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Electrical System Design Guidelines (continued)

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Electrical System Design Guidelines (continued)

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Index

Scope

The scope of this Electrical Manual is to define General Motors recommendations for the design and installation of non-OEM (Original Equipment Manufacturer) low-voltage electrical systems and components in GM vehicles by personnel engaged in the conversion of automotive vehicles. Also included in this manual are guidelines for the interfacing of Upfitter installed electrical systems to the General Motors OEM electrical system. This is not a “how to” manual. It assumes the reader has technical expertise in the area. Ultimate responsibility for all work rests with the Upfitters.

Common Electrical Problems – General Information

GENERAL INFORMATION

This section describes several common automotive electrical problems and failure modes. General Motors recommends that Upfitters become familiar with these common problems. Doing so will help to avoid potential failure and other serious problems in the vehicle's electrical system and components.

FAILURE MODES

Short Circuit

A short circuit is a connection of comparatively low resistance, made either accidentally or intentionally, between two points in an electrical circuit. In other words, a short circuit is a direct connection between two circuits. Typically, when a power circuit shorts to a grounded circuit or conductive metal in the vehicle, it causes a circuit protection device (CPD) to open and protect the wiring from damage. However, it is possible for a short circuit to cause damage to the wiring and to the vehicle. This occurs if a circuit is not properly protected. The tremendous amount of current that flows through a wire, generated by a short, causes the wire to heat up, melt the insulation around the wire and adjacent wires, and may even lead to a thermal event. Damage to a vehicle resulting from a short circuit can be avoided with proper fusing. Therefore, it is very important to follow good circuit protection guidelines any time a new circuit is added to a vehicle electrical system. A short circuit may result when a cut, pinched or chafed wire makes contact with a grounded component of the vehicle.

Open Circuit

An open circuit is a circuit that has lost contact in a way that prohibits the flow of current. This condition creates infinite resistance between two circuits and usually results in the malfunctioning of an electrical component. An open circuit may result from:

- A pinched or cut wire
- Improperly seated terminal(s) in a connector
- A poor or improper terminal crimp
- Corroded terminal(s)
- Improperly connected ring terminal

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Common Electrical Problems – General Information (cont'd)

Intermittent Circuit

An intermittent circuit is a circuit that repeatedly opens or shorts temporarily. In other words, the circuit makes and breaks contact over and over again. It may be caused by:

- A pinched wire
- A loose ring terminal
- Improper seating of terminal(s) in a connector
- Incomplete mating of connectors
- Corroded terminals

Sources of Electrical Problems

A variety of conditions can cause problems with the automotive electrical system and its components. These include:

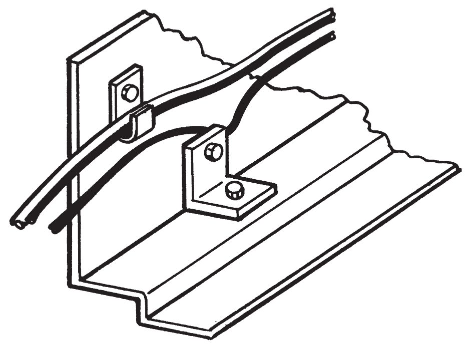
- Cut, broken, pinched or chafed wire
- Burned wiring or melted insulation
- Loose or unconnected ring terminal
- Terminal core grip wings crimped over wire insulation
- Uncrimped terminal core grip wings
- Terminal backed out of connector
- Bent or damaged terminal in connector
- Corroded terminal
- Partially or completely disconnected connector
- Poor or missing ground
- Crossed wire in connector
- Missing wire
- Misrouted wire
- Short wire lead(s)
- Damaged connector
- Improperly installed light bulb
- Disconnected light bulb socket

Common Electrical Problems (cont'd)

CUT OR BROKEN WIRE – May result in a temporary short as cutting occurs and then an open circuit.

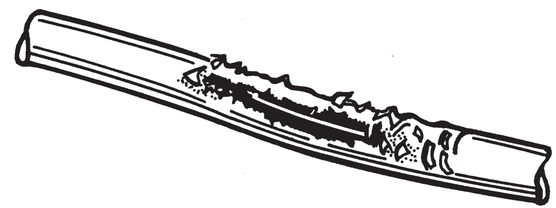
Electrical Problem Example #1

PINCHED WIRE – Wire pinched between two objects such as brackets. Will usually result in a short circuit due to cold flow of insulation material



Electrical Problem Example #2

CHAFED WIRE – Wire insulation has been rubbed away exposing the wire core. Will usually result in a short circuit.

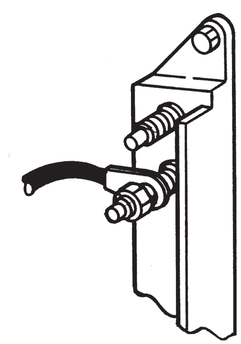


Electrical Problem Example #3

BURNED WIRE OR MELTED INSULATION – Wire located too close to a radiant heat source. Insulation will be discolored and melted, possibly exposing wire core, which will usually result in a short circuit.

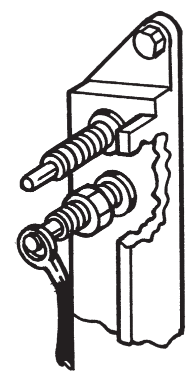
Electrical Problem Example #4

LOOSE RING TERMINAL – Bolt, screw, or nut used to secure the terminal is not completely tightened. Can result in arcing and/or an intermittent or open circuit.



Electrical Problem Example #5

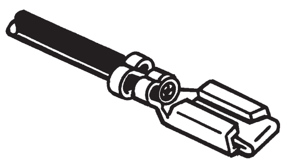
UNCONNECTED RING TERMINAL – Terminal is not secured at all with a bolt, screw or nut. Will result in an open circuit.



Electrical Problem Example #6

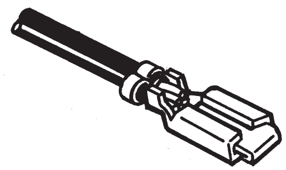
Common Electrical Problems (cont'd)

TERMINAL CORE GRIP WINGS CRIMPED OVER WIRE INSULATION – Terminal has no contact with the wire core due to insulation not being properly removed or positioned. Results in an open circuit.



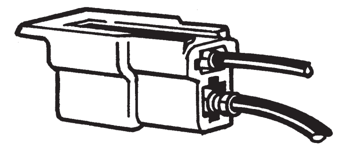
Electrical Problem Example #7

TERMINAL CORE GRIP WINGS NOT CRIMPED – Terminal has not been secured to the wire core resulting in an intermittent or open circuit.



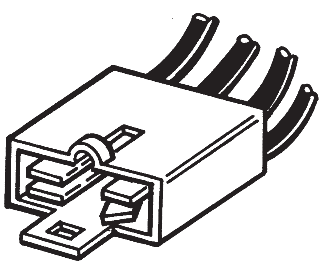
Electrical Problem Example #8

TERMINAL BACKED OUT OF CONNECTOR – Terminal has not stayed properly positioned inside the connector. As it "backs out" an intermittent or open circuit may result.



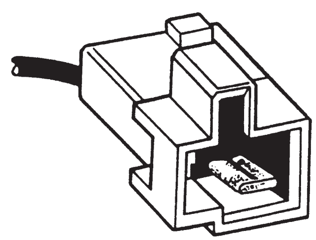
Electrical Problem Example #9

BENT OR DAMAGED TERMINAL IN CONNECTOR – May result in an intermittent or open circuit. A short circuit may occur if the bending causes two terminals to touch.



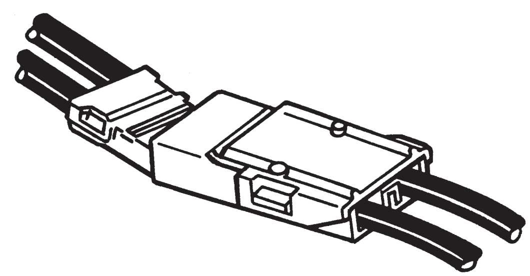
Electrical Problem Example #10

CORRODED TERMINAL – Corroding is evident when a greenish-white powder appears on the terminal. May result in high temperature in the connector or an open circuit due to high resistance.



Electrical Problem Example #11

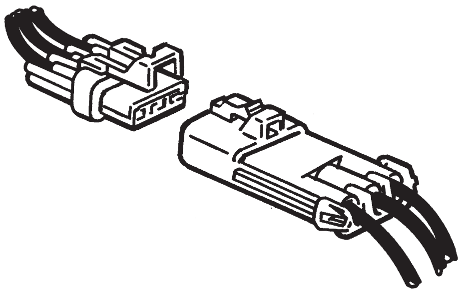
CONNECTOR PARTIALLY CONNECTED – "Partially" indicates that some terminals in a connector are making contact while others are intermittent or open circuit across the connection.



Electrical Problem Example #12

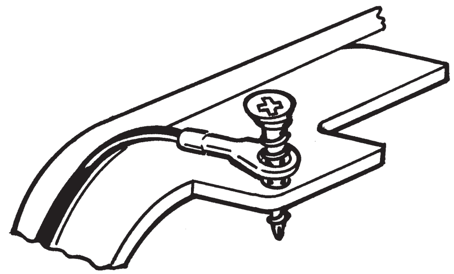
Common Electrical Problems (cont'd)

CONNECTOR COMPLETELY DISCONNECTED – The connector is not mated at all and all terminals are open circuit across the connection.



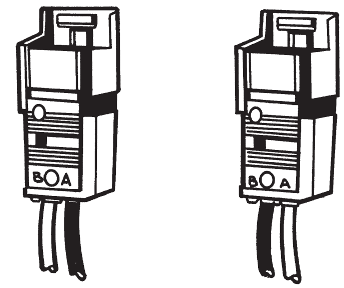
Electrical Problem Example #13

POOR OR MISSING GROUND – Ground terminal not fastened or only partially fastened to the body sheet metal. Can result in an intermittent or open circuit.



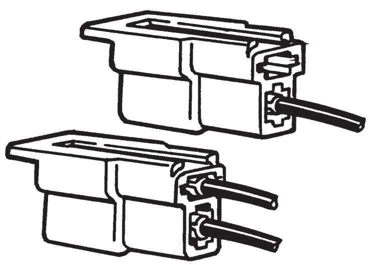
Electrical Problem Example #14

CROSSED WIRE IN CONNECTOR – Wire has been inserted into the wrong cavity in the connector during initial assembly or previous repair. May result in a malfunction of the circuit which could lead to a short circuit.



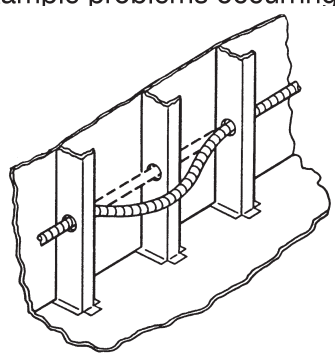
Electrical Problem Example #15

MISSING WIRE – May have been omitted during initial manufacturing of the harness assembly or left out during vehicle build.



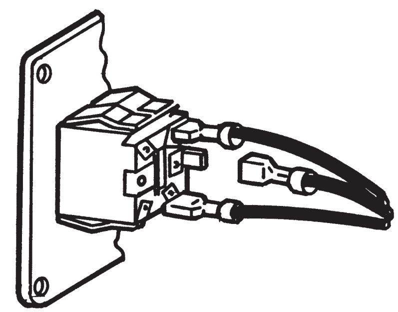
Electrical Problem Example #16

MIS-ROUTED WIRE – Wire has been positioned incorrectly during vehicle build. Will usually result in one or more of the listed example problems occurring.



Electrical Problem Example #17

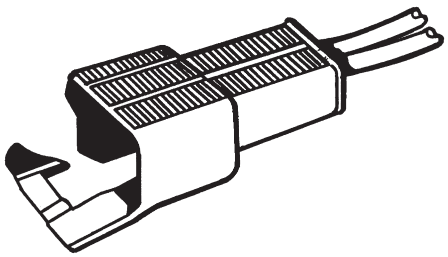
SHORT WIRE LEAD(S) – Wire may have been assembled improperly by harness manufacturer or might have been misrouted during assembly.



Electrical Problem Example #18

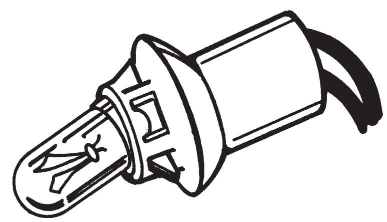
Common Electrical Problems (cont'd)

DAMAGED CONNECTOR – The connector is cracked, broken or melted. Will generally not mate properly and can result in an open or intermittent circuit.



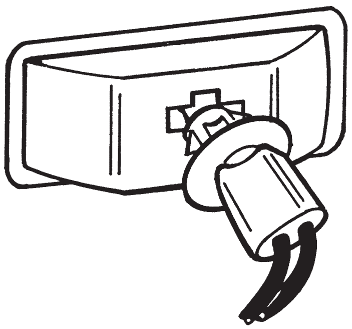
Electrical Problem Example #19

IMPROPERLY INSTALLED LIGHT BULB – The bulb is not making proper contact in the socket and may flicker or not light at all.



Electrical Problem Example #20

DISCONNECTED LIGHT BULB SOCKET – The bulb will light but the socket has come loose from the lamp housing and the lamp will not illuminate properly.



Electrical Problem Example #21

OEM and Auxiliary Battery Guidelines

OEM BATTERY GUIDELINES

The information in this section will help the Upfitter to prevent OEM battery discharge when upfitting GM vehicles. It is the Upfitter's responsibility to make sure that the OEM battery is at the same or higher state of charge when the completed vehicle is shipped, than what it was when the vehicle was received.

Additionally, integration of Upfitter equipment with the vehicle electrical system should be done with the aim of protecting the battery from excessive discharge with the ignition off.

General Information

General Motors Light and Medium Duty Trucks are equipped with maintenance-free, sealed batteries that are designed to perform three major functions:

- Provide a source of electrical energy for cranking the engine
- Act as a voltage stabilizer for the vehicle electrical system
- Provide added energy when the vehicle's electrical load requirements exceed the output of the generator.

When connecting directly to the OEM battery, use only OEM-approved connecting devices. Contact the Upfitter Integration group for approved components.

CAUTION Upfitter provided battery bolts, that incorporate a threaded stud for direct attachment to the battery, should comply with OEM requirements for configuration, length, material, and terminal interface requirements. Failure to do so could compromise the vehicle electrical system performance, reduce battery life and physically damage the battery.

CAUTION Battery bolts should be torqued to 17.0 ± 3.0 Nm. Do not over-torque as this could damage the battery.

CAUTION Terminal attaching nuts, that are installed on Upfitter battery bolt/studs, should always be torqued to a specification that is lower than the installation torque requirement for the battery bolt itself, to prevent battery bolt over-torquing.

Some electrical devices may impose a "parasitic" load on the OEM battery. Upfitters should not install this type of device in a GM vehicle.

Whenever practical and customer convenient, wire non-OEM electrical devices so that they are controlled by the vehicle's ignition system. This will prevent battery discharge if the electrical device is inadvertently left on. (**Note:** See the "Interfacing to the OEM Electrical System" section for recommended connection methods to the OEM ignition circuit.) Upfitter electrical devices that have a parasitic current draw should not be added to the vehicle.

Refer to the appropriate GM service manual for specific information on battery usage, diagnosis and on-vehicle service procedures.

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OEM and Auxiliary Battery Guidelines (cont'd)

Discharge Prevention

General Motors recommends that Upfitters implement practices that will prevent battery discharge that otherwise may occur during the conversion process.

- When storing a vehicle for more than 10 days (either before or after the conversion process), disconnect all negative battery terminals. Some electronic devices, such as the radio, engine control module (ECM), powertrain control module (PCM), and the vehicle control module (VCM), impose small, continuous current drains on the battery. These are commonly called parasitic loads. If the vehicle is stored for an extended period of time, parasitic loads can deeply discharge the battery. Allowing it to stand in a deeply discharged state for long periods of time can permanently damage the battery.

! Discharged batteries can freeze at temperatures as high as 20 degrees Fahrenheit, causing permanent damage. Never charge a frozen battery.

- Periodically (every 30-45 days) recharge the battery of any vehicle that has been stored for 30 days or more. The negative (ground) cable should be disconnected after each recharging.
- Always turn the ignition off before connecting or disconnecting battery cables. Failure to do so may damage the ECM, PCM, VCM, radio or other electronic components.
- Do not start the engine to move the vehicle from one assembly station to another within the same building. This discharges the battery and can foul the spark plugs. GM recommends moving the vehicle by some other method, such as pushing by hand.
- Never leave the vehicle ignition switch in the “ON” position if the engine is not running.
- Do not play the vehicle’s radio, TV, DVD player or other electrical equipment during the conversion process unless required for proper vehicle processing (e.g., testing the operation of such components).
- Do not leave vehicle hood and doors open during non-work periods (over night, work breaks, shift changes, extended downtimes, etc.) if underhood or interior lights have not been disconnected. All electrical current-drawing devices should also be turned off during these periods.
- Some vehicles are equipped with an interior light override switch located on the instrument panel. Keep this switch in the “OFF” position and switch to the “ON” or “DOOR” position only as needed to energize the interior light circuit for checking purposes. (**Note:** Keeping this switch in the “OFF” position nullifies the need for keeping the vehicle doors closed.)
- All Upfitter-added electrical devices should be installed in the “OFF” position and all Upfitter electrical checks performed during the assembly operation should require that the device be left in the “OFF” position. Upfitters may find it more practical to disconnect the negative battery terminal than to implement the protective practices outlined above. If choosing this method, the battery should remain disconnected throughout the conversion process. It should be reconnected only to check the function of the Upfitter-added electrical system or to move the vehicle between buildings or to a storage lot.

CAUTION Battery cable terminal attaching bolts, that are disconnected by an Upfitter, must be torqued to 17.0 ± 3.0 Nm when reinstalled. Do not over-torque.

CAUTION Always reconnect the positive battery cable first, if both the positive and negative cables have been disconnected. This will reduce the potential for accidentally short-circuiting the battery to ground.

CAUTION Care should be exercised when removing and/or reinstalling battery terminal attaching bolts. Inadvertent grounding of the positive terminal can result in severe arcing that could cause injury to the operator.

(continued on next page)

OEM and Auxiliary Battery Guidelines (cont'd)

Charging Procedures

If it is necessary to jump-start a vehicle or recharge an OEM battery, make sure that all charger/cable connections are clean and tight. Refer to the appropriate GM Service Manual and/or Owner's Manual for jump starting procedures. The proper charging procedure follows:

1. Connect the positive lead from the charging device to the positive terminal of the battery.
2. Attach the negative lead from the charging device to a grounded metal vehicle component, away from the battery.

CAUTION Do not attach the negative lead to the braking system's master cylinder or to any electrical/electronic component housing. Doing so can cause damage to the Anti-Lock Brake System (ABS) module or internal components of the electrical/electronic device.

3. Select the charger setting that will render the highest charge rate for 12-volt batteries. Set adjustable chargers at 16 volts.
4. Fully charge the battery.

CAUTION Batteries should be checked every hour while on charge. Discontinue charging if the battery becomes hot (125°F), gasses violently or spews electrolyte through the vents.

CAUTION To avoid a potential explosion, perform this procedure only in a well-ventilated area, away from any flame- or spark-producing source. Failure to do so may cause serious bodily injury.

CAUTION Always turn the ignition switch to the "OFF" position when connecting or disconnecting the battery charger or jumper cables. Failure to do so can damage the ECM, PCM, VCM, radio or other electronic components.

CAUTION Never charge a frozen battery.

OEM BATTERY RELOCATION GUIDELINES

The following guidelines apply to commercial vehicle conversions. General Motors does not recommend relocating the OEM battery in vans, pickup trucks, or sport-utility vehicles.

The following guidelines apply to commercial vehicle conversions. General Motors does not recommend relocating the OEM battery in vans, pickup trucks, or sport-utility vehicles. If it is necessary to relocate the OEM battery, place and position it so that it can make use of the existing battery cables. If this is not possible and longer cables are required, use wire of a proportionately larger gauge.

If relocating the battery requires attaching the negative ground cable to a frame rail, a cable of equal or greater gauge size must be provided between the frame rail and the vehicle engine block. This is necessary because of the heavy electrical loads imposed by the starting circuit.

To ensure proper electrical system operation, refer to the table in Figure 1 to determine the correct battery cable to use.

Combined Length of Positive and Negative Cables	
Cable Guide	**Maximum Cable Length in Inches (Copper Core)**
4	66
2	107
0	170

Figure 1

(continued on next page)

OEM and Auxiliary Battery Guidelines (cont'd)

Installation

When installing batteries and cables, the body upfitter should observe the following guidelines. Noncompliance may result in vehicle electrical system failure, engine shutdown, loss of backup brake system or the possibility of a thermal event.

- Avoid routing cables in areas where they will contact sharp metal edges, either in their normal positions or during maintenance.
- Do not bend cables in a radius smaller than ten times the cable diameter. Doing so may cause insulation failure.
- Support Upfitter-installed battery cables with clips spaced not more than 250 mm apart. This prevents the cables from moving freely and rubbing against any fixed or movable vehicle component.
- Use rubber-lined (not rubber-dipped) cable retaining clips.
- Cables should not be spliced. Cable modifications can cause vehicle starting problems and the loss of other key electrical systems.
- Clip cables to the battery tray in a manner that prevents cable pull loads from transferring directly to the battery posts. Failure to do so can result in loose terminals, poor starting or battery failure. Added strain to posts can cause battery acid to leak.
- Cable attachments to the battery terminal should not place undue strain on the connection.
  - Cables adjacent to the connections should have no sharp bends.
  - Route cables downward, rather than horizontally, from the terminals to prevent lever action which may loosen connections.
- Do not apply terminal corrosion inhibitors or other coatings to sealed electrical contact areas.
- Torque battery terminals to 17.0 ± 3.0 Nm. Do not over-torque.

Mounting Tray

The battery mounting tray should be made of a substantial material (minimum 1.75 mm thick) or sufficiently reinforced to resist flexing and cracking. General Motors also recommends the following:

- The tray should provide firm, continuous support to the battery to prevent amplifying vibration levels.
- The tray or mountings should have no protrusions or projections that would damage the battery.
- To prevent electrolyte spillage or lead fatigue, avoid cantilevered mountings and mount the tray flatly.
- A rounded lip of adequate height should be provided around the perimeter of the tray to ensure stiffness and retention.

It is important to mount the battery in such a way to ensure it is capable of withstanding a static force applied to any of its four corners.

Hold-Down

The battery hold-down should be able to withstand shock loading and prevent any battery movement relative to the mounting base or holddown. Torque requirements for a hold-down should comply with accepted industry standards. General Motors recommends a bottom hold-down, centrally located at the sides of the battery.

(continued on next page)

OEM and Auxiliary Battery Guidelines (cont'd)

Location

GM recommends locating the battery in a well-ventilated area where temperature buildup does not occur. The location should also provide protection against foreign objects which may damage the battery. The vent port areas on the battery ends should be free of obstructions, allowing gases generated during charging to freely dissipate into the atmosphere.

Vibration

The battery mounting should not allow battery vibration levels to exceed accepted industry standards.

