure 143 — Connector Conduit Clip Removal

- | | |
|---------------------|-----------------|
| 1. Mating Connector | 2. Conduit Clip |
|---------------------|-----------------|

3. Use the J 39227 removal tool to release the locking finger inside the connector and pull the terminal/wire assembly out the rear of the connector.

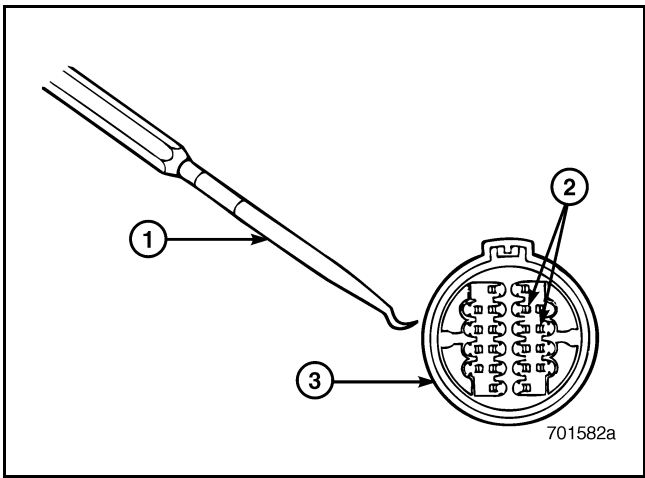


Figure 144 — Terminal/Wire Release from Connector

- | | |
|---------------------------------------|---------------------------|
| 1. J 39227 Removal Tool | 3. Rear View of Connector |
| 2. Connector Terminal Locking Fingers | |

4. Cut the damaged terminal from the wire as close as possible to the terminal end of the wire.

Terminal Replacement

1. Carefully strip insulation to leave 5.0 mm $\pm$ 0.5 mm of bare wire showing.
2. Insert the **new** terminal to be crimped in the J 42215 crimping tool. A spring-loaded terminal positioner at the front of the tool holds the terminal in place. Squeeze the crimper handles for a few clicks to start the crimping process, but leave room to insert the bare wire end.

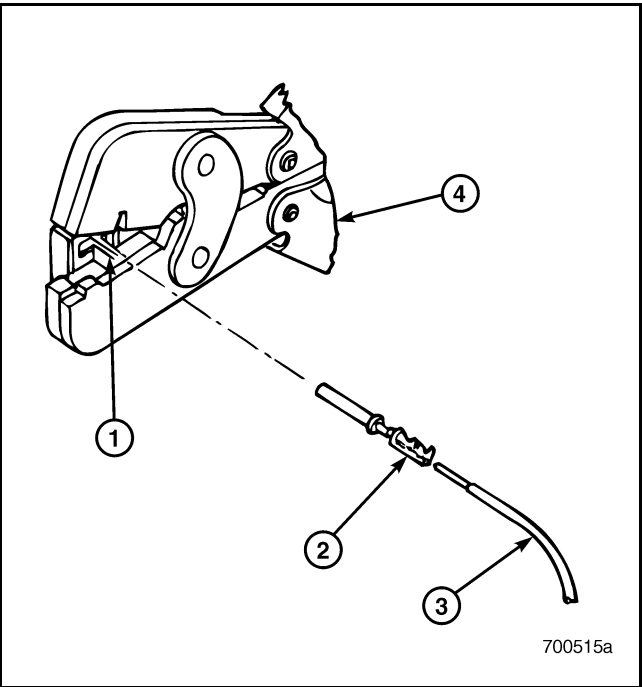


Figure 145 — Terminal Positioning

- | | |
|--------------------------|--------------------------|
| 1. Lock Terminal in Tool | 3. Stripped Wire |
| 2. Socket Terminal | 4. Crimping Tool J 42215 |

3. Insert the bare wire end into the terminal. Squeeze the crimper handles until the crimper handles open when released and remove the terminal/wire assembly from the crimping tool J 42215.