Accessibility

The battery hold-down should be conveniently located, allowing space for tools and hands without the possibility of personal injury. There should be sufficient clearance at both the insulated and grounded terminals so that wrenches can be used without accidental grounding or shorting of the battery. Terminal polarity markings and warning labels should be visible. The battery ground connection must be readily accessible for disconnection as required for vehicle electrical service.

Tilt Angles

Commercial vehicle converters should install the battery so that it is horizontally level (at GVW) under normal vehicle operations. It should not be necessary to tip or tilt the battery more than 40 degrees to install or remove it from the vehicle. Tilting the battery in excess of 40 degrees may cause acid spillage. For short-duration vehicle shipment, the battery should not be tilted more than 19 degrees from the horizontal.

Temperature

The temperature of the electrolyte should not be allowed to exceed 60°C on a continuous basis. The electrolyte can tolerate infrequent peak temperatures of up to 75°C in soak situations only. Shielding may be required to protect the battery from excessive heat sources.

AUXILIARY BATTERY GUIDELINES

Proper location, installation and connection of an auxiliary battery is important to the overall performance of the vehicle's electrical system.

General Information

! Depending on its location in the vehicle, adding an auxiliary battery may affect barrier crash performance. Related testing and certification may be required and is the responsibility of the Upfitter.

Location

! Whenever possible, Upfitters should install auxiliary batteries in locations that eliminate the need for venting and provide for easy service accessibility. Batteries should be located outside the passenger compartment, either in the engine compartment or under the floor pan. GM also recommends installing auxiliary batteries as close as possible to the OEM battery, to minimize voltage drop and cable gauge requirements.

Auxiliary batteries should be located in an area that does not expose the electrolyte to temperatures in excess of 60°C.

(continued on next page)

OEM and Auxiliary Battery Guidelines (cont'd)

Location *(continued)*

If space limitations make it necessary to install the auxiliary battery within the interior of the vehicle (i.e., the luggage compartment or the passenger compartment), the luggage compartment is the recommended alternative. In such cases, to prevent injury to vehicle occupants, strict adherence to the following guidelines is necessary:

- Make sure to house the auxiliary battery in a battery box that is sealed from the vehicle's interior environment and vented to the vehicle's exterior. Battery boxes should also provide a means of draining to the vehicle's exterior any fluids that may accumulate in the battery tray.
- Do not install batteries inside compartments that also contain spark- or flame-producing equipment, such as electric motors, switches or relays as charging operations can generate the formation of explosive hydrogen gas.
- Locate auxiliary batteries in an area of the vehicle that allows easy access for replacement and charging of the battery. See "Serviceability" in the Electrical System Design Guidelines section.

Venting

As mentioned earlier, all batteries located in the passenger or luggage compartments should be vented to the outside of the vehicle. Maintenance-free batteries should also comply with this venting guideline as they contain small vent holes through which explosive hydrogen gas can escape during charging.

Mounting and Fastening

Regardless of location, all auxiliary batteries should be securely mounted and fastened to a battery tray that is securely fixed to the vehicle. This will restrict the battery's movement during normal vehicle operations and especially during impact or rollover accidents.

Connecting and Grounding

Use only General Motors OEM-approved connecting devices whenever making connections to the auxiliary battery.

Always connect auxiliary batteries in parallel with the OEM battery.

Under the following conditions, the auxiliary battery should be connected to include within its circuit a device (such as an isolator, relay or switch) that will electrically separate it from the OEM battery:

- When the auxiliary battery is used strictly as a back-up source of electrical power for engine cranking.
- When the auxiliary battery is used exclusively to power electrical devices added by the Upfitter.

! To minimize electrical resistance and maintain full output voltage at electrical devices, auxiliary batteries should be securely grounded to the vehicle engine block.

Cable Sizing

When installing an auxiliary battery, it is important to specify the correct gauge size of battery cables. Make sure that:

- The gauge size is appropriate for the cable length to minimize voltage drop.
- The cable gauge size is capable of supporting the maximum total current requirement that will be imposed upon the auxiliary battery.

! If the auxiliary battery is wired in parallel with the OEM battery, its cable gauge sizes should be equal to, or greater than, the gauge sizes of the OEM battery cables.

(continued on next page)

OEM and Auxiliary Battery Guidelines (cont'd)

The table in Figure 2 provides information that can help to select the correct cable gauge size.

BATTERY CABLE SAE J1127 CONVERSION/CONSTRUCTION TABLE			
Metric Size	English Gauge	Metric Construction*	Metric Area
13mm^2	6 ga.	37/.66	12.658mm^2
19	4	61/.63	19.015
32	2	127/.57	32.407
32	2	7x19/.57	33.938
40	1	127/.63	39.589
40	1	7x19/.63	41.459
50	0	127/.71	50.282
50	0	7x19/.71	52.657
62	2/0	127/.79	62.251
62	2/0	7x19/.79	65.192
81	3/0	7x37/.63	80.737
103	4/0	7x37/.71	102.543
* No. of Strands/Strand Diameter in mm			

Figure 2

BATTERY DISCHARGE LIMITER GUIDELINES

The design and installation of battery discharge limiting devices, that are installed in GM vehicles by Upfitters, should comply with the following recommendations:

- Be designed to conform to all applicable recommendations outlined in the "Electrical Component Guidelines" sub-section of the Electrical System Design Guidelines section of this manual.
- Do not require that battery cable(s) be cut.
- Be designed to accept unmodified OEM battery cable terminals.
- Incorporate OEM-type battery terminals for the attachment to the OEM battery.
- Attach to the battery with GM-approved bolts.
- Be designed so that if attached directly to the battery, the limiter electrical interface connection be compatible with the battery terminal (post) mating surface (i.e., will make full surface terminal-to-terminal contact). This will allow a solid and tight battery interface connection to be made which will ensure that the vehicle's electrical system is not degraded. The bolt used to attach the limiter to the battery post must be the correct length and should conform to OEM configuration, material and terminal interface requirements. Care must be exercised not to over-torque this bolt (see "OEM Battery Guidelines," General Information — this manual section).

This section contains guidelines and recommendations to assist the Upfitter when interfacing electrical connections to the host OEM wiring system. Improper electrical connections can result in failures of both the Upfitter and OEM electrical systems.

To the maximum degree possible, Upfitter electrical systems should be functionally separated from the OEM electrical system. This will help to prevent potential failures and/or damage to the OEM electrical system in the event there is an Upfitter electrical system failure.

Electrical System Interfacing – New Circuit Guidelines

This section contains guidelines and recommendations to assist the Upfitter when interfacing electrical connections to the host OEM wiring system. Improper electrical connections can result in failures of both the Upfitter and OEM electrical systems.

! To the maximum degree possible, Upfitter electrical systems should be functionally separated from the OEM electrical system. This will help to prevent potential failures and/or damage to the OEM electrical system in the event there is an Upfitter electrical system failure.

NEW CIRCUIT GUIDELINES

To prevent the OEM circuit protection device and/ or the OEM electrical cable from becoming overloaded, GM generally recommends against:

- Adding new circuits to existing OEM fuses and circuit breakers, except as noted in this section of the manual, Upfitter Integration group bulletins and/or New Features booklets and specific model year GM Body Builders Manuals.
- Splicing into OEM circuits to obtain power pick-up feeds for new circuits, except under the conditions outlined in this section of the manual, in Upfitter Integration group bulletins and/or New Features booklets and specific model year GM Body Builders Manuals.

Interfacing to the OEM Electrical System

GM recommends that the Upfitter gain access to the OEM electrical system by way of the provided connectors, electrical convenience centers and/or battery studs and as explained in the electrical section of the specific GM Body Builders Manuals, Upfitter Integration group bulletins and/or New Features booklets.

When interfacing with the OEM electrical system to add a new circuit, always observe the following:

- Never cut into an OEM wire if an alternate method, such as a connector, electrical convenience center, battery stud, etc., is available to gain access to the OEM electrical circuit.
- Always incorporate a circuit protection device into all new Upfitter-added circuits that are not specifically protected by an OEM overcurrent protection device. (See “Circuit Protection Guidelines” under the Electrical System Design Guidelines section.)
- Always conduct an electrical-load study for each circuit and keep the resulting data on file to assure that the added electrical load, combined with any existing OEM loads, will not exceed 80% of the rating for the circuit protection device being used.

! Never replace OEM fuses and/or circuit breakers with fuses and circuit breakers of a higher rating in an attempt to meet the 80% criteria requirement.

- Always use the correct polarized (indexed) connector to interface with OEM connectors and/or convenience centers.
- Ignition accessory and battery feeds, other than those specifically provided for upfitter usage, should only be used to provide a signal source to a relay coil that draws a maximum of one (1) ampere of current. Do not use them to supply direct power to Upfitter-added ignition-controlled or battery-fed electrical devices.
- The adding of Upfitter electrical loads to OEM dimmable lighting circuits is not recommended due to the potential to electrically overload the OEM rheostat.
- Always use the appropriate gauge of wire for the added circuit. Select a wire gauge that is capable of supporting the maximum load to which the added circuit will be exposed. (See “Cable (Wire) Selection Guidelines” under the Electrical System Design Guidelines section.)

(continued on next page)

Electrical System Interfacing – Extending OEM Circuit Guidelines

- If splicing becomes the only alternative for interfacing to the OEM electrical system, the Upfitter should always splice into the OEM wiring in accordance with the splicing guidelines outlined in this manual. Do not use Quicksplice, Scotchlock, wire nuts or similar splicing devices in GM motor vehicles.

GM strongly recommends against interfacing with the OEM electrical system to add an upfitter-installed vehicle remote start system. Doing so creates the potential for detrimentally affecting the vehicle electronics and the On Board Diagnostic (OBD) systems.

Body Builder Junction Block/Connector

When provided by the OEM, the body builder junction block/connector is powered by direct battery- and ignition-controlled circuits. It should be used to power all Upfitter-added circuits that do not require the interfacing to an OEM control device. Circuit protection should be added within 18 inches of the wire's length from the OEM junction block/connector.

EXTENDING OEM CIRCUIT GUIDELINES

If a connector is provided for Upfitter interfacing, use the mating OEM connector to extend the OEM circuit. Examples of OEM circuits with an interfacing connector are interior lighting and rear speaker circuits.

Splicing is less reliable than other connecting methods and is generally not recommended except in cases where the OEM circuit does not have an interfacing connector. In such cases, splicing is acceptable, providing it complies with the recommendations outlined in the "Splicing Guidelines" subhead in the Electrical System Design Guidelines section of this manual. Examples of circuits which do not always provide interfacing connectors are power door lock, front fog lamp and exterior running lamp circuits.

! Caution must be exercised whenever an existing OEM circuit is utilized as the power source for an Upfitter-added circuit. The Upfitter should always incorporate a relay into the system whenever the added load demands a higher current than that which the host OEM wiring or circuit protection device can provide. The OEM wiring can act as a signal source for the relay coil. The relay then channels power from the vehicle battery power-pickup point to the added circuit. The power supply wire extending from the battery power-pickup point should be of the proper size and protected by an appropriate fuse or circuit breaker. (See "Cable (Wire) Selection Guidelines" and "Circuit Protection Guidelines" headings of this Manual.)

! When adding electrical loads to existing OEM circuits, Upfitters should conduct an electrical load study, document its data and keep it on file. Doing so will assure that the OEM wire gauge and circuit protection device is adequate to support the added load. The total circuit current draw (combined Upfitter and OEM electrical loads), should not exceed 80% of the OEM circuit current protection device rating.

! Never replace OEM fuses and/or circuit breakers with fuses and circuit breakers of a higher rating in an attempt to meet the 80% criteria requirement.

Always use the appropriate gauge of wire for the added circuit. Select a wire gauge that is capable of supporting the maximum load to which the added circuit will be exposed. (See "Cable (Wire) Selection Guidelines" under the Electrical System Design Guidelines section.)

When extending OEM circuits, the OEM wire color coding should be maintained throughout the entire circuit run.

Electrical System – Design Guidelines

CABLE (WIRE) SELECTION GUIDELINES

Selecting the correct cable (wire) gauge ensures the proper voltage supply to an electrical device and prevents the cable from overheating.

Cable Ampacity

“Ampacity” is the maximum current (in amperes) that a conductor can continuously carry without exceeding the insulation’s continuous operating temperature. In short, it is the cable’s ampere capacity.

All electrical conductors have some resistance to the flow of electrical current. The resistance of a cable increases as the cross-sectional area or gauge decreases. Conversely, cables with a larger cross section have less resistance and thus, a higher ampacity.

The current in a cable can cause the cable to heat up due to the conductor’s (copper) resistance. When current increases to a level high enough to raise the internal conductor temperature to a point that exceeds the maximum temperature rating of the cable, the insulation begins to degrade. If the circuit does not include an electrical device to limit the current so that it does not exceed the ampacity of the cable, the cable must be sized so that it is protected by the circuit protection element.

Design Recommendations

As a general rule, all Upfitter new and extended circuits should specify wire gauges that have a current-carrying capacity rating of 135% of the circuit’s current protection device. Extended circuits should utilize cable of a gauge equal to or greater than the gauge of the host OEM wiring.

Cable gauge reductions are permissible on power feed circuits after the point at which the Upfitter circuit-protection device is added.

Upfitter extensions of OEM wiring should be color coded with the same wire color as the OEM wire being extended. Upfitter-added circuits should also maintain color continuity throughout the entire run of the circuit (from power-pickup point to the device being wired). The marking of the cable’s circuit function is also recommended.

Cable (Wire) Types

All wiring and insulation should conform to the requirements of SAE J1128 (low-tension primary cable).

- Passenger compartment
  - For normal passenger compartment wiring applications, use GPT (general purpose, thermoplastic insulated) type wiring or its equivalent. This type of wire is PVC insulated and has a continuous operating temperature rating of+80°C (176°F).
- Engine compartment
  - The engine compartment or any other area where temperatures can exceed +80°C (176°F) requires GXL (general purpose, cross-linked polyethylene insulated) type wiring or its equivalent. This type of wire has a continuous operating temperature rating of +135°C (275°F).

Cable (Wire) Gauge Selection

To choose the appropriate cable gauge when adding new circuits or extending existing circuits, follow the steps below. This selection process should be applied for all power, signal and ground circuit requirements.

1. Determine the maximum current (load) the cable is expected to carry.
2. Determine the length of cable needed to extend from the power source to the load. (**Note:** If the device uses a ground wire, also include the length of the ground wire in this calculation.)
3. Refer to Table 1 on page number 16 to determine the initial (preliminary) gauge of cable for the wire length and current requirements established in steps 1 and 2 above. (**Note:** The length number used must match or exceed the total wire length requirement.)

(continued on next page)

Electrical System – Design Guidelines (cont'd)

TABLE 1
CONDUCTOR SIZING TABLE – MAXIMUM 10% VOLTAGE DROP @ 12VDC

GAUGE SIZES		CURRENT DRAW IN AMPERES																			
		1	2	3	4	5	6	7	8	9	10	15	20	25	30	40	50	60	70	80	100
Metric	English	MAXIMUM LENGTH OF SAE J1128 CONDUCTOR (in feet) FROM POWER SOURCE TO DEVICE (see ground circuit note in length determining process)																			
.5mm^2	20	107	53	36	27	21	18	15	13	12	11	7									
.8mm^2	18	172	86	57	43	34	29	25	21	19	17	11	9								
1.0mm^2	16	261	130	87	65	52	43	37	33	29	26	17	13	10							
2.0mm^2	14	413	207	138	103	83	69	59	52	46	41	28	21	17	14						
3.0mm^2	12	651	326	217	163	130	109	91	81	72	65	43	33	26	22	16					
5.0mm^2	10	1043	521	348	261	208	174	149	130	116	104	70	52	42	35	26	21	17			
8.0mm^2	8	1653	827	551	413	331	276	236	207	184	165	110	83	66	55	41	33	28	24	21	
13.0mm^2	6	2892	1446	954	723	578	482	413	362	321	289	193	145	116	96	72	58	48	41	36	29
19.0mm^2	4	4170	2085	1390	1043	834	695	596	521	463	417	278	209	167	139	104	83	70	60	52	42

4. Determine the maximum ambient temperature to which this wire will be subjected, under all vehicle operating conditions.
5. Determine the type of cable required, GPT +80°C or GXL +135°C. This decision should be based on the maximum ambient temperature determined in step 4.
6. Using the maximum ambient temperature figure determined in step 4, locate the temperature figure that matches or exceeds this temperature in Table 2 on page 16 for GPT wire or Table 3 on page D-3 for GXL wire and compare the ampacity rating for that temperature and the preliminary wire gauge you selected from Table 1. If this ampacity rating is equal to or greater than the ampacity rating from Table 1, use the original (preliminary) gauge you selected from Table 1. If the ampacity is less than the ampacity of the gauge of wire selected from Table 1, follow the temperature column down until you reach an ampacity that meets or exceeds your circuit's maximum current-carrying requirement. Follow that ampacity number horizontally to the left, in the table you are using, to determine the new correct cable gauge to be used.

The cable conversion chart in Figure 3 is provided for reader convenience in converting English wire gauges to metric equivalents.

CABLE CONVERSION CHART – METRIC vs. ENGLISH
LOW-TENSION PRIMARY CABLE – SAE J1128

Metric	English	Metric	English
.5mm^2	20 Ga.	5.0mm^2	10 Ga.
.8mm^2	18 Ga.	8.0mm^2	8 Ga.
1.0mm^2	16 Ga.	13.0mm^2	6 Ga.
2.0mm^2	14 Ga.	19.0mm^2	4 Ga.
3.0mm^2	12 Ga.		

(continued on next page)

Electrical System – Design Guidelines (cont'd)

TABLE 2

GPT STANDARD WALL CABLE – 80°C MAXIMUM RATING CABLE – AMPACITY vs. AMBIENT TEMPERATURE

GAUGE SIZES		AMBIENT TEMPERATURE											
		25°C	30°C	35°C	40°C	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C
Metric	English	77°F	86°F	95°F	104°F	113°F	122°F	131°F	140°F	149°F	158°F	167°F	176°F
		MAXIMUM AMPACITY – GPT (PCV) STANDARD WALL CABLE											
.5mm^2	20	16	15	14	13	13	12	11	9	8	7	5	0
.8mm^2	18	20	19	18	17	16	15	13	12	10	8	6	0
1.0mm^2	16	25	24	23	21	20	18	17	15	13	10	7	0
2.0mm^2	14	34	32	30	29	27	25	22	20	17	14	9	0
3.0mm^2	12	45	43	40	38	35	33	30	26	23	18	13	0
5.0mm^2	10	60	57	54	51	48	44	40	35	30	25	17	0
8.0mm^2	8	80	76	72	68	64	59	53	47	41	33	23	0
13.0mm^2	6	112	107	101	95	89	82	75	67	57	46	32	0
19.0mm^2	4	147	140	132	125	116	107	98	87	75	60	42	0

TABLE 3

GXL STANDARD WALL CABLE – 135°C MAXIMUM RATING – CABLE AMPACITY vs. AMBIENT TEMPERATURE

GAUGE SIZES		AMBIENT TEMPERATURE																
		25°C	50°C	65°C	70°C	75°C	80°C	85°C	90°C	95°C	100°C	105°C	110°C	115°C	120°C	125°C	130°C	135°C
Metric	English	77°F	122°F	149°F	158°F	167°F	176°F	185°F	194°F	203°F	212°F	221°F	230°F	239°F	248°F	257°F	266°F	275°F
		MAXIMUM AMPACITY – GXL STANDARD WALL CABLE																
0.50mm^2	20	22	20	18	17	16	16	15	14	13	13	12	11	9	8	7	5	0
0.80mm^2	18	28	25	23	22	21	20	19	18	17	16	15	13	12	10	8	6	0
1.00mm^2	16	35	31	28	27	26	25	24	23	21	20	18	17	15	13	10	7	0
2.0mm^2	14	48	42	38	37	35	34	32	30	29	27	25	22	29	17	14	10	0
3.0mm^2	12	63	56	51	49	47	45	43	41	38	36	33	30	27	23	19	13	0
5.0mm^2	10	85	75	68	66	63	61	58	55	52	48	45	41	36	31	25	17	0
8.0mm^2	8	114	101	92	88	85	81	77	73	69	65	60	54	49	42	34	24	0

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Electrical System – Design Guidelines (cont'd)

Typical Calculation Example

You have calculated that the maximum load to which your circuit will be subjected is 20 amps and your total circuit wire length is calculated to be 20 feet. Read down the 20 amp column in Table 1 until you find a length of wire that matches or exceeds your 20-foot requirement. In this case it is 21 feet. Read across to the left of this number to determine the wire gauge size to be used. You will find it to be 14 gauge (2.0 mm^2 metric). This is your initial (preliminary) gauge requirement.

You have determined that the maximum ambient temperature this wire will be exposed to is 65°C (149°F) and you opt to use GPT cable. Read down under the 65°C column and across from the 14 gauge listing in Table 2 and you find that 17 amps is the maximum ampacity for a 14 gauge wire that will be exposed to a temperature of 65°C. As 17 amps is less than your 20 amp requirement, continue reading down the 65°C column until you reach an ampacity that matches or exceeds your 20 amp requirement. In this case it is 23 amps. Read across to the left of this number to determine your new wire gauge requirement which you will find to be 12 gauge (3.0 mm^2 metric). This is your new wire gauge requirement.

WIRE HARNESS ASSEMBLY GUIDELINES

Design Recommendations

To help ensure a quality electrical build, GM recommends that Upfitters group individual wires together and bundle them into a harness assembly for their protection. This harness assembly should be pre-assembled outside the vehicle and should be built in accordance with the recommendations outlined in the “Cable (Wire) Selection Guidelines,” “Connecting Guidelines” and “Wire Harness Covering Guidelines” in this section. GM also recommends against the use of common, interchangeable, wire harness assemblies that are not specifically designed and tailored to fit the vehicle into which they will be installed. Universal wiring harness assemblies, that are designed to fit many vehicles and usually incorporate circuits that are not always required or used, tend to create conditions that are usually detrimental to a quality electrical build (e.g., open, loose connectors that are susceptible to short circuiting and rattling; unprotected excess wire that gets stored in areas of the vehicle where it shouldn’t be and becomes susceptible to damage by hostile vehicle surfaces and/or components; wire takeout points that do not always get located in the vehicle where they should be). The overall result is a wiring installation process that becomes very difficult to implement on a repetitive basis.

CONNECTING GUIDELINES

Design Recommendations

In order to achieve a high degree of reliability, it is essential to use a quality connection system whenever an Upfitter electrical system is installed in a GM vehicle. General Motors strongly recommends using OEM connection system components when adding a wiring system to a GM vehicle.

For greater reliability, it is recommended that Upfitters use single-cavity male/female connectors, rather than butt-splice sleeves, for single wire connection points. (**Note:** If using butt-splice sleeves, make sure that they comply with the recommendations outlined in the “Splicing Guidelines” subhead in this section of this manual.)