REPAIR PROCEDURES

Terminal Installation

1. Insert the wire seal into the back of the connector.

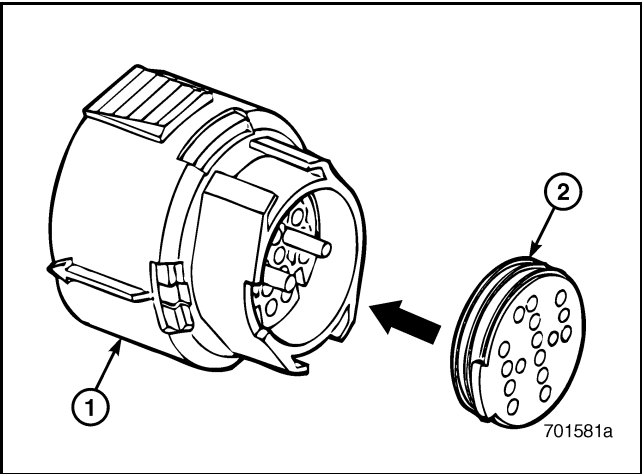


Figure 146 — Wire Seal Installation

1. Mating Connector	2. Wire Seal
---------------------	--------------

2. Push the terminal/wire assembly through the proper hole in the back of the wire seal. Push the wire in until the terminal clicks into position. Gently pull rearward on the wire to be sure that the terminal is fully seated. Install cavity plugs as needed to fill any open cavities.

3. Install the secondary lock into the connector body.

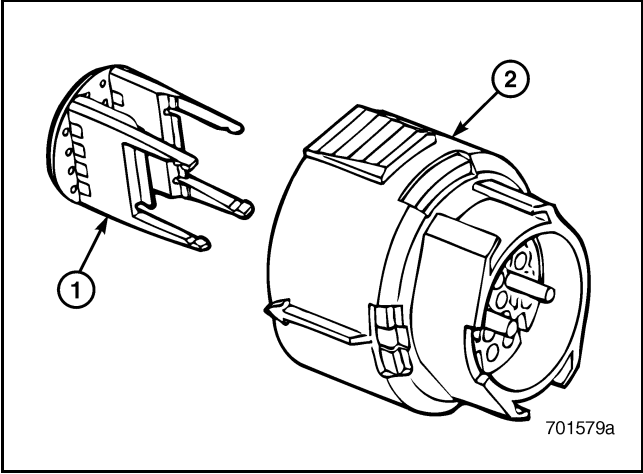


Figure 147 — Secondary Lock Installation

1. Secondary Lock	2. Mating Connector with Female (Socket) Terminals
-------------------	--

4. Close the conduit clip around the conduit and lock into the rear of the connector body.

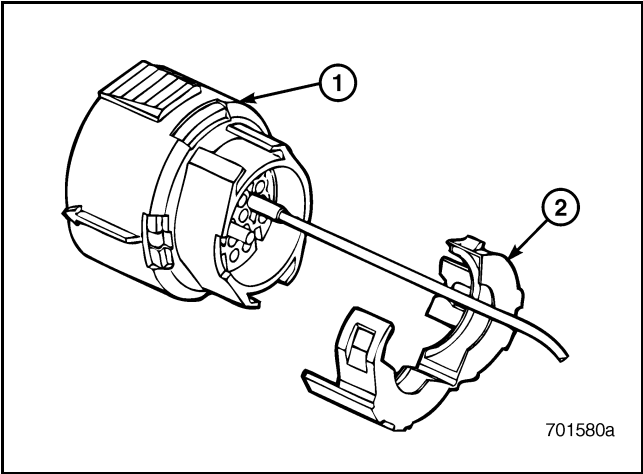


Figure 148 — Positioning Conduit Clip

1. Mating Connector	2. Conduit Clip
---------------------	-----------------



REPAIR PROCEDURES

DELPHI-PACKARD MICRO-PACK 100W (CIRCULAR) CONNECTOR

Typical uses for this connector are:

- Body Builder Interface Connector

To repair this connector, use the following procedure.

Terminal Removal

1. Lift the lock tabs on the side of the connector and remove the lock assist.

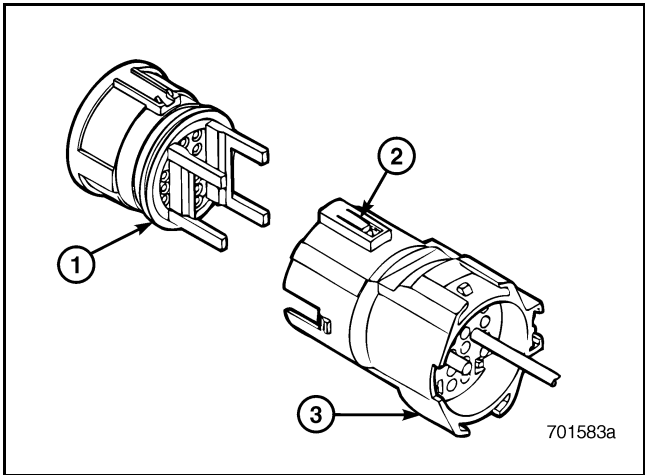


Figure 149 — Releasing Lock Assist Lock Tabs

1. Lock Assist 2. Lock Tab	3. Mating Connector
-------------------------------	---------------------

2. Open the conduit clip on the back of the connector after lifting the lock tabs on each side. Slide the clip back to release it from the connector.

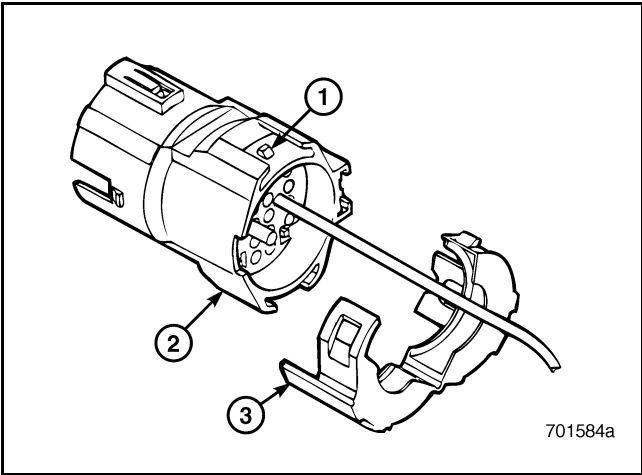


Figure 150 — Releasing Connector Side Lock Tabs

1. Conduit Clip Lock Tab 2. Mating Connector with Male (Pin) Terminals	3. Conduit Clip
---	-----------------

3. Use the J 39227 removal tool to release the locking finger inside the connector and pull the terminal/wire out of the rear of the connector.

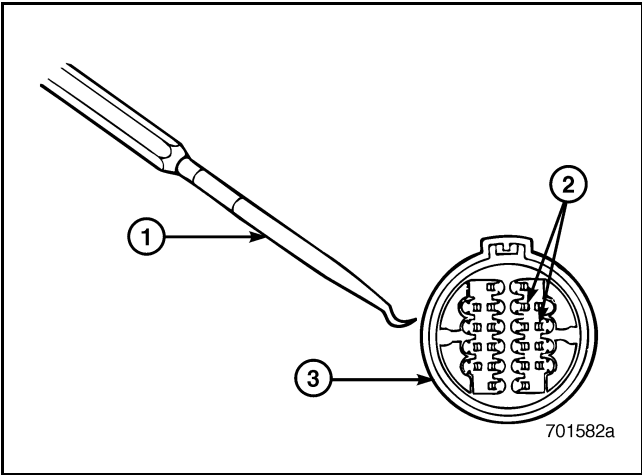


Figure 151 — Releasing Terminal Locking Finger

1. J 39227 Removal Tool 2. Connector Terminal Locking Fingers	3. Rear View of Connector
--	---------------------------



REPAIR PROCEDURES

Terminal Replacement

- 1. Carefully strip insulation to leave 5.0 mm ± 0.5 mm of bare wire showing.
- 2. Insert the **new** terminal to be crimped in the J 42215 crimping tool. A spring-loaded terminal positioner at the front of the tool holds the terminal in place. Squeeze the crimper handles for a few clicks to start the crimping process but leave room to insert the bare wire end.