(continued on next page)

Electrical System – Design Guidelines (cont'd)

General Motors also recommends the following practices:

- The use of multiple-cavity locking connectors that incorporate an indexing feature when more than one set of wires must be connected at a common location. Using this type of connector (instead of individual single connectors or butt-splice sleeves) reduces the number of potential disconnect points.
- Some Upfitter-installed components (i.e., radios, televisions, A/C units, lamps, switches, relays, etc.) require the connecting of multiple circuits. To reduce the number of potential disconnect points, select components that include one of the following design features:
  — Capable of accepting a panel-mount, direct plug-in multiple connector.
  — Incorporates a wiring pigtail that terminates in a multiple cavity connector.
- Make sure that all Upfitter electrical connections, except ground connections, are insulated with a connector body or sleeve. This protects against accidental electrical short-circuiting, both during and after the wiring installation process.
- Use electrical terminals with incorporated grip wings to relieve wire strain and improve wire retention. (See instructions for "Assembling Connection Systems" in this section.)
- Machine crimp all Upfitter-applied electrical terminals, using an appropriate crimp die. If it is necessary to crimp terminals by hand, they should also be soldered to the wire to ensure a reliable electrical connection. (See "Terminal Removal" and "Soldering Guidelines" in this section.)
- Use only sealed, moisture-proof connectors for making connections outside the passenger compartment. Sealed connectors are not necessary on the vehicle's interior, unless there is a chance that they will be exposed to high-moisture conditions. (See Sealed and Unsealed definitions in this section.)
- Use ground terminals made of brass or a copper alloy. They should also be tin plated if they will be exposed to a corrosive environment. To eliminate potential corrosion problems, do not use steel terminals, even if they are tin plated. GM recommends using OEM-type ground terminals or their equivalent for all grounding requirements.
- Use ring terminals with incorporated, internal locking teeth at all grounding screw locations. This ensures a positive ground connection. (See Figure 4.)
- For a reliable connection, select ring terminals that are compatible with the size of the stud, screw or bolt that will be used to attach them to the vehicle.

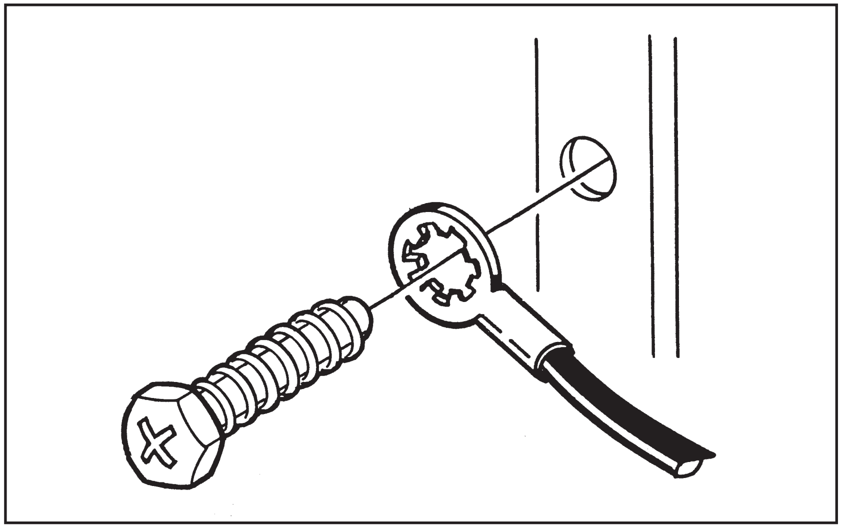

Figure 4

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Electrical System – Design Guidelines (cont'd)

CONNECTOR TYPES

Replace with GM Original Equipment (OE) connection systems, utilizing both sealed and unsealed connectors.

Unsealed Connectors

Unsealed connections (Figure 5) are designed for use in the interior of the vehicle. If used elsewhere, environmental factors, such as moisture and grit, can cause corrosion to build up, leading to a poor connection. Corroded terminals create high resistance in the connection, which in turn can cause intermittent or open circuits.

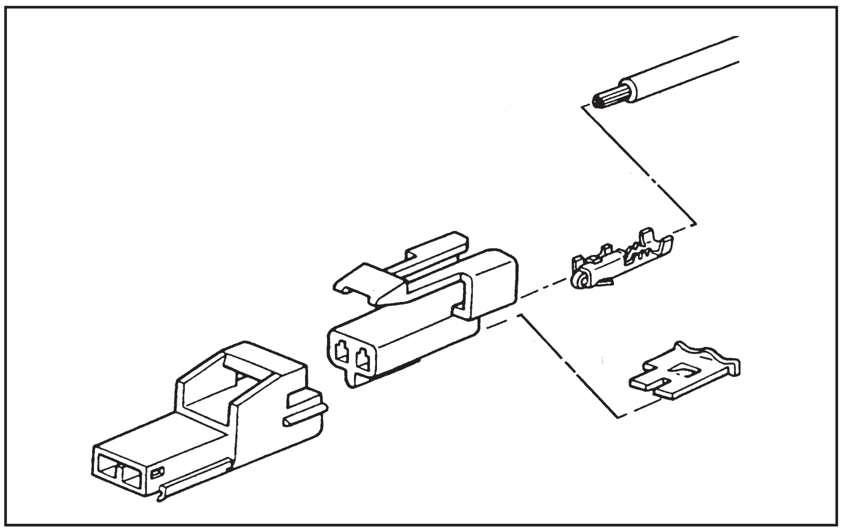


Figure 5

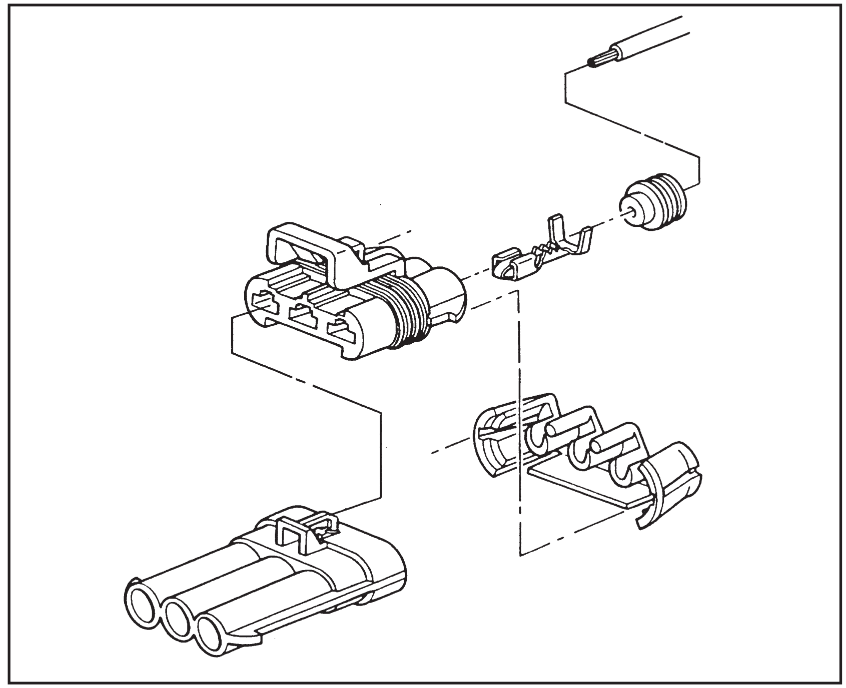


Figure 6

Sealed Connectors

Sealed connection systems (Figure 6) are designed with environmental seals to keep out moisture and grit. This makes them ideal for use outside the vehicle's passenger compartment. Built into this type of connector are two types of seals:

- A connector seal which provides an environmental seal between the mating connectors.
- A cable seal which seals the area where each wire enters the connector.

General Motors recommends using sealed connection systems in areas exposed to the outside environment.

(continued on next page)

Electrical System – Design Guidelines (cont'd)

HOW TO CHOOSE A CONNECTION SYSTEM

Follow the steps below to determine the best connection system for a particular application.

1. Determine the environment to which the connection will be exposed.
   — For connections **inside** the vehicle, use an unsealed connector.
   — For connections **outside** the vehicle, use a sealed connector.
2. Use the charts in Figures 7 and 8 to determine the best available connection type.
3. Determine the number of circuits needed in the connection.
4. Use the connector tables in Appendix II of this manual to determine the appropriate connection system and corresponding part numbers.

Metri-Pack Terminals

Metri-Pack terminals vary in several ways. Understanding these variations is essential in choosing the proper connection system and terminal. Typically, terminals can vary according to:

- Size (blade width or series)
- Type of material or plating
- Size of core grip wings
- Size and type of insulation grip wings

Examples of terminals from each Metri-Pack connection system series are shown in Figure 8. The series indicates terminal size, specifically blade width, of the male terminal.

Terminal size is one way of identifying the current-carrying capabilities of a connection system:

- The higher the series number, the wider the terminal blade.
- The wider the blade, the higher the current capacity.

The connection system parts list in Appendix II categorizes connection systems according to terminal size.

Terminal Characteristics

Terminals are made of different materials and can be either plated or unplated. Plated terminals are more corrosion resistant and, therefore, are recommended for connections in a corrosive environment.

The terminal's core grip wings are designed to accommodate different gauge size wires. Small core grip wings are suitable for small gauge wire, large core grip wings for larger gauge wire. Because of this, it is essential to know the wire size to select the correct terminal.

Current Requirement	Metri-Pack Connector Type
Up to 14 amps	150, 280, 480 and 630 Series
Up to 30 amps	280, 480 and 630 Series
Up to 42 amps	480 and 630 Series
Up to 46 amps	630 Series

Figure 7*

(continued on next page)

Electrical System – Design Guidelines (cont'd)

METRI-PACK TERMINALS

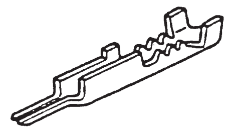
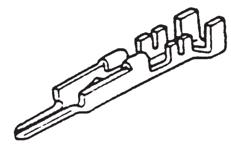
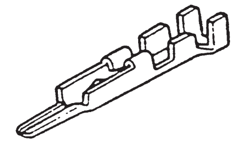
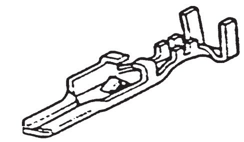
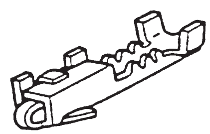
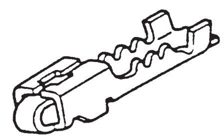
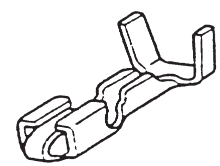
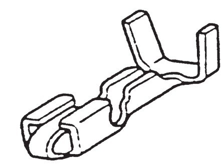
SERIES	150	280	480	630
MALE				
FEMALE				
MAXIMUM CURRENT RATING	14 AMPS	30 AMPS	42 AMPS	46 AMPS

Figure 8*

***Note for Figures 7 and 8:** These values may vary depending on the environment in which the terminals are used (e.g., engine compartment, cab, chassis, etc.) due to temperature effects and other considerations. It is recommended that the upfitter test the terminal in the application in which it is intended to be used to ensure that the current capacity is adequate.*

The current draw of each circuit in a connector system must first be known to enable the correct terminal series to be selected. GM recommends the use of the Metri-pack 150 series for all circuits that draw 14 amperes or less of current. Insulation grip wings are designed to be crimped over the wire insulation in an unsealed connection system, and over the cable seal in a sealed connection system. Terminals meant for use in a sealed system are not interchangeable with those intended for an unsealed system.

Insulation grip wings for sealed systems are generally larger than their unsealed system counterparts. The more rounded shape of the larger grip wings allows them to work well with the round cable seal used in a sealed system.

! Due to the many factors involved in the selection of terminals and cable seals, terminal and cable seal part numbers are not included in Connector System Parts List (Appendix II). For reader convenience in determining the correct terminal usage, a millimeter-to-inches conversion table for cable outside diameter follows (Figure 9).

(continued on next page)

Electrical System – Design Guidelines (cont'd)

CONVERSION TABLE FOR CABLE O.D. – MILLIMETER TO INCHES	
CABLE O.D. (mm)	CABLE O.D. (in.)
1.29 - 1.70	0.051 - 0.067
1.60 - 2.15	0.063 - 0.085
1.65 - 2.15	0.065 - 0.085
1.84 - 2.25	0.072 - 0.089
1.90 - 2.64	0.075 - 0.104
2.01 - 2.85	0.079 - 0.112
2.03 - 2.42	0.080 - 0.095
2.03 - 2.42	0.080 - 0.095
2.03 - 2.85	0.080 - 0.112
2.81 - 3.49	0.111 - 0.137
2.81 - 3.75	0.111 - 0.148
2.89 - 3.65	0.114 - 0.144
3.45 - 4.30	0.136 - 0.169
3.61 - 4.50	0.142 - 0.177
3.72 - 4.48	0.147 - 0.176
4.40 - 5.15	0.173 - 0.023

Figure 9

ASSEMBLING CONNECTION SYSTEMS

To assure a quality crimp, General Motors recommends machine crimping, using an appropriate crimp die. If it is necessary to crimp terminals by hand, follow the procedures outlined in the section at right.

Terminating a Wire (Hand Crimped)

Terminating a wire requires the following tools:

- Wire cutters
- Wire strippers
- Terminal crimp tool (ratcheting-type preferred)
- Soldering iron or Ultratorch

General Motors recommends the following procedure for terminating a hand-crimped wire:

! Sealed connection systems require specific or different assembly steps as noted in the procedure.

1. For **sealed connection systems only**: Slide the appropriate cable seal onto the wire end to be terminated as shown in Figure 10.

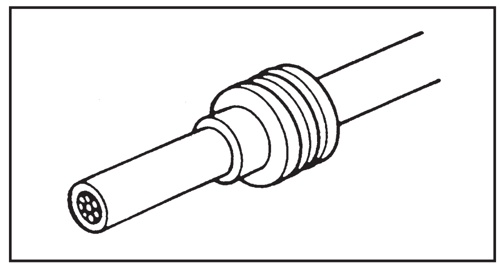


Figure 10

2. Using wire strippers, strip about 3/8" of insulation off of the wire (Figure 11). Be careful not to cut the wire strands.

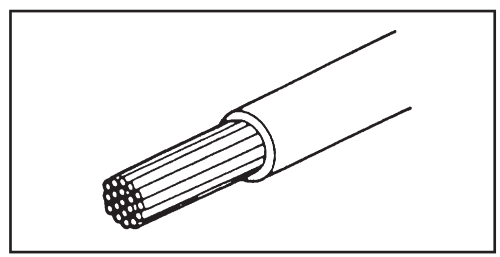


Figure 11

(continued on next page)

Electrical System – Design Guidelines (cont'd)

3. Inspect wire strands. If they have been cut, use wire cutters to cut off stripped portion of wire and strip again.
4. Place wire in terminal core and insulation grip wings. There should be enough core exposed so that it extends just beyond the end of the core grip wings on both sides, with the insulation lying between the insulation wings (see Figure 12).

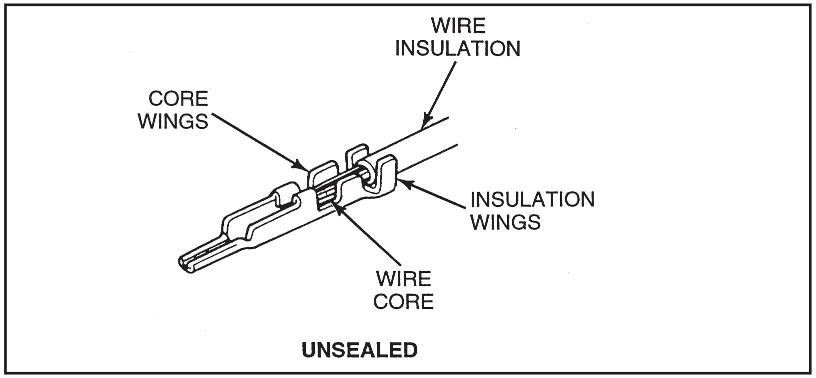


Figure 12

If using a sealed system, the cable seal should rest within the terminal insulation wings as shown in Figure 13. If the core extends too far past the end of the core grip wings, it can interfere with the mating of the terminal.

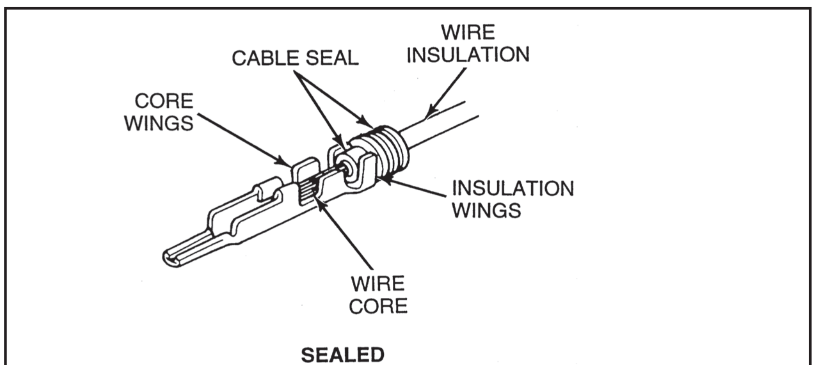


Figure 13

5. Using the appropriate crimping tool, crimp core wings (Figure 14). Use good judgment when applying force. Adhering to the following requirements will help to achieve a good core crimp:
   - Do not bend or crack the terminal.
   - Do not cut the wire strands with the core wings.
   - Make sure that all wire strands are contained inside the core wings.
   - Cable must not fall out of the core wings once they have been crimped.

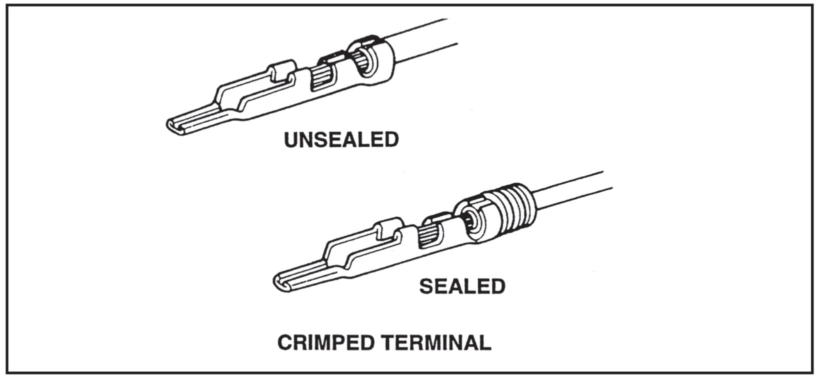


Figure 14

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Electrical System – Design Guidelines (cont'd)

6. Crimp insulation wings using the same procedure as outlined in Step 5. Note that the crimp size is larger for sealed terminal insulation wings than for unsealed. The following will aid in achieving a good insulation crimp:
   - Do not cut into the wire insulation.
   - Do not bend or crack the terminal.
   - Terminal must contact insulation on both top and bottom of crimp area.
   - Do not cut into the cable seal (sealed connection systems only).
7. Solder all hand-crimped terminals. Proper soldering techniques are outlined in “Soldering Guidelines” in this section.

CAUTION Be careful not to use too much solder as wicking can occur. Avoid getting solder on the terminal’s mating interface.

SOLDERING GUIDELINES

Production crimps generally do not require soldering because the crimp is made with precision tooling. Hand-crimping cannot meet the same quality standards. Therefore, soldering is recommended to produce reliable connections in hand-crimped terminals.

Soldering a crimp is important for two reasons:

- It provides a mechanical bond between the terminal and the wire. This helps to prevent wires from pulling loose and causing an open circuit.
- It reduces the possibility of corrosion-related problems. As the core becomes more corroded, the wire develops a higher resistance to current flow. This may cause electrical components to function improperly.

Soldering Procedures

Soldering a terminal requires a soldering iron. The recommended procedure is:

1. Allow soldering tool to preheat for at least one minute. Preheating promotes good, even solder flow.

CAUTION Do not use a soldering gun to solder terminals. Even at low settings, soldering gun temperatures are too high for this application.

2. Heat the terminal core wings and wire core. Avoid heating too close to the wire insulation. Burned or melted insulation can lead to short circuits, open circuits, or corrosion within the wire, resulting in high resistance.
3. Apply solder to core wings as shown in Figure 15. Use just enough solder to obtain even solder flow through the core wings.

CAUTION Use only rosin core/rosin flux solder for soldering terminals. Other flux materials can cause corrosion.

CAUTION Avoid using too much solder which can result in “wicking.” Wicking results when excessive solder is applied to the terminal and it begins to travel up the wire core, like candle wax up a wick. This can cause the wire to become stiff or brittle and produce a flex point. Eventually, this can lead to a broken wire and an open circuit.

CAUTION Do not get solder on terminal mating surfaces.

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Electrical System – Design Guidelines (cont'd)

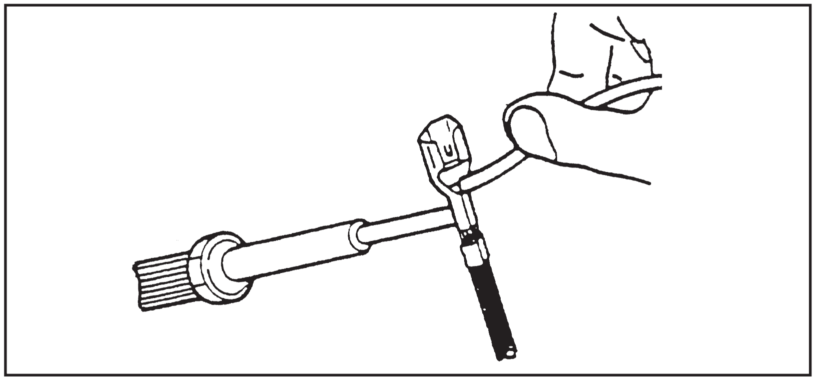

Figure 15

4. Check circuit for electrical continuity.

SEATING TERMINALS

No special tools are required for this procedure.

1. Insert the terminal into the connector cavity from the back (non-mating side) of the connector (Figure 16). Push until the terminal "clicks" into the connector cavity.

CAUTION Never use force to insert a terminal.

2. Pull gently on the wire to ensure that the terminal is seated properly and will not pull out from the back of the connector.

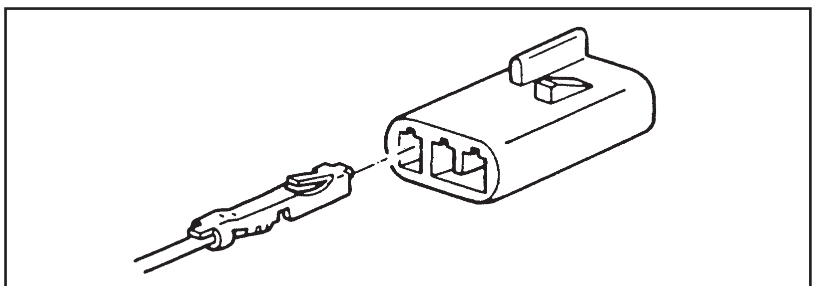

Figure 16

ADDING SECONDARY OR TPA LOCKS

Secondary and terminal position assurance (TPA) locks vary in size and shape, depending on the type of connector being used. Some connectors do not have secondary or TPA locks. Follow the procedures in this section to add secondary locks.
These procedures require no special tools.

Unsealed Connector — TPA Lock

Once all terminals have been seated in the connector, the TPA lock can be installed. Push the TPA lock into the back of the connector until it locks into place (Figure 17).