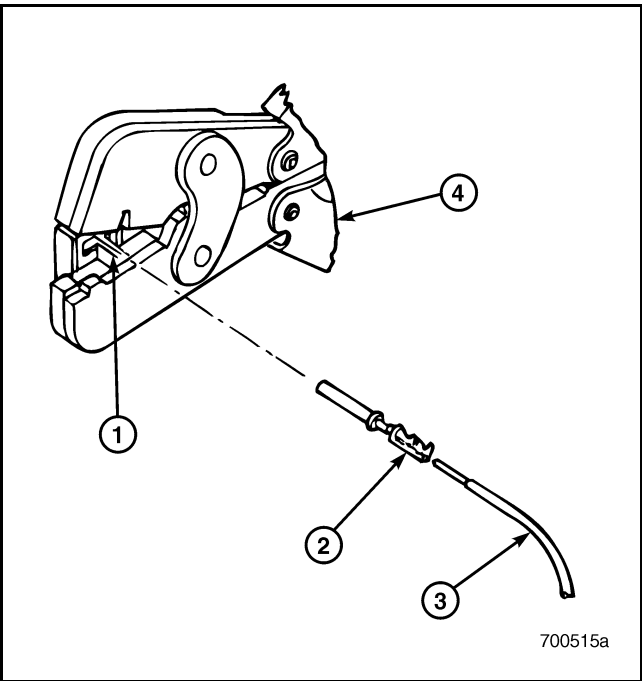


Figure 152 — Terminal Positioning

1. Lock Terminal in Tool	3. Stripped Wire
2. Socket Terminal	4. Crimping Tool J 42215

- 3. Insert the bare wire end into the terminal. Squeeze the crimper handles until the crimper handles open when released, and remove the terminal/wire assembly from the crimping tool J 42215.

Terminal Installation

- 1. Insert the wire seal into the back of the connector.

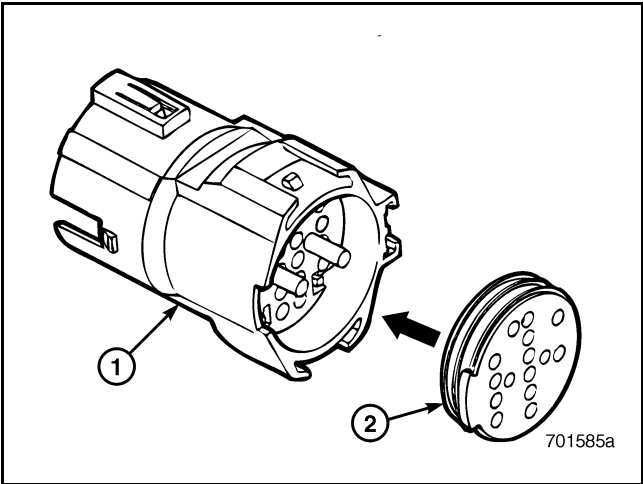


Figure 153 — Wire Seal Installation

1. Mating Connector	2. Wire Seal
---------------------	--------------

- 2. Push the terminal/wire assembly through the proper hole in the back of the wire seal. Push the wire in until the terminal clicks into position. Gently pull rearward on the wire to be sure that the terminal is fully seated. Install cavity plugs as needed to fill any open cavities.
- 3. Install the lock assist into the connector body until the side lock tabs fully engage.

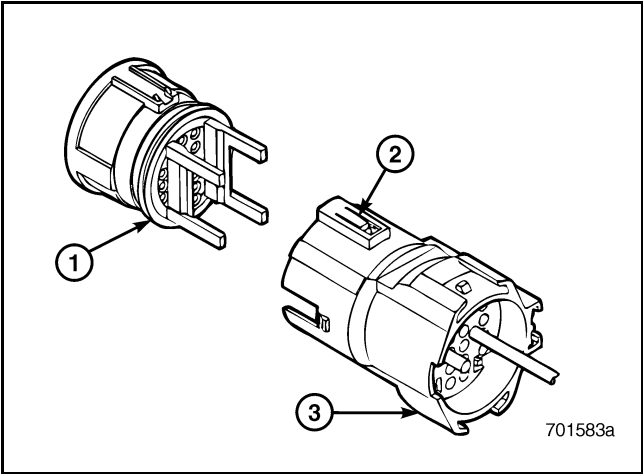


Figure 154 — Connector Lock Assist Installation

1. Lock Assist	3. Mating Connector with Male (Pin) Terminals
2. Lock Tab	



REPAIR PROCEDURES

4. Close the conduit clip around the conduit and lock into the rear of the connector body.

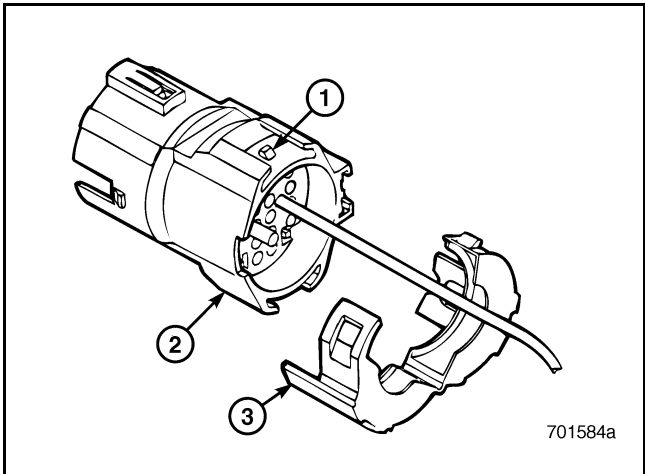


Figure 155 — Installing Conduit Clip

- | | |
|---|-----------------|
| 1. Conduit Clip Lock Tab | 3. Conduit Clip |
| 2. Mating Connector with Male (Pin) Terminals | |