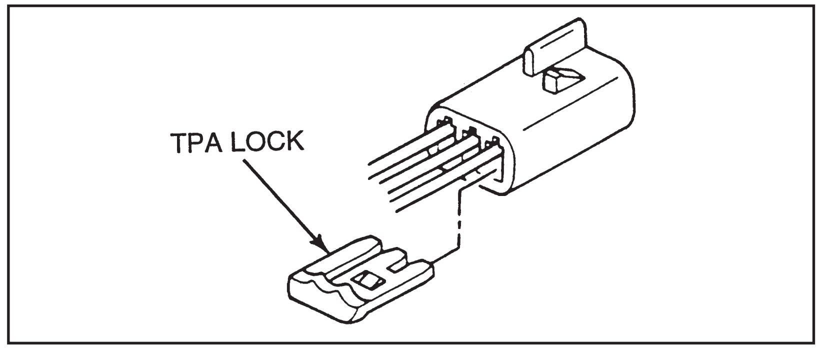

Figure 17

Sealed Connector — Secondary Lock

Once all terminals have been seated in the connector, the secondary lock can be installed. Push the secondary lock over the back of the connector (Figure 18) until it locks onto the connector.

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Electrical System – Design Guidelines (cont'd)

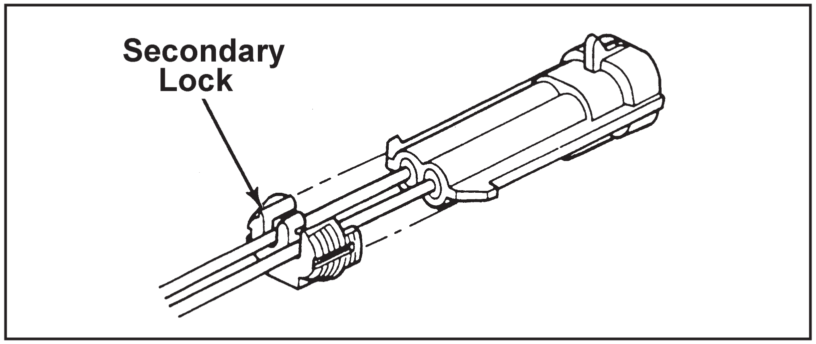

Figure 18

Hinged Secondary Locks

Some connectors have hinged secondary locks. Once all terminals have been seated, snap the secondary lock down over the back of the connector as shown in Figure 19.

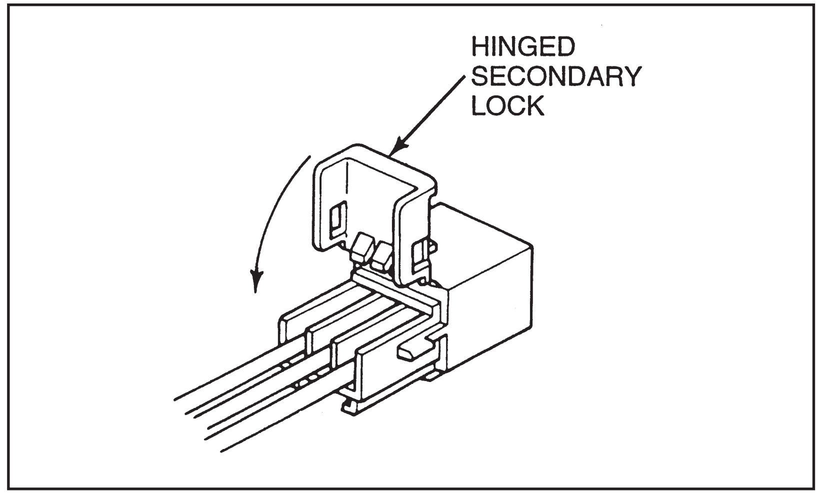

Figure 19

MATING TWO CONNECTORS TOGETHER

Once all terminals have been seated and secondary locks added, mate the two connectors. Simply push them together until the inertia lock snaps into place, locking them together (Figure 20). Pull on the connectors to ensure they are properly mated.

CAUTION Never pull on the wires.

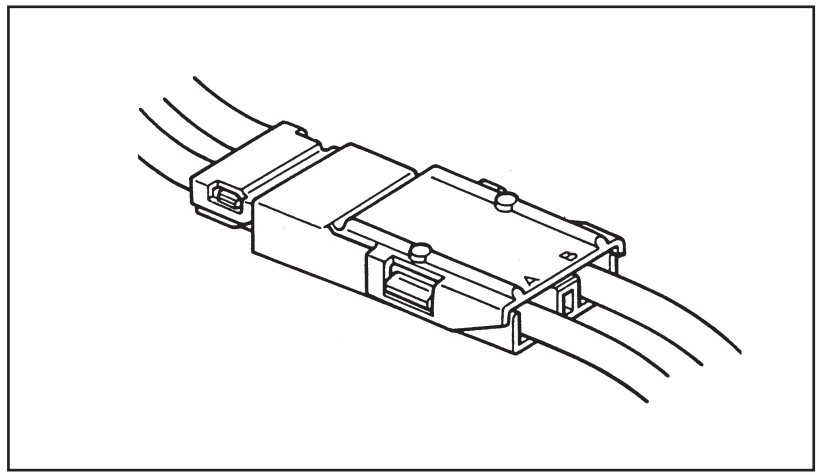

Figure 20

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Electrical System – Design Guidelines (cont'd)

DISASSEMBLING CONNECTION SYSTEMS

This procedure can be done using a small screwdriver or pick.

- To remove a connector position assurance (CPA) lock — Remove the CPA lock by simply depressing the tabs on either side and pulling the lock out of the connection. (See Figure 21.)
- To disconnect a connector — Using your thumb or a small screwdriver or pick, lift up on the inertia lock tab. Pull the connectors apart.

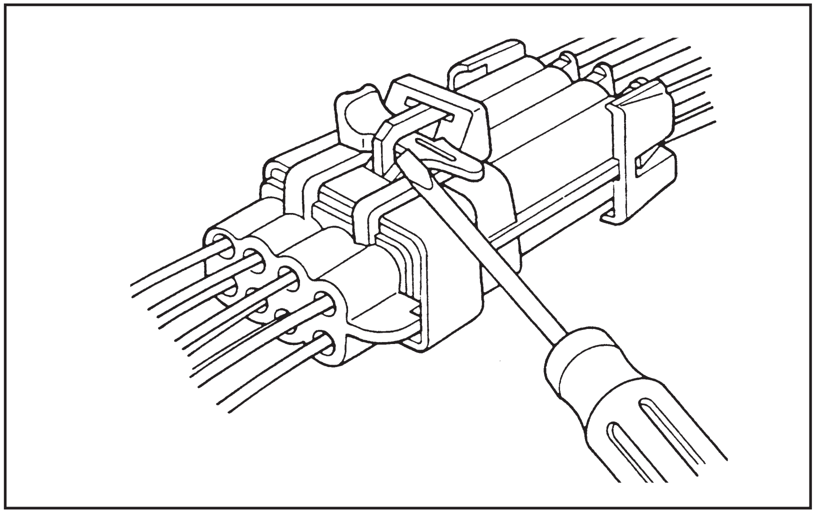

Figure 21

Removing TPA or Secondary Locks

- To remove a TPA lock — Using a small screwdriver or pick, carefully depress the locking tabs on either side of the connector. (See Figure 22.) Remove the TPA lock from the back side of the connector.

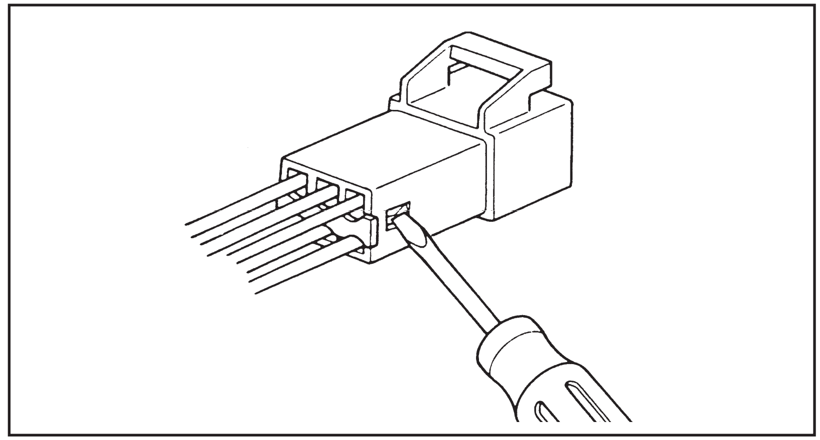

Figure 22

- To remove a secondary lock — Use a small screwdriver or pick to carefully lift the secondary lock over the locking tabs on either side of the connector and remove. (See Figure 23.)

CAUTION Be careful not to bend or deform the locks or connectors if they are to be used again.

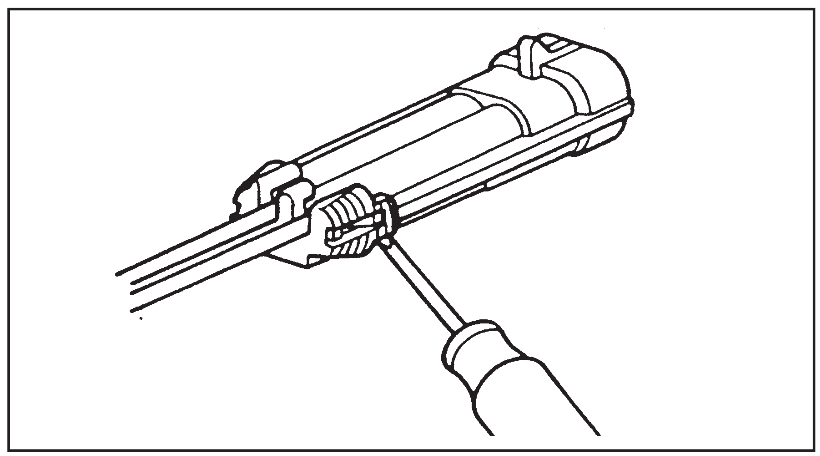

Figure 23

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Electrical System – Design Guidelines (cont'd)

TERMINAL REMOVAL

Special tools are required to remove the terminal without damaging it or the connector in which it is inserted. Because connectors are designed to firmly retain terminals, it is sometimes difficult to remove them. Different style terminals have different removal procedures, but most common terminals can be removed using the procedure below. This procedure will work with all parts in the connection systems parts list (Appendix II).

A terminal removal tool (e.g., pick or safety pin) is required to remove a push-to-seat terminal from a Metri-Pack connector.

1. Disconnect the mating connector.
2. Remove any secondary or TPA lock.
3. Grasp the wire and push the terminal to the foremost position in the connector cavity. Hold the terminal in this position. The terminal locking tang is now separated from the ridge inside the connector cavity. This makes it easy for the terminal removal tool to unseat the terminal.
4. Locate the terminal lock tang in the connector cavity channel by looking into the connector from the mating end.
5. Insert an appropriately sized pick straight into the connector cavity from the mating end of the connector (Figure 24).
6. Depress the lock tang with the pick or pin to unseat the terminal.
7. Gently pull the wire to remove the terminal through the back of the connector.

CAUTION: If force is required to remove the terminal, the locking tang has not been properly depressed. Forcing a terminal out of the connector can damage the cavity walls.

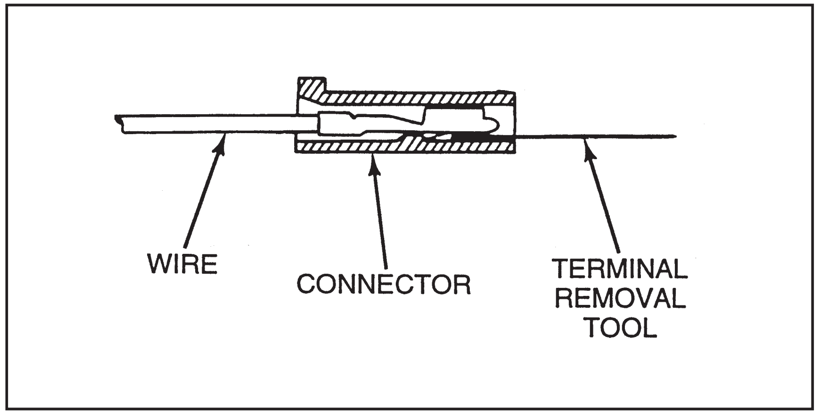

Figure 24

Splicing Guidelines

As mentioned earlier, General Motors recommends against splicing into OEM wiring to add or extend a circuit. However, if no other method is available, splicing should comply with the procedures recommended in this section.

To ensure a reliable connection, do not use Quicksplice, Scotchlock, wire nuts and/or similar splicing devices in General Motors vehicles.

Splicing Two Wires

The crimp-and-seal splice sleeve is recommended for splicing two wires together. It has several advantages, including:

- It is easy to use. Only one part is needed to complete the splice and it does not require soldering.
- When heated, the glue-lined sleeve bonds to the wire insulation, creating an excellent environmental seal. This makes it perfect for use both inside and outside the vehicle.
- The bond between the splice and the wire, added to the wire crimp, creates a very strong splice.

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Electrical System – Design Guidelines (cont'd)

The table in Figure 27 lists available crimp-and-seal splice sleeves. As previously noted, these parts include a glue-lined tube that, when heated, shrinks over the wires to seal them off from the environment. To assure reliable splicing, always select the splice sleeve properly sized and designed for the wire gauge in use.

The **butt-splice sleeve** can be used for applications that do not require sealing, such as those inside the passenger compartment of the vehicle. It does not, however, create as strong a splice as that of the crimp-and-seal splice. Do not use unsealed buttsplice sleeves for splices that will be located outside the passenger compartment of the vehicle.

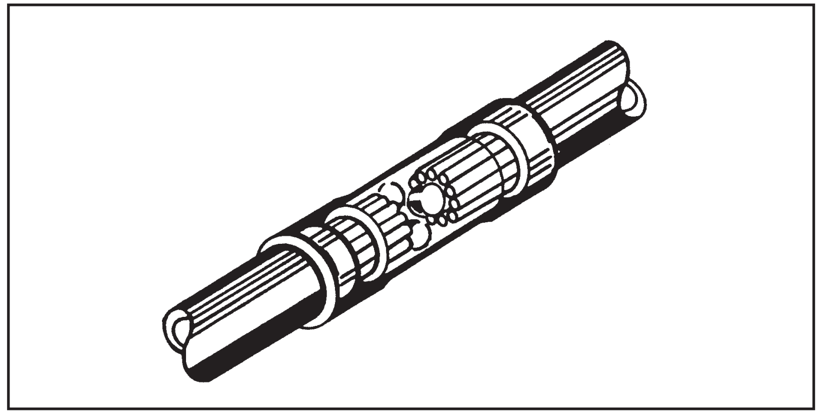


Figure 26

Recommended splicing procedure:

1. Strip about 3/8" of the insulation from the ends of the two wires to be spliced (Figure 25).

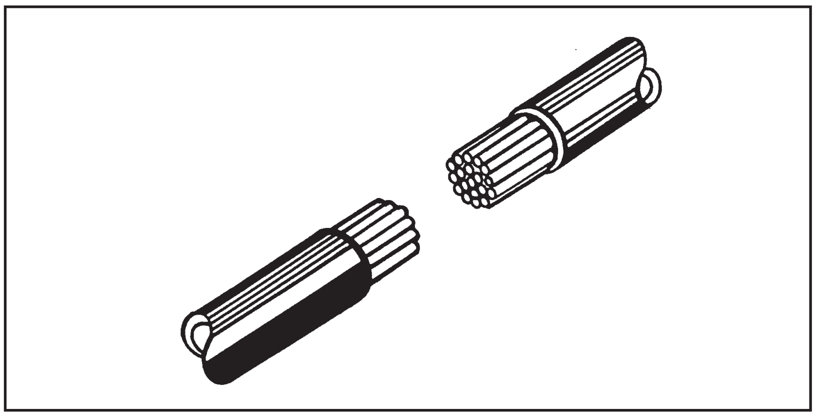
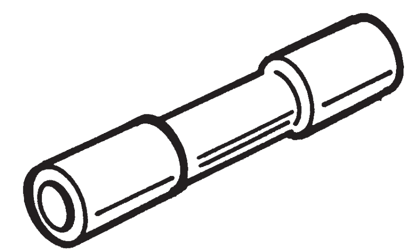


Figure 25

2. Insert stripped wires into the splice sleeve until they reach the wire stop located at the center of the sleeve (Figure 26).

CRIMP-AND-SEAL SPLICE SLEEVE



PART NUMBER	SLEEVE COLOR	WIRE SIZE	
		English	Metric
12089189	Salmon	18-20	0.80-0.50
12089190	Blue	14-16	2.00-1.00
12089191	Yellow	10-12	5.00-3.00

Figure 27

(continued on next page)

Electrical System – Design Guidelines (cont'd)

3. Crimp the splice sleeve on each end. Each wire must be crimped individually. For proper placement, see Figure 28. (**Note:** Use the appropriate crimp tool designed specifically to use with both crimp-and-seal and butt-splice sleeves.)

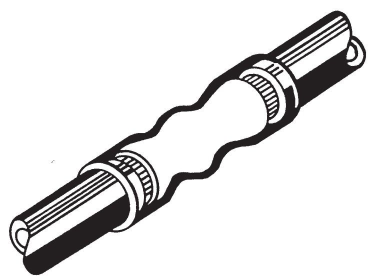


Figure 28

4. For crimp-and-seal splice sleeves: Using a hot air gun, apply heat to the splice sleeve. As the sleeve shrinks, the glue inside will begin to melt. When the sleeve stops shrinking and glue appears at the ends of the sleeve (Figure 29), remove heat. Allow to cool.

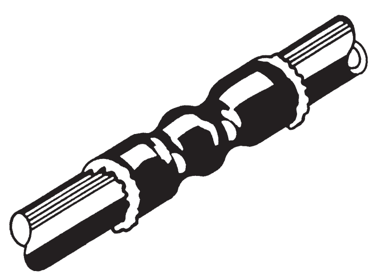


Figure 29

5. Check for electrical continuity.

! GM recommends against burying in-line splicing devices (that are used in lieu of connectors) in wiring harnesses. Such devices should remain reasonably accessible to service technicians. (See “Serviceability” in this section.)

Splicing Multiple Wires

The **splice clip** is the recommended method for splicing more than two wires together.

It is similar in function to terminal core grip wings, except the splice clip is designed to accept more than one wire. Splicing is accomplished by placing the wires into the clip, crimping and then soldering them. Soldering ensures a good electrical connection as well as a strong splice. GM recommends using splice tape, heat-shrink tubing or glue-lined heat-shrink tubing to protect and insulate the spliced wires.

This type of splice is acceptable anywhere in the vehicle. If used outside the passenger compartment, however, the splice should be appropriately sealed.

Recommended splicing procedure:

1. Strip about 3/8" of the insulation from the ends of the wires to be spliced (Figure 26).
2. The preferred location for any splice is a minimum of 1.5" from another splice.
3. Determine the proper splice clip for the number and size of wires to be spliced. (Refer to “Choosing a Splice Clip“ in the “Splicing Guidelines” in this section.)
4. Position the stripped wire ends in the splice clip. The wire core should be visible on both sides of the splice clip (Figure 30).

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Electrical System – Design Guidelines (cont'd)

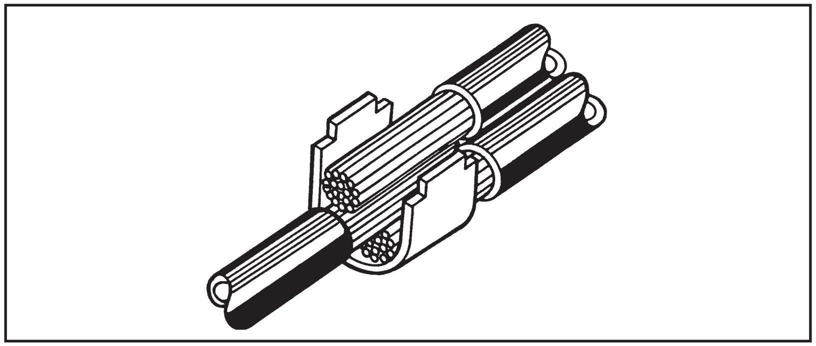

Figure 30

5. Close the clip securely by hand crimping, using a pair of pliers (Figure 31).

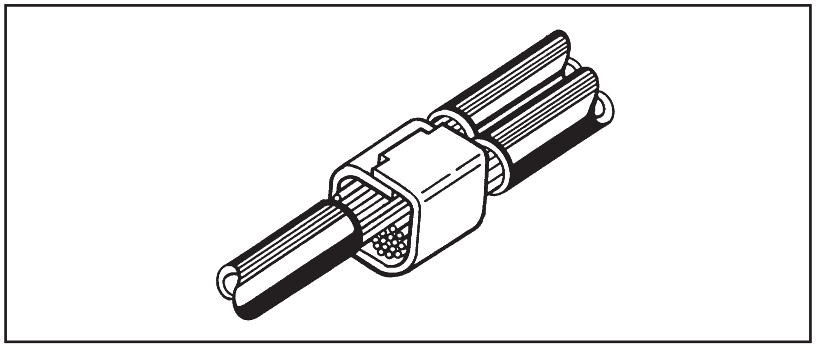

Figure 31

CAUTION Be careful not to crimp insulation under the splice clip.

6. Apply solder to the splice clip as outlined in the next section.
7. Check circuits for electrical continuity.
8. Cover the splice with splice tape or heat-shrink tubing. The tape or tubing must extend beyond the splice on both sides to cover the edges of the insulation.

! If the splice is located outside the passenger compartment, use glue-lined heatshrink tubing for optimum weather sealing.

Soldering the Splice Clip

As previously noted, soldering helps to ensure a reliable connection and strengthens the splice. Listed below are the recommended steps for soldering a splice clip:

1. Preheat the soldering tool for at least one minute before applying solder. This promotes good, even solder flow.

Do not use a soldering gun to solder splice clips. A soldering gun gets too hot, even at low settings.

2. Heat the splice clip and wire core. Avoid heating too close to the insulation. Burned or melted insulation can lead to a short circuit, open circuit or corrosion within the wire, causing high resistance.
3. Apply solder to the hole in the splice clip as shown in Figure 32. Use just enough solder to produce an even flow through the splice clip.

CAUTION Use only rosin core/rosin flux solder for soldering splice slips. Other flux materials can cause corrosion.

CAUTION Avoid using too much solder as it can result in “wicking.” Wicking occurs when excessive solder begins to travel up the wire core, like candle wax up a wick. This can cause the wire to become stiff or brittle and produce a flex point, eventually leading to a broken wire and open circuit.