2. Use a sharp knife to carefully remove the shrink tubing from the rear of the connector plug.
3. Use a small screwdriver to release the locking lever for all of the terminals. Pull the wire and terminal out of the rear of the connector.

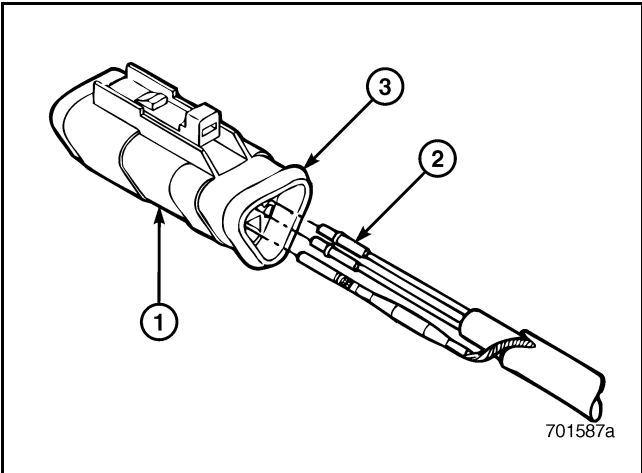


Figure 157 — Removing Wires and Terminals

- | | |
|-----------------------------|------------------------------------|
| 1. Connector Body | 3. Shrink Tubing Installation Area |
| 2. Standard Socket Terminal | |

DEUTSCH DT SERIES CONNECTOR

Typical uses for this connector are:

- J1939 Serial Port Connector

To repair this type of connector, use the following procedure.

Terminal Removal

1. Use a small-bladed screwdriver to remove the wedge lock that holds the terminals in place.

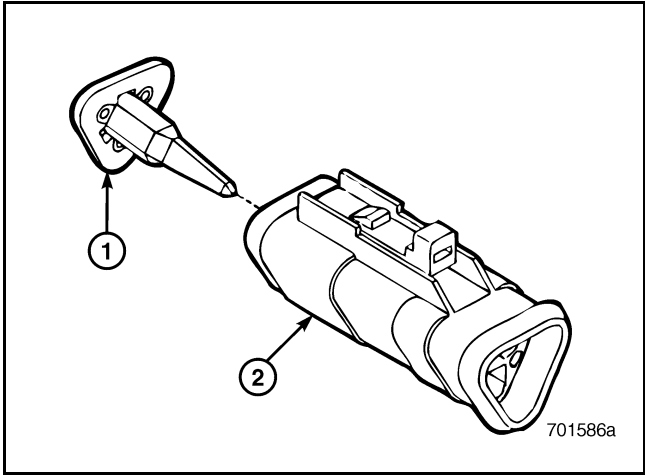


Figure 156 — Removing Wedge Lock

- | | |
|---------------|-------------------|
| 1. Wedge Lock | 2. Connector Body |
|---------------|-------------------|



REPAIR PROCEDURES

Terminal Crimping

1. Strip 0.24–0.32 inch (6–8 mm) of insulation from the wire. (There is no insulation on the shield wire.)
2. Set crimping tool J 34182 wire size adjustment to number 18. To set the wire size, remove the retainer pin. Lift and rotate the indicator until 18 is aligned with the arrow labeled “SEL NO.”. Reinstall the retainer pin.