4. Check circuit for electrical continuity.

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Electrical System – Design Guidelines (cont'd)

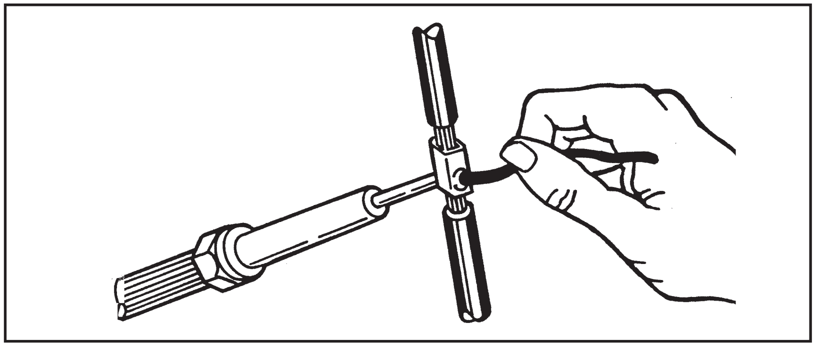


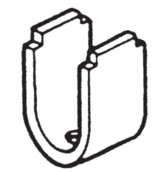
Figure 32

Choosing a Splice Clip

Choosing the right splice clip is extremely important to the overall durability and quality of the splice. Always consider the number and size of wires to be spliced when making a selection.

To determine the best typical splice clip for a particular application, calculate the area of the wire's cross section. Use the optimum range in the table below (Figure 33) to determine the appropriate splice clip part number. The wire cross-sectional areas shown in Figure 34 are for cable. Typical cables do not vary much from these numbers. Simply add up the cross-sectional area for each wire in the splice to get the total cross-sectional area for the splice.

SPLICE CLIP



PART NUMBER	SPLICE CROSS-SECTIONAL AREA mm^2	
	OPTIMUM	ALLOWABLE
05297428	2.16 - 3.29	1.35 - 3.55
00821240	2.80 - 5.50	2.40 - 6.45
01839906	5.50 - 8.90	4.0 - 10.85
01864022	8.90 - 12.15	7.0 - 12.45
05290433	12.15 - 19.35	9.4 - 21.3
02962985	21.3 - 35.0	16.0 - 44.75

Figure 33

WIRE SIZE		CROSS-SECTIONAL AREA (mm^2)
ENGLISH (GAUGE)	METRIC (mm^2)	
22	0.35	0.308
20	0.50	0.549
18	0.80	0.805
16	1.00	1.177
14	2.00	1.947
12	3.00	3.019
10	5.00	4.757

Figure 34

(continued on next page)

Electrical System – Design Guidelines (cont'd)

The calculation example below illustrates how to select the appropriate splice clip:

Problem:
Determine the best splice clip to use for a splice with one 12-gauge wire, two 16-gauge wires and one 18-gauge wire.

1. Calculate the total wire cross-sectional area as shown in Figure 35.
2. Using the number just calculated, choose the best splice clip from the preceding splice clip table (Figure 33). The best splice clip for a cross-sectional area of 6.178 mm^2 is part number 01839906. The optimum range for that clip is 5.50 mm^2 to 8.90 mm^2.

GAUGE	AREA (mm2)		# WIRES	TOTAL
12	3.019	x	1	3.019
16	1.177	x	2	+ 2.354
18	0.0805	x	1	+ 0.805
Total cross-sectional area (sum of total area for each gauge size)			=	6.178

Figure 35

WIRE HARNESS COVERING GUIDELINES

Using the proper wire coverings is an important part of a good electrical system. This section contains GM-recommended wire-covering guidelines for Upfitter-installed electrical systems. Whenever possible, wiring should be bundled into a harness that is prebuilt outside the vehicle. This harness should be covered with some type of protective outer jacket. Protecting wiring with an outer covering reduces the possibility of several common electrical problems. For example, when a wire is pinched or cut, it is usually because it was not where it was supposed to be. Wire coverings bundle wires together and keep them within their designated location within the vehicle. Similarly, when a wire is chafed or burned, it is not uncommon to find that it has rubbed against a sharp object or come too close to a heat source. Protective devices and/or the appropriate wire coverings can eliminate these types of problems. GM recommends Upfitters select and use wire coverings that are appropriate to the environment to which their wiring will be exposed.

Wire Coverings

Common coverings for automotive wiring are tape, profile conduit and convoluted conduit. (**Note:** See “Wire Routing Appearance Guidelines” when selecting underhood wiring coverings.)

Tape

Tape is generally used as either a spot tape or as a harness wrap to keep wires bundled together. It is less costly than convoluted or profile conduit but does not provide much protection against pinching or abrasion. Tape is recommended for use only where minimum or no wire protection is required.

Profile Conduit

General Motors recommends using profile conduit where long, straight runs of wiring are required. Profile conduit protects the wiring by encapsulating it and controlling its position within the vehicle.

Convoluted Conduit

Where added protection is needed, GM recommends using convoluted conduit to hold wire bundles together. Convoluted is pinch and abrasion resistant and is available in many types and sizes.

- Nylon conduit — provides protection for wiring near heat sources.
- Polyethylene conduit — good for general passenger compartment use. Both nylon and polyethylene conduits come in a variety of sizes, ranging from 6 mm to 40 mm in diameter. Part numbers for both types are shown in Figure 36.

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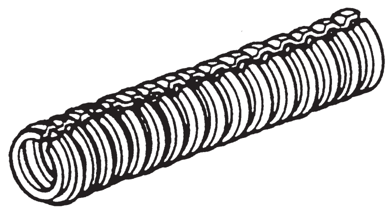
Electrical System – Design Guidelines (cont'd)

CONVOLUTED CONDUIT PARTS LIST



SIZE		SPLIT POLYETHYLENE	POLYAMIDE
MM	INCHES		
6	0.250	R-64496	R-64498
8	—	—	R-70240
9	0.350	R-68234	R-68235
10	0.413	R-67588	R-68236
13	0.500	R-67587	R-68237
16	0.625	R-68239	R-68238
19	0.750	R-68269	R-68240
22	0.875	R-65715	R-65716
25	1.000	R-68529	R-68423
30	1.150	R-71305	R-70239
40	1.570	—	R-70434

Typical Usage:	Passenger Compartment	Engine Compartment
Pitch and Abrasion Resistance	Good	Excellent
Automotive Fluid Resistance	Excellent	Excellent
Color:	Black	Black w/Grey Stripe

DIMENSIONS

Sizes (mm)	6	8	9	10	13	16	19	22	25	30	40
O.D.	9.85	11.65	12.79	14.77	17.33	20.91	24.70	28.68	32.78	37.6	46.7
I.D.	6.35	7.75	8.87	10.4	12.61	15.68	18.86	22.2	25.72	30.0	41.0

Figure 36

The procedure for determining the appropriate conduit size follows.

! Edges and slits in nylon conduit are sharp surfaces. Wires exiting nylon conduit should be tape wrapped for their protection.

To select the right size of convoluted conduit to use, follow the procedure below:

1. Determine the sum of the diameters of the cables to be covered (S).
2. Select the effective diameter constant (C).
3. Calculate the effective diameter (D).
4. Determine minimum conduit size (inside diameter) required. Choose conduit size based on calculated effective diameter (D).

Selecting Convoluted Conduit

STEP 1: Determine the sum of the diameter of the cables to be covered (S).					
SIZE		TWP/TXL THINWALL		GPT/GXL STD WALL	
mm^2	Gauge	mm	in	mm	in
0.22	24	1.40	0.055	—	—
0.35	22	1.55	0.061	—	—
0.50	20	1.75	0.069	2.11	0.083
0.80	18	2.04	0.080	2.34	0.092
1.0	16	2.17	0.085	2.56	0.101
2.0	14	2.58	0.102	2.97	0.117
3.0	12	3.12	0.123	3.57	0.140
8.0	8	—	—	5.41	0.213
13.0	6	—	—	6.76	0.266

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Electrical System – Design Guidelines (cont'd)

STEP 2: Select the effective diameter constant (C).	
NUMBER OF CABLES TO BE COVERED	CONSTANT C
1	3.15
2	2.58
3	2.18
4	1.95
5	1.74
6	1.58
7	1.48
8	1.39
10	1.29
11	1.21
12	1.15
13	1.11
14	1.07
15	1.03
16	0.99
17	0.98
18	0.95
19	0.93
20	0.91

STEP 3: Calculate the effective diameter (D).

$$\frac{S \times C}{3.1416} = D$$

STEP 4: Determine minimum conduit size (inside diameter) required. Choose conduit size based on calculated effective diameter (D).			
CALCULATED EFFECTIVE DIAMETER		CONDUIT SIZE	
mm	in	mm	in
less than 5.3	less than 0.21	6	0.25
5.4 - 6.6	0.22 - 0.26	8	0.31
6.7 - 7.4	0.27 - 0.29	9	0.35
7.5 - 8.9	0.30 - 0.35	10	0.41
9.0 - 10.7	0.36 - 0.42	13	0.50
10.8 - 13.5	0.43 - 0.53	16	0.62
13.6 - 16.0	0.54 - 0.63	19	0.74
16.1 - 18.5	0.64 - 0.73	22	0.87
18.6 - 21.3	0.74 - 0.84	25	1.00
21.4 - 25.1	0.85 - 0.99	30	1.18
25.2 - 33.5	1.00 - 1.32	40	1.57

CIRCUIT PROTECTION GUIDELINES

All Upfitter-installed circuits require protection against electrical overload, which can damage not only the circuit but also the vehicle.

Why Is Circuit Protection Needed?

For each size of wire, there is a maximum amount of current that it can carry. When a device fails or a short circuit occurs, the actual current flow may exceed the current-carrying capacity of the wire.
When too much current flows through a wire, it may generate enough heat to melt or burn the wire insulation.

! The primary function of circuit protection is to protect the wiring, not electrical devices. In most cases, circuit protection will indirectly protect devices subjected to an overload condition. Many electrical devices, however, contain their own fuses and circuit breakers.

(continued on next page)

Electrical System – Design Guidelines (cont'd)

When Should Circuit Protection Be Used?

Use circuit protection:

- On all new Upfitter-added circuits
- When using a power feed source (wire from the battery) that is not already protected by some type of circuit protection
- For added safety or to protect a device that could be damaged by too much current
- When splicing into a power circuit with a wire of a gauge size that is smaller than that permitted by the circuit-protection device.

(**Note:** To avoid this, use a wire of equal or larger gauge when splicing into existing wiring.)

What Types of Circuit Protection Should Be Used?

- Automotive Type Fuses
  - Ato Fuses (blade type fuse) can be used singly in an individual fuseholder, and/or in multiples, mounted in a fuse panel.
  - Automotive glass fuses can be used singly in individual fuseholders or in multiples mounted in a fuse panel.
  - Maxi Fuses are newly available, larger, high-current blade-type fusing devices which have a slower blow time than high current Ato Fuses. They can be used singly in individual fuseholders or in multiples in a fuse panel.

See Appendix II for automotive fuse part numbers.

- Automotive Type Circuit Breakers
  - Automatic reset type (cycling) trips and continuously self-resets when subjected to current overload.
  - Automatic reset type (non-cycling) trips when subjected to current overload; remains open until power or load is removed.
  - Manual reset type trips when subjected to an overload and remains open until it is manually reset.

! GM recommends using automatic reset (non-cycling) and manual reset type circuit breakers.

! Terminal and connector part numbers for both Ato Fuse and Maxi Fuse applications can be found in Appendix II. They have been chosen based on using cable. Terminal selection must be based on the outer diameter of the cable insulation.

Circuit Protection Design Recommendations

! Before adding any additional loads to an existing OEM circuit, conduct an electrical load study and document its data. The total circuit current draw, including Upfitter-added loads, should not exceed 80% of the OEM circuit current-protection device rating.

! Conduct electrical load studies for all new Upfitter-added circuits to determine the correct circuit protection device rating to use. To avoid nuisance failures, select circuit protection devices with a rating of 125% of the maximum load to be carried by the circuit.

CAUTION Never replace an OEM circuit-protection device with a device of a higher amperage rating.

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Electrical System – Design Guidelines (cont'd)

General Motors also recommends the following:

- Locate fuseholders/panels and/or circuit breakers in the passenger compartment if possible. If located in the engine compartment, they should be environmentally sealed.
- Clearly mark all Upfitter-added fuseholders and fuse panels to indicate both the fuse function and the maximum replacement fuse size(s).
- Clearly mark all Upfitter-added circuit breakers with their maximum amperage rating.
- Install and fasten fuseholders and circuit breakers as necessary to prevent rattling.
- Do not bury in-line fuses in the wiring harness or at random locations. Instead, cluster them together at an access point that is both logical and convenient to the customer/service technician. Provide related service information in the Upfitter owner's manual.
- Install fuse panels in a convenient, customer-accessible location. Provide related service information in the Upfitter owner's manual.
- Limit the number of functions per fuse and/or circuit breaker. The preferred arrangement is one function per fuse or circuit breaker. This makes diagnosis easier in the event of malfunction.
- When adding new circuits to power-added electrical components, wiring should be rated and fused for the components' maximum current draw. Inrush and stall currents should also be considered. (See "Cable (Wire) Selection Guidelines" section.) For owner convenience, the Upfitter should consider providing spare fuses, a special tool for their removal if required, and a diagram or label identifying fuse functions and locations.

ELECTRICAL COMPONENT GUIDELINES

Selecting quality electrical components is essential to the longevity of the vehicle's electrical system. With the exception of normal wear-out items, such as light bulbs and fuses, all Upfitter-added electrical components are expected to last the life of the vehicle, regardless of the warranty length. General Motors' current design and durability standards specify 10 years and/or 100,000 miles.

When adding electrical devices, it is extremely important to follow all manufacturer instructions on installation and electrical connection(s).

All service replaceable electrical components should be marked with either a vendor or Upfitter identifying part number.

Ratings

To assure that only correctly-rated electrical components are installed, all added current-drawing and/or control devices should be marked to indicate the following:

- Current draw (amperes) or wattage rating (watts) for current drawing devices
- Maximum connected load (amperes) for control devices
- Voltage at which they are designed to function Exceptions to this are devices such as light bulbs, for which current draw and wattage numbers are readily available in industry catalogs.
- All Upfitter-added electrical components should have a DC voltage rating not less than the system voltage. They should also be appropriately marked to indicate their voltage rating. Passive electrical components, such as relays and circuit breakers, should be marked with their maximum ampere current capacity at 12-14 VDC.

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Electrical System – Design Guidelines (cont'd)

- Upfitter-installed switches should have a DC rating of not less than 100% of the expected maximum connected load. Inductive startup and tungsten inrush loads must be taken into consideration when determining the maximum connected load.
- Upfitter-installed relays should have a DC current rating of at least 150% of the expected maximum connected load. The additional 50% over specification is to protect the relay from high start-up inductive loads from motors or high inrush tungsten loads from lighting devices.
- Interior lighting devices should be equipped with bulbs with candle-power or wattage rating recommended by the manufacturer. Using bulbs of higher ratings can result in lamp damage due to the high heat generated when lamps are left on for extended periods of time.

Component Tolerance Levels

Upfitter-added components should also be capable of operating when exposed to a variety of conditions. Electrical components should be capable of withstanding:

- Temperatures ranging from –40°C to +85°C.
- Up to 14 volts DC, applied in a reverse polarity direction for a minimum of 30 seconds. Exposure to a reverse polarity condition may result from improper vehicle jumpstart battery connection or a reversed electrical connection.
- Upfitter-added electrical systems should tolerate a 24-volt vehicle jumpstart without degradation or damage to any electrical component.
- Short-term electrical overloads from stall or inrush currents without acting as a fuse or exhibiting internal component welding. (Exceptions are fuses and circuit breakers.)
- Normal vehicle shock or vibration. Newly installed components additionally must be compatible with the fluids normally found in or around the vehicle. For example, exterior components should be compatible with engine oil, automatic transmission fluid, ethylene glycol, window washer solvent and 5% salt water solutions. Interior components should be compatible with alcohol- or ammonia-based cleaners, vinyl plasticizers, soapy water and soft drinks.

Component Handling

Upfitters should exercise due care when handling, installing or storing Upfitter and/or OEM furnished electrical components. Unseen damage could result in a delayed failure of a component, a warranty claim, and a dissatisfied customer.

- Unprotected electrical components should not be stored in environments that would expose them to dust, dirt, water, grease, paint overspray, high humidity, etc.
- Care should be taken to assure that electrical components are not dropped or otherwise mishandled when being installed by Upfitters. Never install an obviously damaged part.
- Do not stack unprotected electrical components, such as radios and radio speakers, as they could easily sustain damage that may not be obvious to the installer.
- Do not allow foreign materials, such as metal chips or filings to become attached to either the cone or magnet of speakers. These and other contaminants can cause a buzz or rattle sound in the speaker.

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Electrical System – Design Guidelines (cont'd)

- OEM-furnished electrical components, that are shipped in the dunnage box, should remain in their protective packaging until they are needed for installation.

Component Precautions

GM does not recommend the installation of remote-start systems in GM trucks. This is due to the potential to detrimentally affect the function of the electrical, ECM/ PCM/ VCM and OBD II systems. Installation could also compromise the vehicle theft deterrent features and could result in a safety issue if the vehicle is started in gear.

RADIO FREQUENCY INTERFERENCE (RFI) PREVENTION

When delivered, General Motors vehicles comply with all current radio frequency interference (RFI) standards. It is important that Upfitters take all necessary precautions to maintain the RFI integrity of OEM systems and components. Additionally, Upfitters should install only signal-receiving/transmitting devices that are compatible with both the OEM and Upfitter electrical systems.

The recommended guidelines are:

- Electrical devices should be designed or electrically isolated to prevent radio frequency interference to the OEM radio or Upfitter-installed radio, TV or DVD, etc. This is particularly important when adding inductive load devices such as mechanically or electronically commutated DC motors.
- Protect all Upfitter-added audio/video circuits from electrical ignition noise (from gasoline powered internal combustion engine) which may interfere with normal radio or TV reception.
- Use individual, clean (separate, single-function) circuits to power any added signal receiving/transmitting devices.
- To prevent possible electrical interference, never allow audio and video equipment power and signal circuits to share a common ground wire with other electrical equipment.
- Never route coaxial antenna cables adjacent to vehicle power circuit wires or within 8" of vehicle control modules.
- Make sure that added electrical or electronic devices that may emit electromagnetic radiation comply with SAE Standard J551 — Performance Levels and Methods or Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000 MHz).

SERVICEABILITY

Serviceability is the relative ease with which a component or system can be diagnosed, removed, replaced, repaired or adjusted. Some vehicle upfitting decisions can adversely affect the serviceability of either the OEM- or Upfitter-installed electrical system, or both. Therefore, it is very important that Upfitters consider potential service requirements when designing electrical systems for conversion vehicles.

Service should be able to be accomplished:

- With minimum interference from unrelated parts
- In a minimum amount of time
- With reasonably priced parts and materials
- With standard hand tools and shop equipment
- Within the expertise of the average technician, with a minimum of special training
- Without damage to components or systems

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Electrical System – Design Guidelines (cont'd)

Design Parameters

General Motors recommends the addition of the most simple electrical designs possible to allow for obvious, easy and accurate diagnostic procedures. Also, the design of an Upfitter electrical system should not adversely affect the serviceability of any OEM component and/or system. Another key design consideration is the most likely service facility and its capabilities.

The following guidelines will help the Upfitter to design a more serviceable electrical system:

- Design or install components and systems that can be easily serviced or replaced and are compatible with existing service industry capabilities.
- Design electrical system and components that eliminate multiple-part failures resulting from the failure of a single device.
- To reduce replacement costs, install components that can be rebuilt to original specifications.
- Install electrical components and systems capable of withstanding a 24-volt jump start without degradation or damage.
- Make sure that the electrical components or systems can withstand 14 volts DC applied in reverse polarity without degradation or damage.
- Limit the number of functions per fuse (one function per fuse, if possible). This will aid in diagnosing short circuits by subdividing circuitry.
- Provide easy service access to electrical components, such as connectors, crimp-and-seal and butt-splice sleeves, fuses, relays and circuit breakers. For connector service access, provide wiring service loops at all electrical component locations. Also allow for adequate tool access.
- Fasten wiring and electrical components to the vehicle so that they can be easily removed and reinstalled.
- Color code wire insulation consistently throughout the entire circuit length, including pigtails to individual components.
- Install readily available components whenever possible to reduce parts proliferation and replacement costs.

! Service parts should be available for a minimum of 10 years after the vehicle has been sold to the customer.

Diagnosability

Design and install electrical systems and components so that technicians can accurately determine the nature and location of a failure within a reasonable time frame and at a minimal cost.

Accessibility

The preferred electrical system designs provide for easy physical access to all electrical wiring, connections and components without major disassembly or interference from other vehicle components or systems. Avoid designs which can only be accessed by uncontrolled piercing of the wire insulation. GM strongly recommends against such practices as they can result in wire damage, corrosion, lost electrical integrity and eventual circuit failure.

Repairability/Replaceability

General Motors recommends the installation of systems and components that can be repaired within a minimum amount of time and a reasonable cost, using standard, readily available hand tools and shop equipment. The skill required for performing repair and replacement procedures should also fall within the average technician's range of expertise.

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Electrical System – Design Guidelines (cont'd)

Limited-Life Components

When considering limited-life components, such as light bulbs or fuses, choose readily available parts that the average customer can easily replace (i.e., within 5 minutes), using common, everyday tools. For Upfitter-added lighting devices, use standard 12-volt automotive type bulbs. Select fuses that are serviceable under industry standards. Both light bulbs and fuses should be easily obtained in the aftermarket and located for easy access within the vehicle (i.e. without major disassembly of vehicle systems, components, trim or hardware). See "Circuit Protection Guidelines" section.

FMVSS/CMVSS REQUIREMENTS

This section addresses the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) applicable to the OEM electrical system. Special Vehicle Manufacturers should not alter any OEM electrical component, assembly or system in a way that will either directly or indirectly result in the nonconformance of that component, assembly or system to any applicable FMVSS/CMVSS standard.

This section contains information to help the Upfitter interpret FMVSS CMVSS standards that apply to electrical components, assemblies or systems in GM vehicles. In no way is this information intended to supplement or amend the specific requirements of any FVMSS/CMVSS standard. The Upfitter is responsible for obtaining copies of any and all FMVSS/CMVSS regulations that apply to the operations they perform and for interpreting how their operations will affect the vehicle's compliance to these standards.

Whenever an Upfitter alters any electrical component, assembly or system which requires FMVSS/CMVSS certification, adequate records must be generated and maintained on file, to document compliance to the applicable standard(s).

FMVSS/CMVSS 108: Lamps, Reflective Devices and Associated Equipment

The vehicle, as shipped from GM to the Upfitter, is in compliance to this standard as outlined in the Incomplete Vehicle Document. Alterations to any component, assembly or system included in this standard requires the Upfitter to recertify compliance to the standard.

- The relocation and/or the substitution of the center high-mounted stop lamp (CHMSL) requires Upfitter certification to FMVSS 108 sections §5.1.1.27, §5.3.1.8, §5.4 and §5.54.
- Cutting (splicing) into any OEM wire that provides either an electrical power or ground circuit path, for any device listed in FMVSS 108, will require the Upfitter to certify that circuit continuity has not been interrupted to that device.

FMVSS/CMVSS 118: Power Operated Window Systems

The vehicle, as shipped from General Motors to the Upfitter, is in compliance to this standard as outlined in the Incomplete Vehicle Document. The Upfitter must not alter the power window electrical system in any way that will affect the way in which the system functions.

- This standard requires the ignition key, that controls the activation of the vehicle's engine, to be in the "ON," "START" or "ACCESSORY" position to enable the power-operated windows to be closed. Upfitters must not alter this function.