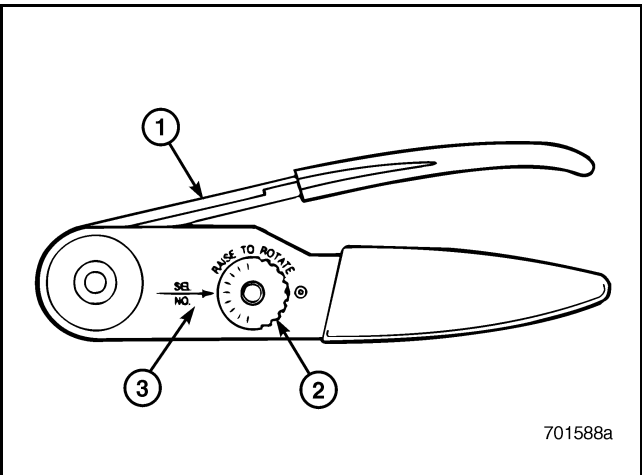


Figure 158 — Setting Wire Size Adjustment

1. Crimper J 34182	3. SEL NO. Arrow
2. Wire Size Indicator	

3. Insert the contact end of the terminal down into crimping tool J 34182. Adjust the crimping tool depth by loosening the locking ring until the depth adjusting screw is free. Turn the adjusting screw until the wire end of the terminal is just above flush with the top of the crimping hole. The depth adjustment screw must be backed out a large amount to accept the extended shield terminal. The crimping jaws will now contact the middle of the terminal barrel. Tighten the locking ring to retain the adjustment.

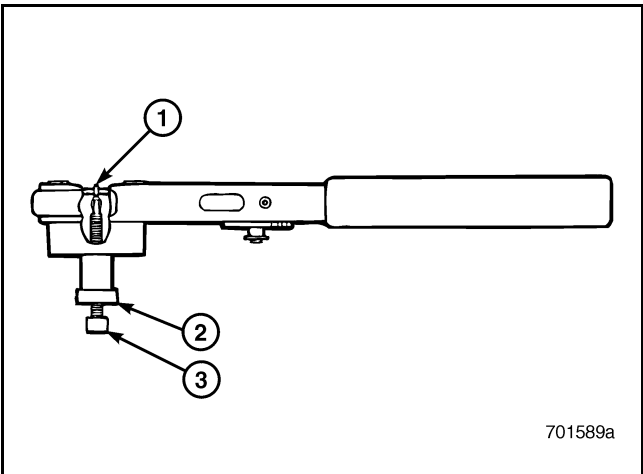


Figure 159 — Adjusting Crimping Tool Depth

1. Terminal	3. Depth Adjustment Screw
2. Locking Ring	

4. Fully insert the wire into the terminal so that the stripped portion of the wire is in the crimp area. A small section (0.020–0.040 inch [0.5–1.0 mm]) of wire will be visible above the terminal barrel.
5. Squeeze the crimping tool handle until it releases. The terminal is now crimped onto the wire.
6. Remove the terminal and wire from the crimping tool.
7. Tug on the terminal to make sure the crimp is tight.



REPAIR PROCEDURES

Terminal Insertion

1. Slide the wire with crimped terminal attached, into the rear of the connector.

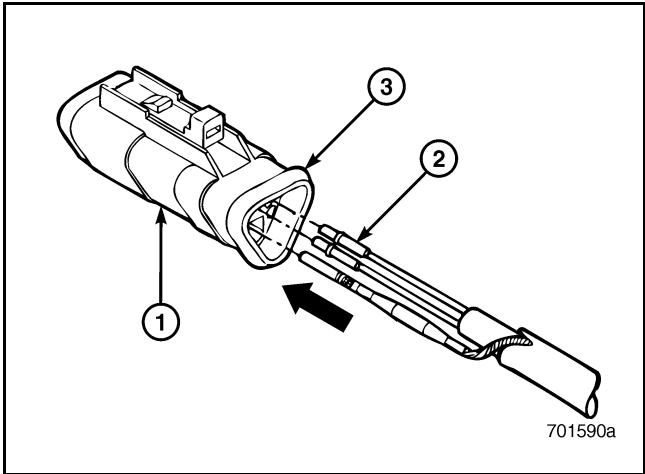


Figure 160 — Inserting Wires and Terminals

1. Connector Body 2. Standard Socket Terminal	3. Shrink Tubing Installation Area
--	------------------------------------

3. Slide the shrink tubing over the raised area of the connector. Use a heat gun to shrink the tubing into position over the connector and harness.