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Electrical System – Installation Guidelines

ELECTRICAL SYSTEM INSTALLATION GUIDELINES WIRE HANDLING GUIDELINES

Proper handling will protect wire from damage which may otherwise occur during the conversion process. General Motors recommends the following precautions:

- Do not allow OEM or Upfitter wiring or connectors to hang or lay in areas where they can be damaged by subsequent assembly operations (i.e., welding flash, paint overspray, etc.). Temporarily fasten them out of the way or protect them until they are needed.
- Do not route wiring temporarily over, under, between or in doorjamb areas. Closing doors can result in damage to the wire.
- Do not tie wire assembly branches together to keep them out of the way. Knotting or tying wires together can result in damage.
- Keep wire assembly connectors in a protected location as the vehicle progresses through subsequent assembly stations. Store

connectors in an accessible location, away from potentially damaging activities, until that point in the build sequence when they are mated.

- If required, temporarily fasten uncontrolled wiring assemblies to prevent them from dragging under or behind the vehicle.
- Establish and sequence assembly operations and work stations so that there is no employee competition for work space, which can lead to missed operations.
- Do not allow electrical components to hang from wiring leads. The weight of a component can damage the wire or cause complete or partial disconnect.
- Implement practices to protect Upfitter and OEM wiring and connectors that lay temporarily on the floor from damage which may result from normal operator activities. Do not walk, step on or lay heavy objects on wiring.

WIRE ROUTING GUIDELINES

Proper wire routing is essential to the electrical system's long-term reliability. Improper wire routing can lead to many different electrical malfunctions and costly repairs. Following the simple guidelines in this section can help the Upfitter to produce a more trouble-free electrical system. GM strongly recommends that visual graphic displays depicting Upfitter wiring routings be prominently displayed at all electrical work stations to promote consistency in installation processes. GM also recommends that OEM wiring not be rerouted or relocated within the vehicle unless it would become vulnerable to damage due to Upfitter assembly operations.

Location

- Route wiring so that it does not come into contact with any of the vehicle's moving parts (e.g., seat-adjuster and power sofa mechanisms, sunroof mechanisms, brake and clutch pedals, etc.).
- Be sure to allow a distance of at least 125.0 mm (5 inches) between the wiring and any source of radiant heat. Heat can deteriorate wiring insulation to the point where breaks in the insulation can occur, this in turn can result in arcing and a short circuit condition. Examples of radiant heat sources are exhaust manifolds and pipes, catalytic converters, EGR valves, light bulbs and electronic device heat sinks.
- Where possible and practical, install wiring inside the vehicle. If exterior wiring is necessary, make sure to adequately protect it from road hazards.

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Electrical System – Installation Guidelines (cont'd)

- As much as possible, route wires in and through areas where they are least vulnerable to damage from subsequent assembly operations (e.g., blindly driven trim attaching screws). If wiring must be routed through vulnerable areas, take great care to sufficiently protect the wiring.
- Route wiring away from potentially damaging vehicle surfaces, such as sharp or abrasive objects, raw sheet metal holes, sharp metal flanges, spot-weld flash points, etc.
- Route wiring in the I/P area so that it doesn't hang down around pedals or in areas that can be contacted by either driver or passenger foot movements.
- Upfitter underhood wiring, that is routed near the OEM battery, should be kept a minimum of 75.0 mm (3 inches) away from the battery vent holes as caustic fumes emitted from these vent holes can have a deteriorating affect on wiring insulation.
- Route Upfitter wiring in areas that can be easily accessed for service and repair.
- When routing wiring to connectors on electrical/ electronic modules or similar devices, it is recommended that a water drip loop be incorporated in the wire just before it connects to the module. This will prevent water that may have accidentally entered the vehicle from tracking along the wire and entering the module.
- When routing wiring through a grommet from the outside to the inside of the vehicle, it is recommended that a water drip loop be incorporated in the wiring just before it enters the grommet. This will prevent water from tracking along the wire and entering the interior of the vehicle through the grommet. See "Wire Harness Assembly Guidelines" and "Serviceability" under the "Electrical System Design Guidelines" section for additional recommendations regarding wiring location.

Tension

Any strain exerted on the wiring between two fixed points that is greater than the weight of the wiring itself is referred to as "tension." General Motors recommends routing wire to avoid tension and allow some, but not excessive, slack between fixed attached points. Examples of fixed attaching points are clips, clamps, connectors and grommets.

Accessibility

Upfitter-installed wiring connections should be accessible during vehicle assembly operations. Recommended locations are those where the wiring connectors are completely visible and easily accessed by the operator. Whenever possible, avoid "blind" connections which prevent the operator from seeing the connection and using both hands to make the connection.

Appearance

All Upfitter-added wiring, in the vehicle passenger compartment, should be visually hidden from the customer's normal line of sight.

The appearance of visually exposed wiring in the engine compartment of GM vehicles is important in that it can convey either a positive or negative quality connotation. GM recommends the following guidelines be followed when Upfitters add visually exposed wiring in the engine compartment of GM vehicles:

- Every effort should be made to hide all wiring from the normal line of sight of the customer.
- All wiring that cannot be hidden should be covered with black colored conduit or tape.
- All visually exposed electrical connectors, TPA and CPA devices should be black or dark gray in color.
- Every effort should be made to route visually exposed electrical wiring either parallel to or perpendicular to engine and/or body sheet metal lines.
- Identification tape, attached to wiring and/or connectors, should be removed prior to shipping the vehicle, if it will be in the customer's normal line of sight.

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Electrical System – Installation Guidelines (cont'd)

WIRE FASTENING GUIDELINES

All Upfitter-added wiring should be positively fastened to prevent pinching, entrapment, misrouting or other conditions that could lead to potential electrical problems. Use ties, clips, clamps or other fasteners to secure wires in their intended locations, away from areas that would expose them to damage during assembly operations.

Additional recommendations are:

- Develop and establish procedures that ensure the correct and consistent selection, use, quantity and placement of wiring fasteners within the vehicle.
- Use "stick-on" wiring clips capable of maintaining adhesive qualities for a minimum of 10 years, over a temperature range of –40°C (40°F) to +85°C (185°F).
- Apply stick-on wiring clips only to surfaces that are clean and free from debris. This will assure that their adhesive qualities are not compromised.
- GM strongly recommends against the practice of using tape as the primary method of securing wires to the body sheet metal. Doing so will generally result in an unacceptable process due to uncontrolled production variations. If tape is used as an auxiliary or secondary means of attachment, it must be capable of maintaining its adhesive qualities for a minimum of ten years, over a temperature range of –40°C (40°F) to +85°C (185°F) and should be applied only to surfaces that are clean, dry and free of dirt or other contaminants that could prevent permanent adhesion.
- When using profile conduit to route and retain the wiring within the vehicle, positively fasten the conduit — not the wiring — to the vehicle structure.
- Make sure to securely fasten and insulate all Upfitter-adding wiring from all hard vehicle surfaces. This will prevent squeaks and rattles during normal vehicle operation. Taping wires to the body structure, to prevent squeaks and rattles, is not recommended.

WIRE AND ELECTRICAL COMPONENT PROTECTION GUIDELINES

Protecting wiring in a vehicle with some type of protective device reduces the possibility of several common electrical problems. For example, when a wire is cut, it is usually because it was not properly protected from a hostile surface. Similarly, when a wire is chafed or burned, it is common to find that it was rubbing against a sharp object or located too close to a heat source.

Protective Devices

Sometimes it is necessary to route unprotected wiring through a raw metal hole. In such cases, the hole should be edged with either a wiring grommet or hole edge protector. Taping the raw metal edges will not adequately protect the wiring.

Wiring grommets and wiring pass-through devices, used to channel wiring between the passenger compartment and the vehicle's exterior must seal both the hole in the sheet metal and the area around the wire. This prevents moisture and noxious fumes from entering the vehicle. Grommet mounting surfaces should be flat and free of contaminants that could prevent a positive seal.

When it is impossible to avoid routing wire near a radiant heat source, use heat shields, heat reflective tape and/or heat-retardant conduit to protect the wiring. See "Wire Routing Guidelines" section.

Exterior wiring (i.e., in the lower half of the engine compartment, exterior wheel wells and underbody areas) is highly vulnerable to damage from stones, sand, dirt, water and road debris. To protect wiring in these areas, install splash or debris shields. See "Wire Routing Guidelines" section.

Wire paths, especially vehicle floor areas, should be clean and free of foreign objects and debris (i.e., metal shavings from cutting and drilling operations, lost screws, etc.). If it is not possible to thoroughly clean the vehicle prior to wiring, use a hard-surfaced conduit or other means to protect the wiring.

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Electrical System – Grounding Guidelines

Externally mounted electrical devices such as opera lamps, relays, fuse holders, circuit breakers, etc., should be environmentally sealed or incorporate a sealing gasket. This will prevent potential corrosion of electrical contacts and the subsequent electrical failure of the device.

Upfitter-added relays, switches, electric/electronic modules and/or similar devices, that maintain a "B+" potential, should be mounted and/or shielded in such a way as to prevent water from accidently entering the device. Water entry could cause the device to short circuit internally and result in a thermal incident. GM recommends that these types of devices be mounted with their terminals facing downward and that the connecting wiring harness incorporate a water drip loop.

GROUNDING GUIDELINES

- Proper grounding is important for quality electrical systems and protection from unwanted electrical feedback.
- Use GM-provided ground studs or connectors when possible. Refer to the appropriate Body Builder Manual for locations of these studs and connectors.
- Choose ground fasteners (studs, ring terminals, etc.) that are plated for corrosion resistance. Make sure that they are compatible with the ground material to minimize the possibility of galvanic corrosion. Ring terminals should have an anti-rotation feature. (See Figure 37).
- Do not use rivets or sheet metal screws to establish a ground connection.
- Make sure that all grounding surfaces are clean and free of paint, sealers and non-conductive materials.
- Make sure that all grounding surfaces are clean and free of paint, sealers and non-conductive materials.
- Avoid stacking ring terminals if possible. If stacking cannot be avoided, no more than two ring terminals should be stacked at any one location.
- As far as possible, locate ground attachments such that they are readily accessible to the service community.

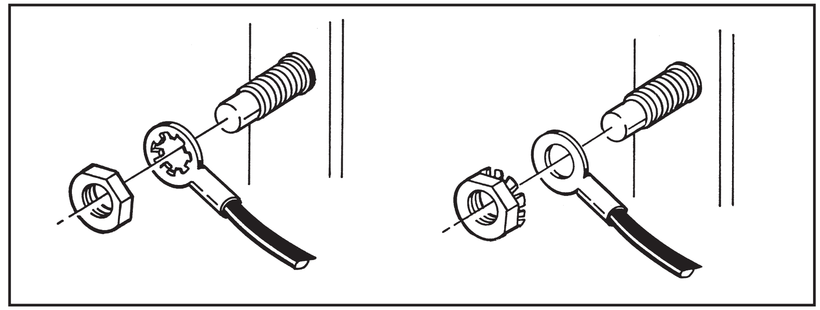

Figure 37

ISOLATION OF "CLEAN" AND "DIRTY" ELECTRICAL GROUNDS

For a circuit to power an electrical load it is necessary that there is a return path to ground from the load. In automotive applications, this ground is equivalent to the negative terminal on the battery. Depending on the type of load, the ground can be considered as either a "clean" or a "dirty" ground. If clean grounds are combined with dirty grounds, the loads with the clean grounds may not function correctly due to voltage and current transients from the dirty grounds. Also, the voltage drop from the dirty load can induce noise in the signals read by electronic modules. Serial data devices which use clean grounds may not work properly due to voltage offsets from dirty grounds. It is important to adequately isolate clean and dirty grounds in order minimize these effects.

Clean Grounds

Clean grounds can be characterized by the following:

- DC resistive loads with steady state currents less than 2 amps.
- Pulse-width-modulated (PWM) resistive loads, with peak "on" currents less than 2 amps.
- Speed sensors and other generators of variable frequency signals feeding high impedance resistive loads (less than 500 ohms).

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Electrical System – Grounding Guidelines (cont'd)

Clean Grounds (cont'd)

- DC lamp loads, with steady state currents less than 1 amp.
- PWM lamp loads, with peak “on” currents < 1 amp (not including inrush current).
- Serial data signals.

Dirty Grounds

- Resistive or lamp loads falling outside the “clean” boundaries described above.
- Any load that has either a capacitive or inductive component that would cause either “turn-on” transients (inrush currents), or “turn-off” transients (voltage spikes).
- Motor loads (except for small devices such as display stepper motors).
- Solenoid loads.

WELD NUTS, WELD STUDS, SCREW/WASHERS AND TERMINALS USED FOR GROUNDING

Weld Nuts

An M6 x 1 unthreaded weld nut and M6 x 1 x 20 hex head thread-rolling screw with flat washer (Taptite™ or equivalent) is recommended for body electrical grounding. These components are ideal for the welding and assembly processes, and provide a reliable ground path.

- A good weld (drawn Arc type) is made between the fastener and the base metal.
- The conductive contact area between the threads of the bolt and the nut must be adequate.
- There is enough joint clamp load in the joint to prevent loosening and loss of the conductive ground path.
- The proper weld schedules must be used.
- The grip length of the joint must be adequate to maintain clampload integrity.

If a weld nut can not be used, a surface weld stud with a loose nut should be used. The following conditions may prevent the use of a weld nut:

- Water or exhaust may intrude through through holes.
- Panel back side has no clearance for the weld nut.
- Panel back side has no access for nut attachment.

Weld Studs

The weld stud consists of an M6 x 1.0 x 21 stud with an M-Point coated with a conductive hexavalent chrome-free finish. The nut is part of the stud assembly, eliminating masking the threads and base of the stud and nut to prevent being coated by paint. The weld stud also has an anti-rotation feature which prevents the terminal from turning when tightened. Use weld studs only when a weld nut cannot be used. The preferred grounding method is the weld nut.

Washer

- The washer should have nominal outer diameter of 17 mm and a minimum thickness of 2 mm.
- The washer must be located under the screw's head.

Ground Terminal

A M6 thread-forming bolt with an unthreaded weld nut and an anti-rotation tab that fits into a hole in the sheet metal is the recommended ground terminal. This terminal should be able to withstand a 10 Nm dynamic torque without deforming the tab. A maximum of two terminals should be stacked in one location. The second terminal does not have a tab and should be located between the tabbed terminal and the body. If one wire is a larger gage than the other, the larger gage wire should be placed in the tabbed terminal.

Electrical System – Customer Convenience

OEM COMPONENT LOCATION GUIDELINES

Upfitters should never relocate OEM electrical components such as batteries, fuse centers, junction blocks, relays, ECMs, PCMs, VCMs, electronic modules, ground screws, etc., for the sake of facilitating their build process. Approval should be sought from an Upfitter Integration team member in the event that an Upfitter feels there is an absolute necessity to relocate one of these components.

CUSTOMER CONVENIENCE

Customer convenience is of primary concern and importance when designing and installing electrical systems.

FUNCTION MARKING

It is recommended that the function (e.g., power sofa) and operating parameters (e.g., on/off, up/ down) of each added electrical switch be permanently printed on the switch, switch bezel or switch escutcheon plates.

LOCATION IDENTIFICATION

Upfitter owner manuals should include information on the location of all added fuses, listing the amperage rating of each fuse. If a fuse block has been added to the vehicle, it is also recommended that an illustration of the front of the fuse block be shown in the owner's manual.

INSTRUCTIONS

Upfitters should provide the customer with a "convenience packet" containing operating instructions for all added electrical accessories (i.e., TVs, VCPs, radios, cassette tape players, etc.).

DOCUMENTATION

Upfitters should provide the selling dealer and/or the buying customer with documentation or a means of obtaining documentation which, at minimum, contains the following:

- Basic schematic drawings of Upfitter-added electrical systems (see Figure 38)
- A list of cable (wire) color, gauge, function and circuit protection for all added electrical circuits (see Figure 39)
- A diagram illustrating the location of all added wiring within the vehicle (see Figure 40)
- A list of maximum additional loads (in amperes) that can be added to Upfitter circuits

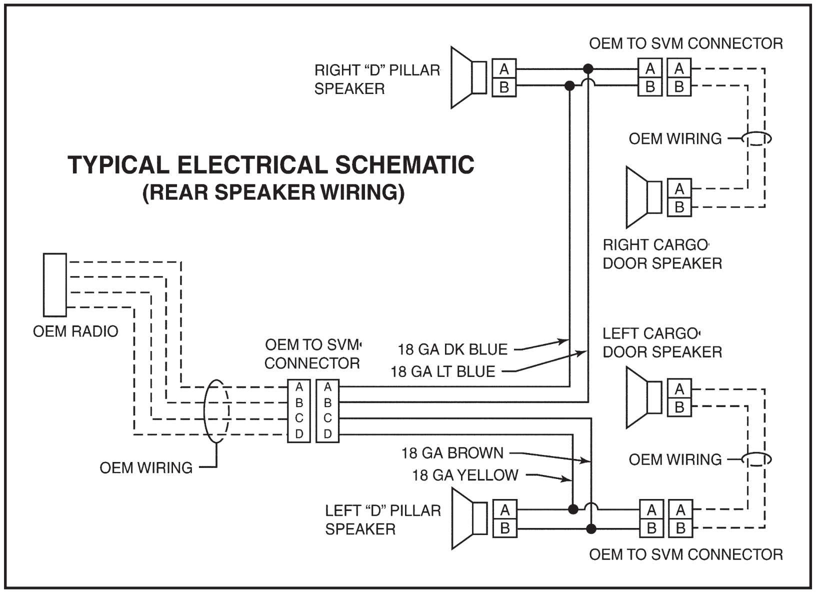

Figure 38

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Electrical System – Customer Convenience (cont'd)

ELECTRICAL WIRING SYSTEM DATA								
CIRCUIT DESCRIPTION				WIRE		CIRCUIT PROTECTION		
No.	Function	Origin	Draw	Size	Color	Type	Rating	Location
1	Drivers power seat feed	OEM I/P connector	12 amps	12 GA	Red	C/B	25 amp	OEM fuse panel
2	Video cassette player feed	SVM fuse panel	4 amps	18 GA	Pink	Fuse	7.5 amp	SVM fuse panel
20	Opera lamp feed	OEM "B" pillar connector	3 amps	18 GA	Brown	Fuse	20 amp	OEM fuse panel

NOTE: The data listed in the above chart is for illustration purposes only and does not necessarily reflect actual circuit data.

Figure 39

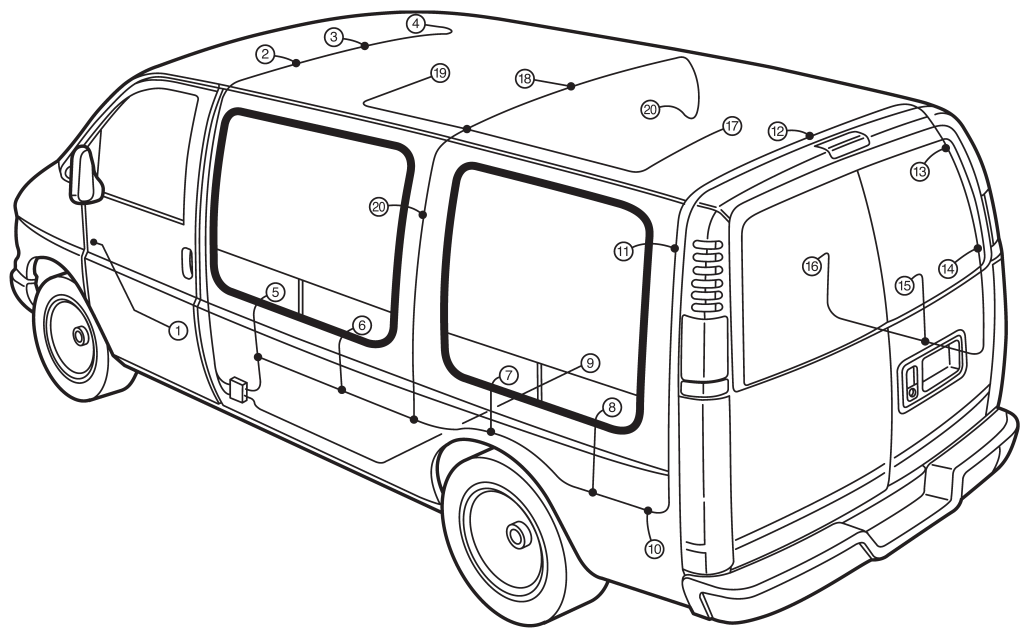

Figure 40

(continued on next page)

Electrical System – Headlamp/Foglamp Guidelines

HEADLAMP AIMING

The Upfitter is responsible for aiming all headlamps on GM vehicles they convert prior to shipping the vehicle. Headlamps can be aimed using one of two methods:

- Mechanical aimer method
- Aiming screen method

! For headlamps incorporating both high and low beams in one combination lamp, aiming is required only for the low beams.

! Refer to the applicable GM Service Manual for specific headlamp aiming procedures.

Electrical System – SIR Precautions

Caution: When performing service on or near the SIR components or the SIR wiring, the SIR system must be disabled. Refer to SIR Disabling and Enabling . Failure to observe the correct procedure could cause deployment of the SIR components, personal injury, or unnecessary SIR system repairs.

The inflatable restraint sensing and diagnostic module (SDM) maintains a reserved energy supply. The reserved energy supply provides deployment power for the air bags. Deployment power is available for as much as 1 minute after disconnecting the vehicle power. Disabling the SIR system prevents deployment of the air bags from the reserved energy supply.

SIR Disabling and Enabling

SIR component location affects how a vehicle should be serviced. There are parts of the SIR system installed in various locations around a vehicle. To find the location of the SIR components refer to SIR Identification Views .

There are several reasons for disabling the SIR system, such as repairs to the SIR system or servicing a component near or attached to an SIR component. There are several ways to disable the SIR system depending on what type of service is being performed. The following information covers the proper procedures for disabling/enabling the SIR system.

Condition	Action
If the vehicle was involved in an accident with an air bag deployment	Disconnect the negative battery cable(s)* Refer to Repairs and Inspections Required After a Collision in the appropriate service manual.
When performing SIR diagnostics.	Follow the appropriate SIR service manual diagnostic procedure(s)*
When removing or replacing an SIR component ora component attached to an SIR component.	Disconnect the negative battery cable(s)*
If the vehicle is suspected of having shorted electrical wires.	Disconnect the negative battery cable(s)*
When performing electrical diagnosis on components other than the SIR system.	Remove the SIR/Air bag fuse(s) when indicated by the diagnostic procedure to disable the SIR system.

** DTCs will be lost when the negative battery cable is disconnected.*

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Electrical System – SIR Disabling and Enabling

SIR Identification Views

The SIR Identification Views shown below illustrate the approximate location of all SIR components available on the 2009 G/H Van. For other models, refer to the appropriate GM Service Manual.