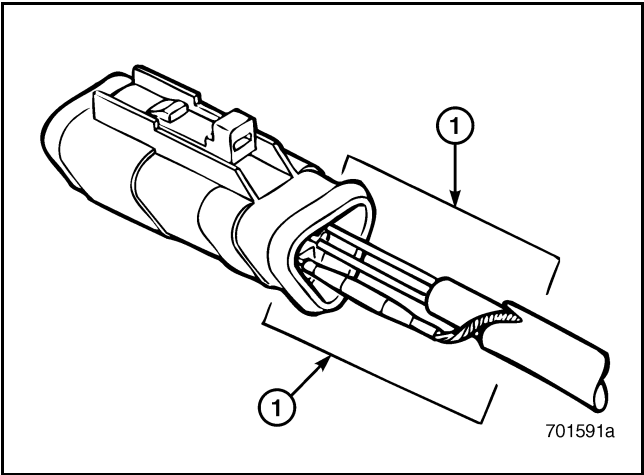


Figure 162 — Applying Shrink Tubing

1. Shrink Tubing Applied to this Area

2. Insert the wedge lock to hold the terminals in place. Make sure that the connector seal fits tight to the connector.

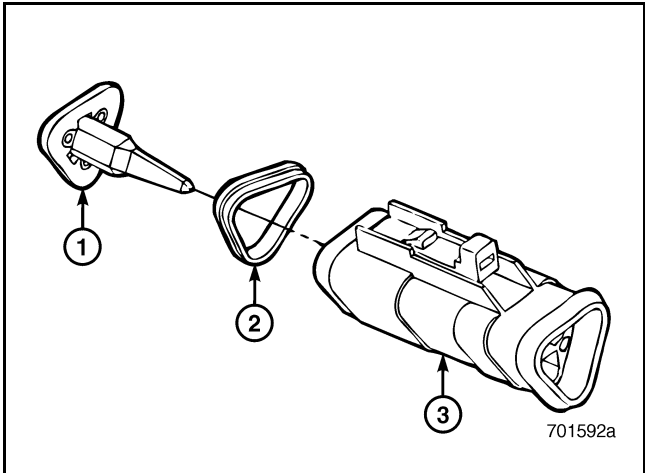


Figure 161 — Inserting Wedge Lock

1. Wedge Lock 2. Connector Seal	3. Connector Body
------------------------------------	-------------------



REPAIR PROCEDURES

Chassis Electrical Sealant Application

DESCRIPTION

There are several areas on MACK truck chassis that require the application of electrical sealant spray. The fuel tank sending unit terminals, starter solenoid terminals, engine ground terminals and various other terminals, or exposed electrical contacts, must be sealed from the elements. This is to prevent corrosion, which leads to terminal deterioration and electrical leakage, and to insulate against accidental shorting and damage to electrical circuits.

This clear or colored (usually red) insulating spray is varnish like, and can be used to coat exposed electrical contacts or terminals. Electrical sealant has high insulating properties and is moisture and chemical resistant. The Department of Transportation (DOT), requires that the exposed fuel tank sending unit connections, be insulated.

ELECTRICAL GREASE

To prevent corrosion of the lamp socket terminals, particularly with the clearance and marker lamps, apply a coating of electrical sealing grease, such as Lubriplate DS-EX. Apply grease to the socket and terminal assemblies.

NOTE

Do not use electrical greases on any V-MAC connector.

USAGE AND LOCATION

The following is a list of the various locations that benefit from the use of electrical sealant spray such as KRYLON 1385 Red Insulating Varnish.

- Various Relay Accessory Wire Terminals
- Backup Alarm
- Taillight Wire Connections
- Fuel Tank Sending Unit Connections
- Battery Disconnect Switch
- Battery Hold Downs
- Various Solenoid Wire Terminals
- Starter Exposed Terminals
- Engine and Frame Ground Wires and Terminals
- Alternator Wire Terminals
- Any Exposed Terminals Requiring Corrosion Protection



NOTES



SPECIAL TOOLS & EQUIPMENT

SPECIAL TOOLS & EQUIPMENT



SPECIAL TOOLS & EQUIPMENT

RECOMMENDED ELECTRICAL TOOLS

The following list of tools is recommended for each of the different types of connectors on the vehicle. They can be purchased individually as needed.