Example Shown: 2009 Chevrolet Express / GMC Savana

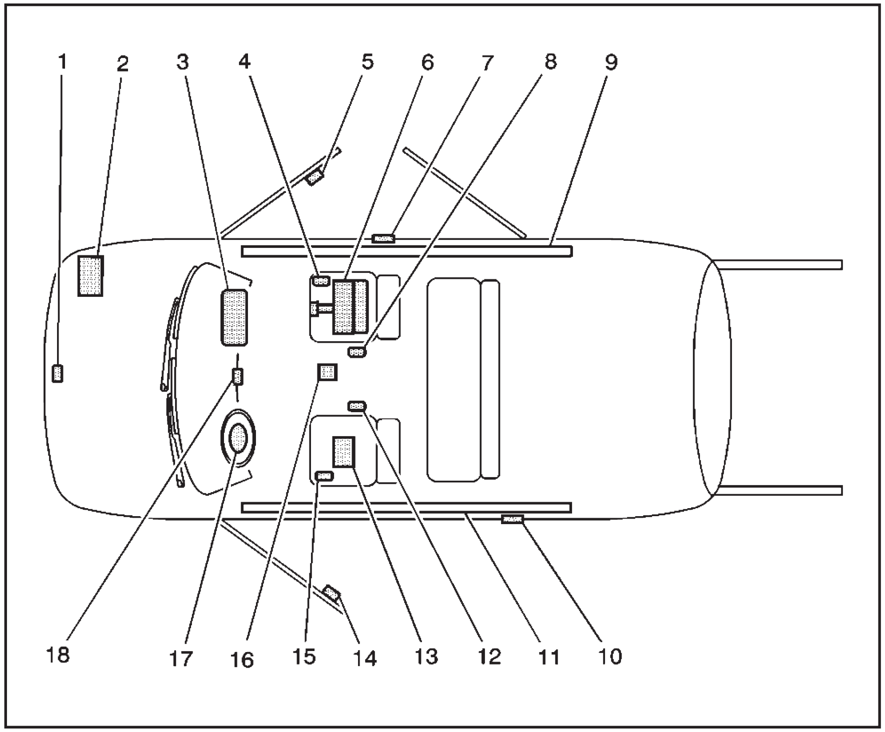

Figure 54

1. **Impact Sensor, Front** – Located under the hood on the bottom side of the radiator support, center of vehicle
2. **Vehicle Battery** – Located in the engine compartment on the passenger side I/P Air Bag – Located at the top right under the instrument panel
3. **I/P Air Bag** – Located at the top right under the instrument panel
4. **Seat Position Sensor, Passenger** – Located underneath the seat mounter to cross seat beam
5. **Side Impact Sensor (SIS), RF** – Located inside of front right door
6. **Passenger Presence System** – Located on the front passenger seat under the seat bottom trim
7. **Side Impact Sensor (SIS), RR** – Located near the side step under door step mat
8. **Seat Belt Buckle Pretensioner, Passenger** – Located left side of front passenger seat
9. **Inflator Module for Roof Rail Air Bag** – Either a LF located behind roof headliner for the passenger and side door or two inflator modules, a LF for the front passenger and a LR the side door
10. **Side Impact Sensor (SIS), LR** – Located LH side, inside vehicle, forward of wheel well
11. **Inflator Module for Roof Rail Air Bag, LF** – Located behind roof headliner on left side of vehicle
12. **Seat Belt Buckle Pretensioner, Driver** – Located right side of driver seat
13. **Sensing and Diagnostic Module (SDM)** – Located underneath the vehicle carpet under the center console
14. **Side Impact Sensor (SIS), LF** – Located inside of front left door
15. **Seat Position Sensor, Driver** – Located underneath the seat mounter to cross seat beam
16. **Rollover Sensor** – Located between front seats under carpet
17. **Steering Wheel Air Bag** – Located on the steering wheel
18. **I/P module Indicator and I/P Module Disable Switch** – Located near radio as a switch bank

(continued on next page)

Electrical System – SIR Disabling and Enabling (cont'd)

General Service Instructions

The following are general service instructions which must be followed in order to properly repair the vehicle and return it to its original integrity:

- Do not expose inflator modules to temperatures above 65ºC (150ºF)
- Verify the correct replacement part number. Do not substitute a component from a different vehicle.
- Use only original GM replacement parts available from your authorized GM dealer. Do not use salvaged parts for repairs to the SIR system.

Discard any of the following components if it has been dropped from a height of 91 cm (3 feet) or greater:

- Inflatable restraint sensing and diagnostic module (SDM)
- Any Inflatable restraint air bag module
- Inflatable restraint steering wheel module coil
- Any Inflatable restraint sensor
- Inflatable restraint seat belt pretensioners
- Inflatable restraint Passenger Presence System (PPS) module or sensor

Disabling Procedure - Air Bag Fuse

1. Turn the steering wheel so that the vehicles wheels are pointing straight ahead.
2. Place the ignition in the OFF position.
3. Locate and remove the fuse(s) supplying power to the SDM. Refer to SIR Schematics or Electrical Center Identification Views in appropriate service manual.
4. Wait 1 minute before working on the system.

Important: The SDM may have more than one fused power input. To ensure there is no unwanted SIR deployment, personal injury, or unnecessary SIR system repairs, remove all fuses supplying power to the SDM. With all SDM fuses removed and the ignition switch in the ON position, the AIR BAG warning indicator illuminates. This is normal operation, and does not indicate an SIR system malfunction.

Enabling Procedure - Air Bag Fuse

1. Place the ignition in the OFF position.
2. Install the fuse(s) supplying power to the SDM. Refer to SIR Schematics or Electrical Center Identification Views in appropriate service manual.
3. Turn the ignition switch to the ON position. The AIR BAG indicator will flash then turn OFF.
4. Perform the Diagnostic System Check - Vehicle if the AIR BAG warning indicator does not operate as described. Refer to Diagnostic System Check - Vehicle in appropriate service manual.

Disabling Procedure - Negative Battery Cable

1. Turn the steering wheel so that the vehicles wheels are pointing straight ahead.
2. Place the ignition in the OFF position.
3. Disconnect the negative battery cable from the battery.
4. Wait 1 minute before working on system.

Enabling Procedure - Negative Battery Cable

1. Place the ignition in the OFF position.
2. Connect the negative battery cable to the battery.
3. Turn the ignition switch to the ON position. The AIR BAG indicator will flash then turn OFF.
4. Perform the Diagnostic System Check - Vehicle if the AIR BAG warning indicator does not operate as described. Refer to Diagnostic System Check - Vehicle in appropriate service manual.

(continued on next page)

Electrical System – SIR Disabling and Enabling (cont'd)

Enabling Procedure - Negative Battery Cable

1. Place the ignition in the OFF position.
2. Connect the negative battery cable to the battery. Refer to Battery Negative Cable Disconnection and Connection .
3. Turn the ignition switch to the ON position. The AIR BAG indicator will flash then turn OFF.
4. Perform the Diagnostic System Check - Vehicle if the AIR BAG warning indicator does not operate as described. Refer to Diagnostic System Check - Vehicle .

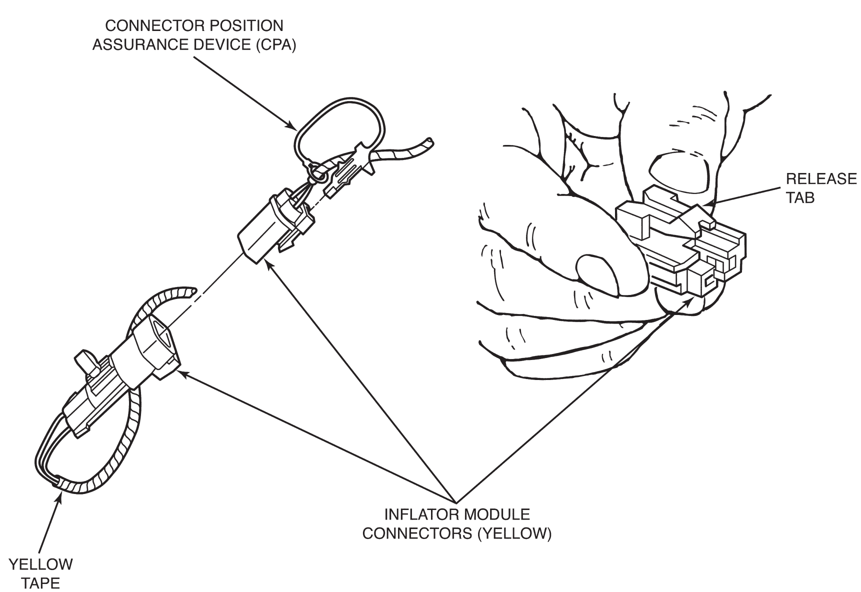

Figure 53

WELDING PRECAUTIONS

To avoid damaging the OEM electrical system or components during welding procedures, GM recommends the following precautionary measures:

- Do not route welder electrical cables on, near or across any vehicle electrical wiring or components while welding is in progress.
- Remove or adequately shield any electrical or electronic components which can be damaged by excessive temperatures created by the welding operation.
- Protect all wiring and electrical components from damage that can be caused by welding flash (sparks).
- Make sure that the welder ground clamp is of an adequate size and placed as close as possible to the area being welded. Never use a vehicle suspension component as a welding ground point.
- Prior to any welding, disconnect all battery negative cables.
- Disable the air bag system as outlined in the “SIR Service Precautions” section of this manual.
- Disconnect any electrical/electronic computer modules located near the area to be welded.

After welding is complete, carefully inspect any electrical wiring or components in the weld area for degradation or damage.

HIGH VOLTAGE PRECAUTIONS

Caution labels should be affixed to all electrical components, such as inverters, wiring harnesses, electroluminescense lighting devices, etc., that either produce, transmit or operate on elevated voltages (usually 110 volts).

Electrical System – Appendix I

GLOSSARY OF TERMS AND DEFINITIONS

Accessible: Capable of being removed or exposed without damaging the vehicle or its finished interior or exterior surfaces.

Ampacity: The maximum current, expressed in amperes, that a conductor can carry on a continuous basis without exceeding the insulation's temperature rating (ampere capacity).

Ampere: A unit of electrical current equivalent to a steady current produced by one volt applied across a resistance of one ohm.

ANSI: American National Standards Institute

Approved: Acceptable to the "authority having jurisdiction."

Automatic: A device that is self-acting, that operates by its own mechanism reacting to an outside stimulant such as application/ loss of current, change in current strength, pressure, or mechanical configuration.

Auxiliary battery: A secondary device for the storage of low-voltage energy.

AWG: American Wire Gauge

Battery: A device for storage of low-voltage electrical energy.

Butt splice: A device used to join two wires together.

Cable: See "wire."

Cable seal: A device to environmentally protect a connection system.

Cavities: The areas within a connector which hold the terminals. There is one cavity for each terminal in the connector.

Circuit: The complete path of electric current to and from its power source.

Circuit breaker: A device designed to open a circuit automatically on a predetermined overcurrent, without damage to itself, when properly applied within its rating.

Circuit segment: Any portion of a path of electric current for which a specific purpose or function exists.

CMA: Circular Mil Area

CMVSS: Canadian Motor Vehicle Safety Standards

Component: Any material, fixture, device, apparatus or similar item used in conjunction with, or that becomes part of, the completed electrical system installation.

Conductive: Capable of conducting electrical energy.

Conductor: Anything that provides a path for electric current.

Conduit: A tube or trough for protecting wires or cables.

Connection system: A group of parts the purpose of which is to make an electrical connection between wires or wire harness assemblies and is mechanically detachable.

Connector: A molded plastic device that houses one or more terminals and fastens or joins one or more conductors together and provides the mechanical connection in the connector system.

Connector seal: A device to environmentally protect a connection system.

Conversion vehicle: A vehicle that contains the permanent addition to, or modification of, any item or system from its original state as supplied by the original equipment manufacturer (OEM). This includes the addition of separate, fully independent systems that were not present in the vehicle as supplied by the OEM.

Conversion wiring system: Any wiring or wiring system installed or provided by the vehicle modifier.

(continued on next page)

Electrical System – Appendix I

Converter: A modifier of an OEM vehicle.

Core: The conductive portion of a wire (usually copper).

Core wings: The part of a terminal which is crimped to the wire core to make an electrical connection between the wire and terminal.

CPA lock: Connector position assurance lock; a plastic tab that can be inserted through a hole in the inertia lock which provides a redundant connector locking device.

Dash panel: The partition that separates the engine compartment of a vehicle from the vehicle passenger compartment; sometimes referred to as the "firewall."

Device: Any item of the electrical system, other than conductors or connectors, that carries or utilizes electrical current to perform a function.

ECM: Engine Control Module.

Equipment: Any material, device, appliance, fixture, etc., used as part of, or in connection with, the electrical system.

Exposed: Unprotected from inadvertent contact by another component, part or item.

FMVSS: Federal Motor Vehicle Safety Standards

Fuse: A specifically rated overcurrent protective device that incorporates a circuit-opening fusible part that is severed by the heat generated by the overcurrent passing through it.

Fuseblock: Two or more fuseholders sharing the same mounting base, but not necessarily the same power source.

Fuseholder: A device in which a single fuse is securely held, providing isolation of the source conductor from the distributing conductor.

GPT: General purpose thermoplastic; PVC insulated wire.

Grounded: A conducting connection between an electrical circuit or component and ground.

GXL: General purpose cross-linked (polyethylene insulated wire).

Harness: A grouping of electrical conductors provided with a means to maintain their grouping.

Incomplete vehicle: An assemblage consisting, as a minimum, of frame and chassis structure, powertrain, steering system, suspension system, and braking system, to the extent that those systems are to be part of the completed vehicle, that requires further manufacturing operations.

Indexing feature: Mechanical feature of a connector (usually a tab and slot) which allows connectors to be mated in only one way.

Inductive load: Any device (motors, magnetic solenoid, etc.) that utilizes a process by which electrical energy is used to create magnetic forces.

Inertia lock: The locking device on a connector that keeps connectors together once mated.

Insulated: Protected with a non-conductive coating.

Isolated circuitry: A wiring system with distribution and overcurrent protection totally separate and independent from the vehicle's OEM wiring system.

Locking tang: Metal tab(s) on a terminal that locks the terminal in the connector cavity.

Low voltage: An electromotive force rated 24 volts, nominal or less, generally 12 volts in automotive applications.

OEM: Original Equipment Manufacturer; in this case, General Motors.

Ohm: A unit of electrical resistance equal to the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.

(continued on next page)

Electrical System – Appendix I (cont'd)

Open circuit: Condition by which electrical continuity is disrupted or broken in an electrical circuit.

Overcurrent: Any current that exceeds the rated current of equipment or ampacity of a conductor. Overcurrent may result from overload, short circuit or ground fault.

Overcurrent protection device: A device, such as a fuse or circuit breaker, designed to interrupt the circuit when the current flow exceeds a predetermined value.

Parasitic load: A small, continuous electrical draw on the battery.

PCM: Powertrain Control Module.

Pigtail: External conductors (wire leads) that originate within an electrical component or device.

Power source: The specific location or point that electrical current is obtained to supply the conversion wiring system.

Rating: Value that determines the current or voltage carrying capacity of a conductor or device.

Rating maximum: The point of highest current that a circuit breaker or fuse is intended to interrupt at under specified test conditions.

Ring terminal: Part used to connect wiring leads to threaded studs or directly to sheet metal. Also see “Terminal.”

RVIA: Recreation Vehicle Industry Association

SAE: Society of Automotive Engineers

Sealed: Closed or secured tightly for protection from environmental factors such as moisture or noxious fumes.

Secondary lock or TPA lock: Terminal position assurance lock; a separate or hinged part of a connector which prevents terminals from pulling out of the back of the connector.

Short circuit: A connection of comparatively low resistance accidentally or intentionally made between points in an electric circuit.

SIR: Supplemental Inflatable Restraint (air bag system).

Splice: A means of joining one or more conductors (wires).

Splice clip: A device used to facilitate splicing three or more wires.

Upfitter: Special Vehicle Manufacturer. The manufacturer or converter that installs additional equipment or modifies any item or system from its original state as supplied by the original equipment manufacturer (OEM).

Terminal: A metal device at the end of a wire or device which provides the electrical connection. Terminals are referred to as either male or female.

TPA lock: Terminal position assurance lock. Prevents a terminal from backing out of a connector. Thermally protected: A device provided with a means of protection that opens the circuit’s source of current when excessive heat is generated.

Unsealed: Not closed or secured for protection from environmental factors.

VCM: Vehicle Control Module.

Volt: A unit of electromotive force equal to a force that, when steadily applied to a conductor with a resistance of 1 ohm, produces a current of 1 ampere.

Waterproof: Constructed to prevent moisture from entering the enclosure under specified test conditions.

Weatherproof: See “Waterproof.”

Wire: An electronically conductive core material (usually made of copper) covered with a nonconductive insulating material. Also referred to as “lead” or “cable.”

Wire nut: A twist-on wiring connector/insulator not designed for automotive use.

Electrical System – Appendix II – Connecting Terminology

CONNECTING TERMINOLOGY

Connection system: A group of parts the purpose of which is to make an electrical connection between wires or wiring harness assemblies and is mechanically detachable.

Wire: An electronically conductive core material (usually copper) covered with a non-conductive insulation. Also referred to as "lead" or "cable."

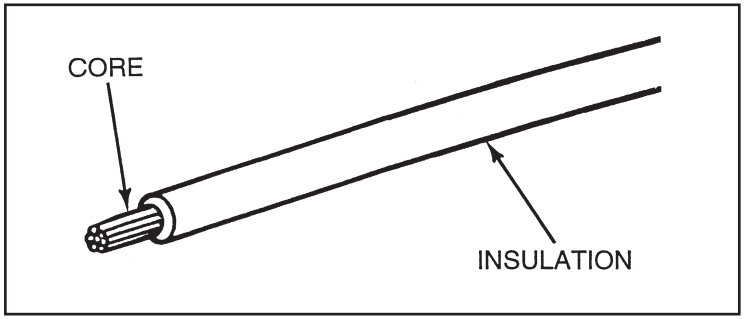

Figure 54

Connector: A plastic molded part which houses one or more terminals and provides the mechanical connection in the connection system.

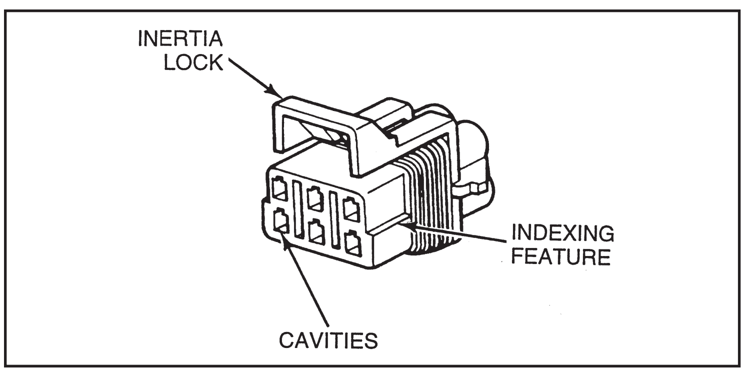

Figure 55

Indexing feature: A mechanical feature of a connector (usually a tab and slot) which allows connectors to be mated in only one way.

Inertia lock: A locking device on a connector that keeps connectors together once mated.

Cavities: Areas within a connector which hold the terminals. There is one cavity for each terminal in the connector.

Terminal: Metal part attached (crimped) to the end of a wire which provides the electrical connection. Terminals are referred to as either "male" or "female."

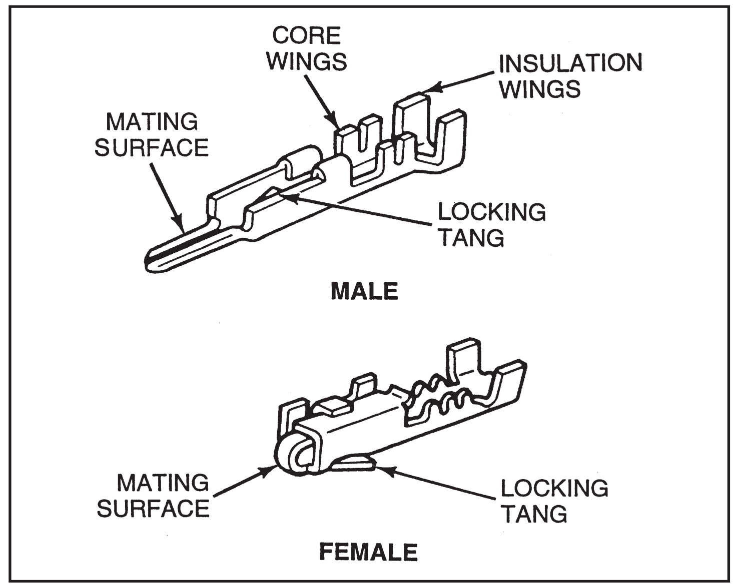

Figure 56

Core wings: A part of the terminal which is crimped to the wire core to make an electrical connection between the wire and the terminal.

Insulation wings: A part of the terminal which is crimped to the wire insulation to provide added retention strength, strain relief for the core crimp, and in a sealed system, to hold the cable seal.

(continued on next page)

Electrical System – Appendix II – Connecting Terminology

Locking tang: A metal tab on a terminal that locks the terminal in the connector cavity.

Secondary lock or TPA lock: Terminal position assurance lock; a separate or hinged part of a connector which helps keep terminals from pulling out of the back of the connector.

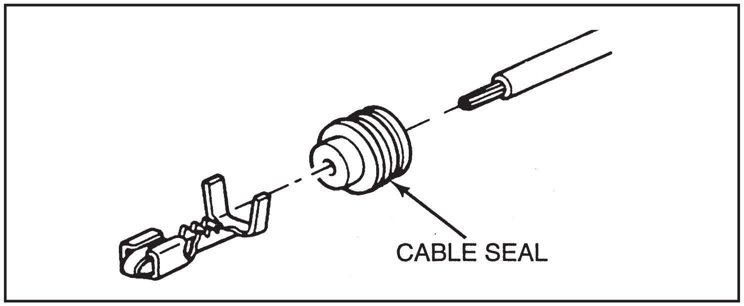

Figure 57

CPA lock: Connector position assurance lock; a plastic tab that can be inserted through a hole in the inertia lock which provides a redundant lock between connectors and ensures proper mating.

Cable seal: Three-ribbed seal that is attached to a wire and provides environmental protection in a connection system.