- Deutsch Connector Pin Remover — J 34513
- Deutsch Connector and DT Series Crimping Tool — J 34182
- Weather Pack Connector Insert Remover — J 28742-A
- Weather Pack Terminal Crimping Tool — J 35606
- Delphi-Packard 56 Series Connector Insert Remover — J 33095
- Delphi-Packard 56 Series Terminal Crimping Tool — J 25563
- Delphi-Packard 150 Series Connector Terminal Remover — J 35689-A
- Delphi-Packard 150 Series Terminal Crimping Tool — J 35123
- Delphi-Packard Micro-Pack 100W Connector (Rectangular and Circular) Crimping Tool — J 42215
- Delphi-Packard Micro-Pack 100W Connector (Circular) Terminal Removal Tool — J 39227



INDEX

INDEX



INDEX

A	J
ACTUAL7	JUMPER WIRE16
B	K
BATTERIES — GENERAL INFORMATION ..39	KEY-POWERED CIRCUITS31
BATTERY TESTS42	L
BATTERY-POWERED CIRCUITS30	LIGHTING55
C	LOCATING SHORTS OR GROUNDED CIRCUITS25
CHARGING SYSTEM52	M
CHARGING SYSTEM TESTS53	MISCELLANEOUS CIRCUITS — DESCRIPTION/FUNCTION55
CHASSIS ELECTRICAL SEALANT APPLICATION101	MULTIMETER (VOLT-OHM METER)16
CHECKING CIRCUIT GROUNDS28	MULTIMETER (VOLT-OHM METER) USAGE17
CIRCUIT BREAKERS34	O
CIRCUIT CONTINUITY CHECKS26	OHM'S LAW13
CIRCUIT TYPES11	OPERATION40, 45, 52
COMMON ELECTRICAL PROCEDURES ...80	P
CONVENTIONAL7	PARALLEL CIRCUITS11
CORRECT USE OF TIE WRAPS80	PERIODIC MAINTENANCE41
CURRENT7	POWER DISTRIBUTION30
D	R
DESCRIPTION39	RECOMMENDED ELECTRICAL TOOL104
DIAGNOSTIC APPLICATIONS22	RESISTANCE10
DIAGNOSTIC TECHNIQUES22	RESISTANCE, HEAT AND CURRENT FLOW10
DIAGNOSTIC TOOLS16	S
E	SAE TYPE 134
ELECTRICAL CONCEPTS2	SAE TYPE 234
EXPRESSING ELECTRICAL VALUES15	SAE TYPE 335
G	SENDING UNITS58
GAUGE TESTING62	SERIES CIRCUITS11
GAUGES56	SERIES-PARALLEL CIRCUITS12
GROUND CIRCUITS32	SOURCES OF VOLTAGE5
H	SPECIFIC GAUGE AND SENDING UNIT TESTS64
HORN74	SPEED SENSORS72
I	STARTING SYSTEM45
INTRODUCTION2	



INDEX

T

TESTING CIRCUIT BREAKERS35
TROUBLESHOOTING46
TROUBLESHOOTING METHOD22
TROUBLESHOOTING OF INSTRUMENT
CLUSTER, GAUGES, SENDING UNITS,
SENSORS AND HORN62
TYPES OF BATTERIES41
TYPES OF CURRENT8
TYPICAL CONNECTORS83
TYPICAL ELECTRIC EQUIPMENT PANEL . .33

U

UNDERSTANDING ELECTRICITY2

V

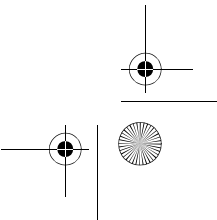
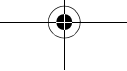
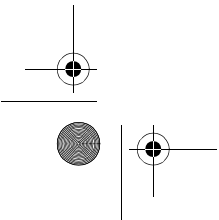
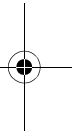
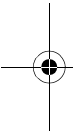
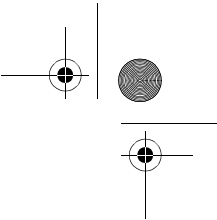
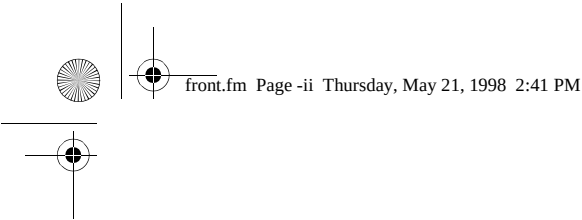
VOLTAGE4

W

WIRE IDENTIFICATION37
WIRE SIZES36



NOTES





PRINTED IN U.S.A.
8-212

ELECTRICAL TROUBLESHOOTING SERVICE MANUAL

© MACK TRUCKS, INC. 1999