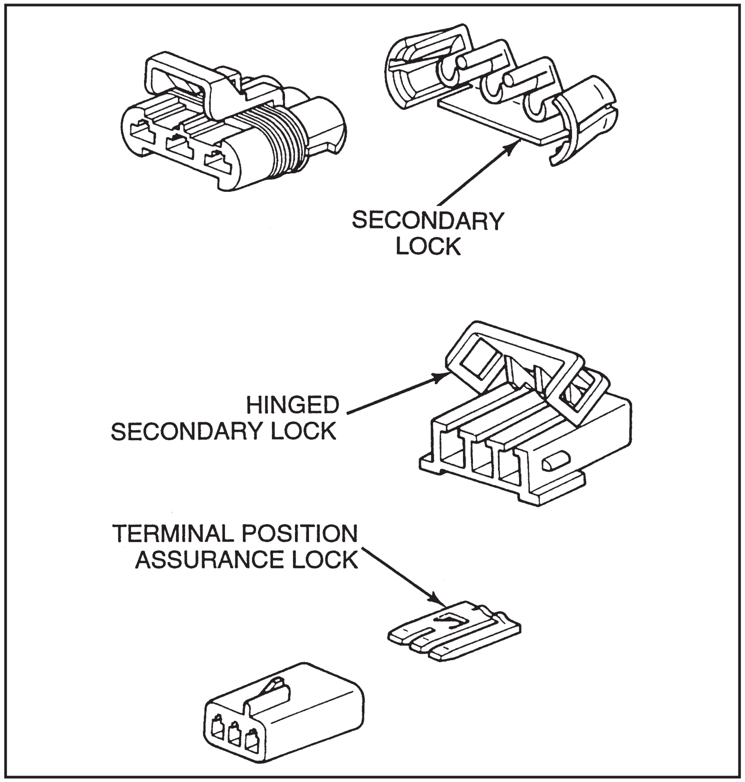

Figure 58

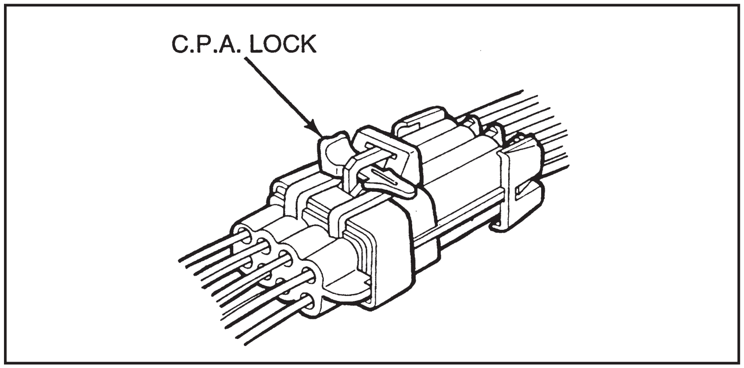

Figure 59

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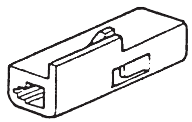
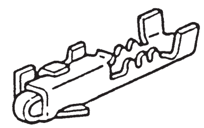
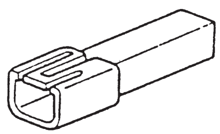
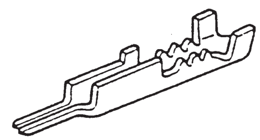
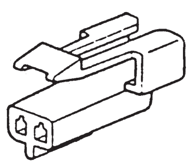
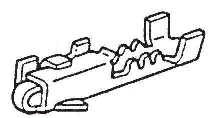
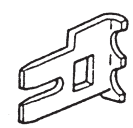
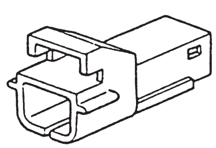
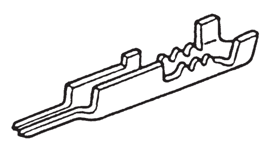
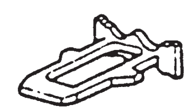
Electrical System – Appendix II – Unsealed Connection Systems

METRI-PACK 150 SERIES 1 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12047682		None
 Male - 12047683		None

METRI-PACK 150 SERIES 2 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12052832		 12047664
 Male - 12052833		 12047665

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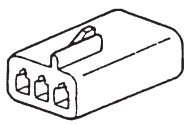
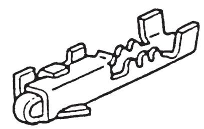
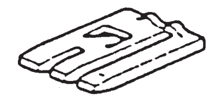
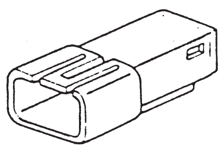
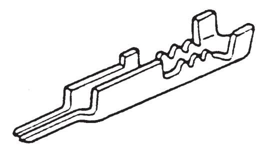
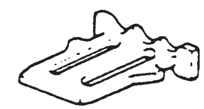
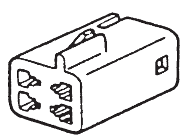
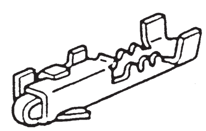
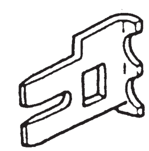
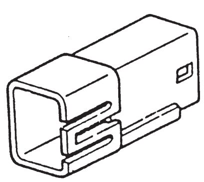
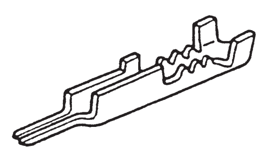
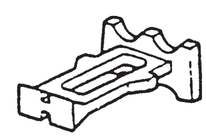
Electrical System – Appendix II – Unsealed Connection Systems (cont'd)

METRI-PACK 150 SERIES 3 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12047781		 12047783
 Male - 12047782		 12047784

METRI-PACK 150 SERIES 4 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12047785		 12047664 (2 reqd)
 Male - 12047786		 12047787

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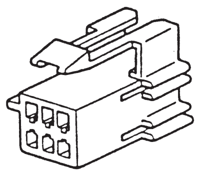
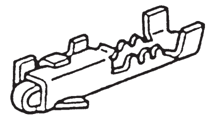
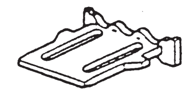
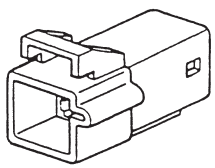
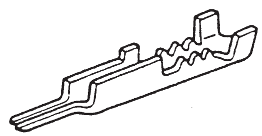
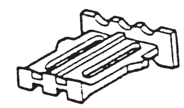
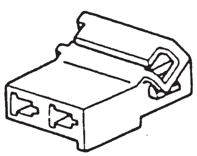
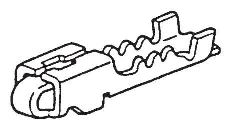
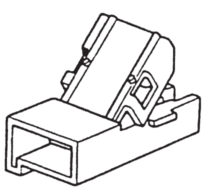
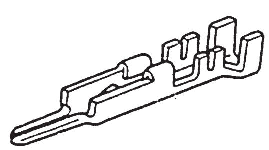
Electrical System – Appendix II – Unsealed Connection Systems (cont'd)

METRI-PACK 150 SERIES 6 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12064762		 12064764 (2 reqd)
 Male - 12064763		 12064765

METRI-PACK 280 SERIES 2 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12034343		Hinged (part of connector)
 Male - 12034344		Hinged (part of connector)

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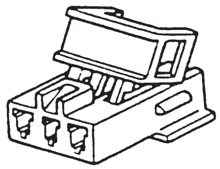
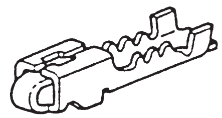
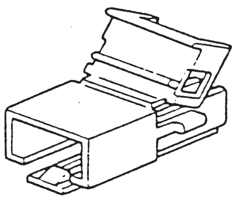
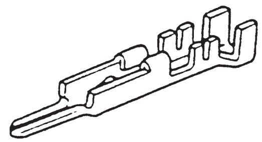
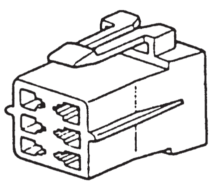
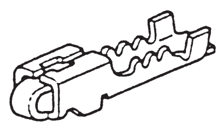
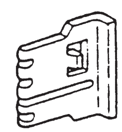
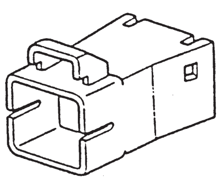
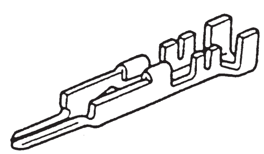
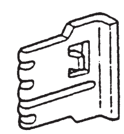
Electrical System – Appendix II – Unsealed Connection Systems (cont'd)

METRI-PACK 280 SERIES 3 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12020397		Hinged (part of connector)
 Male - 12020398		Hinged (part of connector)

METRI-PACK 280 SERIES 6 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12064752		 12064753
 Male - 12064754		 12064755 (2 reqd)

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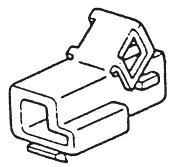
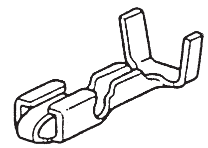
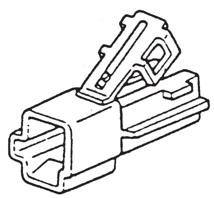
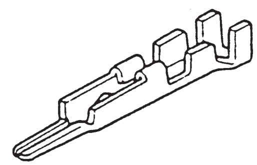
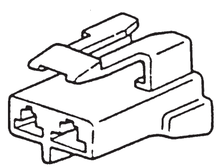
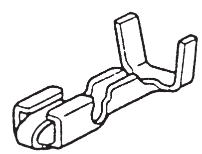
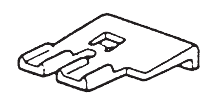
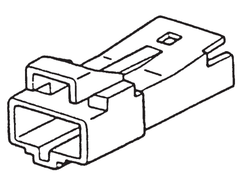
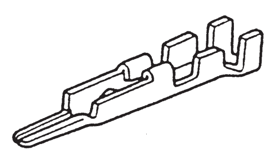
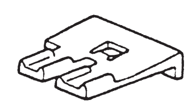
Electrical System – Appendix II – Unsealed Connection Systems (cont'd)

METRI-PACK 480 SERIES 1 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12015952		Hinged (part of connector)
 Male - 12015987		Hinged (part of connector)

METRI-PACK 480 SERIES 2 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12064749		 12059860
 Male - 12064750		 12064751

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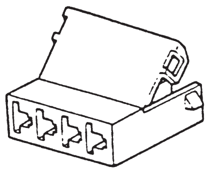
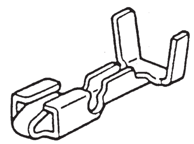
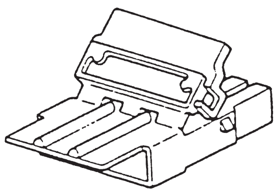
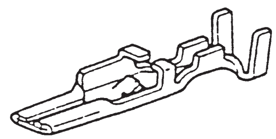
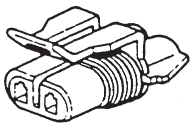
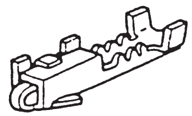
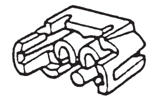
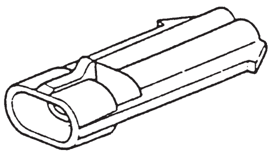
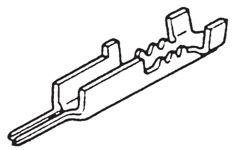
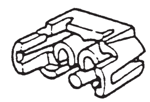
Electrical System – Appendix II – Unsealed Connection Systems (cont'd)

METRI-PACK 630 SERIES 4 CAVITY

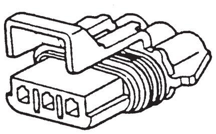
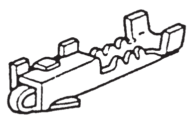
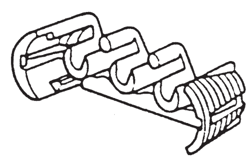
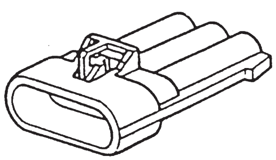
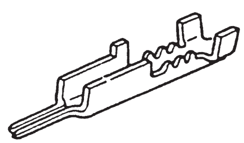
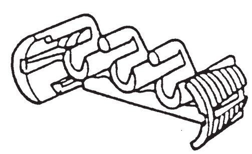
CONNECTOR	TERMINALS	SECONDARY LOCK
 Female - 12015664		Hinged (part of connector)
 Male - 12034295		Hinged (part of connector)

Electrical System – Appendix II – Sealed Connection Systems

METRI-PACK 150 SERIES 2 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK	CABLE SEALS
 Female - 12052641		 12052634	
 Male - 12162000		 12052634	

METRI-PACK 150 SERIES 3 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK	CABLE SEALS
 Female - 12110293		 12052845	
 Male - 12129615		 12052845	

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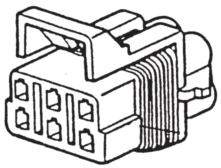
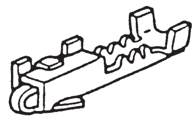
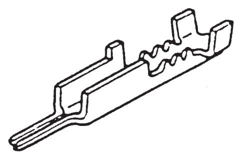
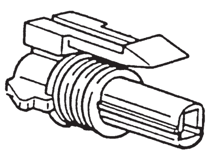
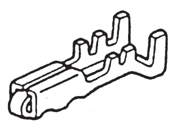
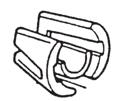
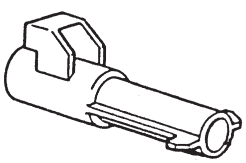
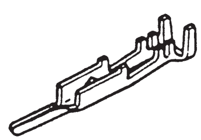
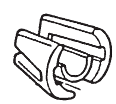
Electrical System – Appendix II – Sealed Connection Systems (cont'd)

METRI-PACK 150 SERIES 6 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK	CABLE SEALS
 Female - 12052848		12052850	
Male - 12124107		12052850	

METRI-PACK 280 SERIES 1 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK	CABLE SEALS
 Female - 12065172		 12065249	
 Male - 12065171		 12065249	

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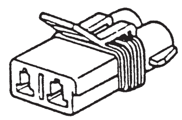
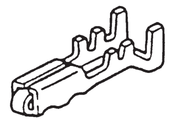
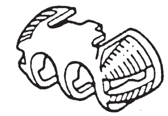
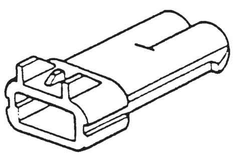
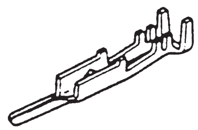
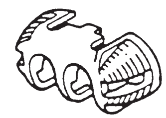
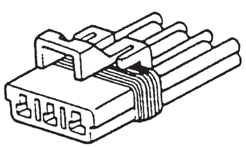
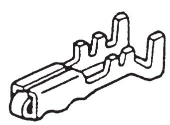
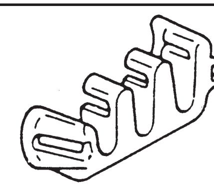
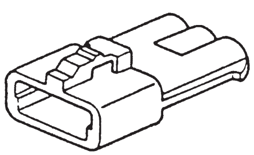
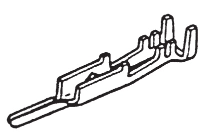
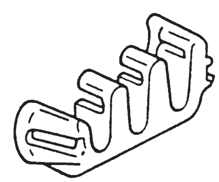
Electrical System – Appendix II — Sealed Connection Systems (cont'd)

METRI-PACK 280 SERIES 2 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK	CABLE SEALS
 Female - 15300027		 15300014	
 Male - 15300002		 15300014	

METRI-PACK 280 SERIES 3 CAVITY

CONNECTOR	TERMINALS	SECONDARY LOCK	CABLE SEALS
 Female - 12040977		 12034145	
 Male - 15300003		 15300015	

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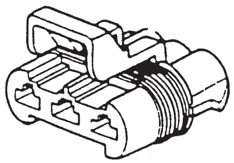
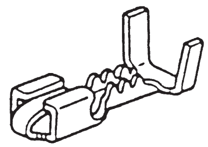
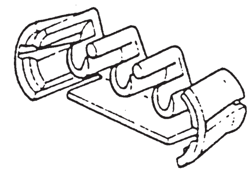
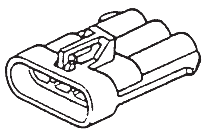
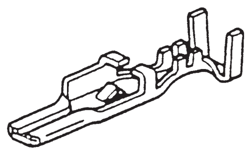
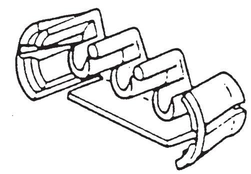
Electrical System – Appendix II – Sealed Connection Systems (cont'd)

METRI-PACK 630 SERIES 3 CAVITY

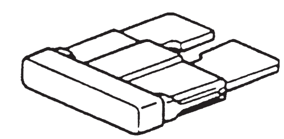
CONNECTOR	TERMINALS	SECONDARY LOCK	CABLE SEALS
 Female - 15300027		 15300014	
 Male - 15300002		 15300014	

Electrical System – Appendix II – Fuses

ATO FUSE

Characteristics:

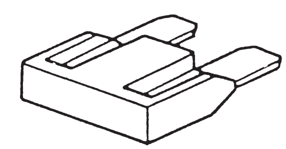
- Common automotive fuse, widely available for use in both a sealed or unsealed connection system.

AMPERE RATING	FUSE COLOR	GM PART NUMBER	LITTLEFUSE PART NUMBER	ATO FUSE GRAPHIC
3	VIOLET	12004003	0257003.PXOCR	
5	TAN	12004005	0257005.PXOCR	
7.5	BROWN	12004006	0257007.PXOCR	
10	RED	12004007	0257010.PXOCR	
15	LIGHT BLUE	12004008	0257015.PXOCR	
20	YELLOW	12004009	0257020.PXOCR	
25	NATURAL	12004010	0257025.PXOCR	
30	LIGHT GREEN	12004011	0257030.PXOCR	

MAXI FUSE

Characteristics:

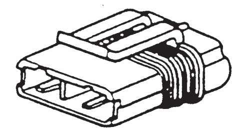
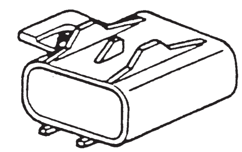
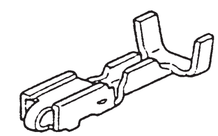
- Designed to replace fusible links – slower blow time than ATO Fuses
- Higher current fuses

AMPERE RATING	FUSE COLOR	GM PART NUMBER	LITTLEFUSE PART NUMBER	MAXI FUSE GRAPHIC
20	YELLOW	12065931	0299020.PXOCR	
30	GREEN	12065932	0299030.PXOCR	
40	AMBER	12065933	0299040.PXOCR	
50	RED	12065934	0299050.PXOCR	
60	BLUE	12065935	0299060.PXOCR	

(continued on next page)

Electrical System – Appendix II – Fuses (cont'd)

ATO FUSE COMPONENTS

COMPONENT DESCRIPTION	PACKARD PART NUMBER	TYPICAL WIRE SIZE	COMPONENT GRAPHIC
Single Fuse Connector and Seal Assembly:	12092677 12066681 12033769 12085030	CABLE O.D. (mm)* 1.84 - 2.25 1.90 - 2.64 2.89 - 3.65 3.72 - 4.48	
Cover for Sealed System: Note: Cover has Mounting Hole for Easy Mounting	12033731		
Terminals for Sealed System:	12020156 12066614 12033997	18 - 20 Gauge 14 - 16 Gauge 12 Gauge	

NOTE: The above connector and seal assemblies are a pull-to-seat style connector. The wire must first be fed through the connector and seal, stripped, terminated, and then pulled back into the connector to seat.

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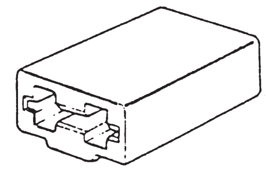
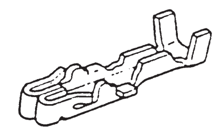
Electrical System – Appendix II – Fuses (cont'd)

ATO FUSE COMPONENTS

ATO Fuse Connectors (Unsealed)

COMPONENT DESCRIPTION	PACKARD PART NUMBER	TYPICAL WIRE SIZE	COMPONENT GRAPHIC
Single Fuse Connector (Unsealed):	12010105		
Terminals for Unsealed System:	12089951 12089950 12089953	18 - 20 Gauge 14 - 16 Gauge 10 -12 Gauge	

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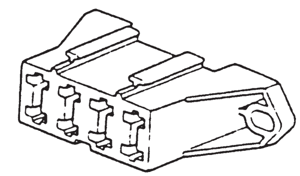
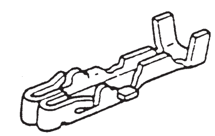
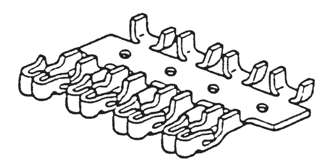
Electrical System – Appendix II – Fuses (cont'd)

ATO FUSE COMPONENTS

ATO Fuse Block

COMPONENT DESCRIPTION	PACKARD PART NUMBER	TYPICAL WIRE SIZE	COMPONENT GRAPHIC
Four Fuse Connector (Unsealed):	12004943		
Terminal (Single):	12089951 12089950 12089953	18 - 20 Gauge 14 - 16 Gauge 10 -12 Gauge	
Terminal (Bussed):	12004572 12004571 12052823 12004568	18 - 20 Gauge 14 - 16 Gauge 12 Gauge 10 Gauge	

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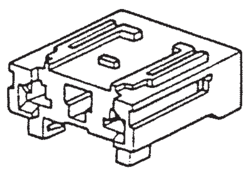
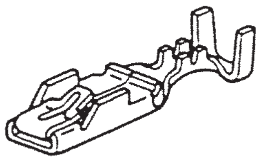
Electrical System – Appendix II – Fuses (cont'd)

MAXI FUSE COMPONENTS

COMPONENT DISTRIBUTION	PACKARD PART NUMBER	TYPICAL WIRE SIZE	COMPONENT GRAPHIC
Connector (Stackable):	12110057		
Secondary Lock:	12110058		
Terminals:	12065916 12110127	14 - 12 Gauge 10 Gauge	

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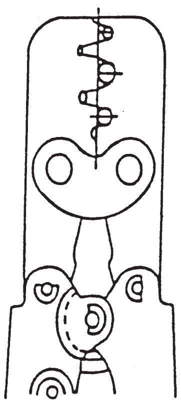
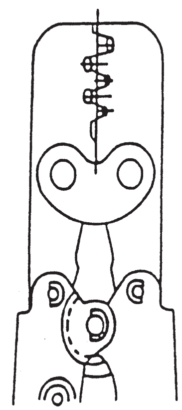
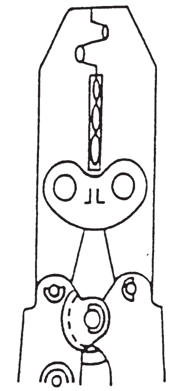
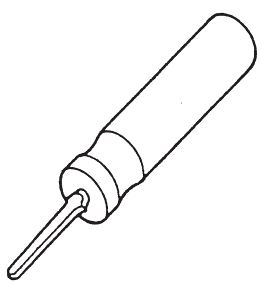
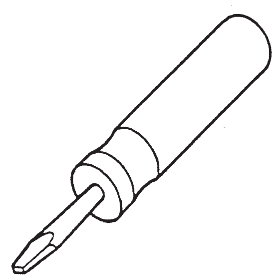
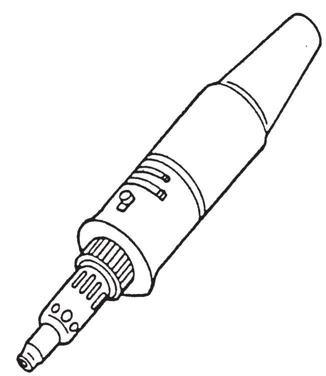
Electrical System – Appendix II – Available Tools

CRIMPING TOOLS

 Terminal Crimp Tool	 Terminal Crimp Tool	 Terminal Crimp Tool (also used for splice sleeves)

OTHER TOOLS

 Standard Small Pick - Green	 Standard Large Pick - Blue	 Ultratorch for heat-shrinking tubing and soldering

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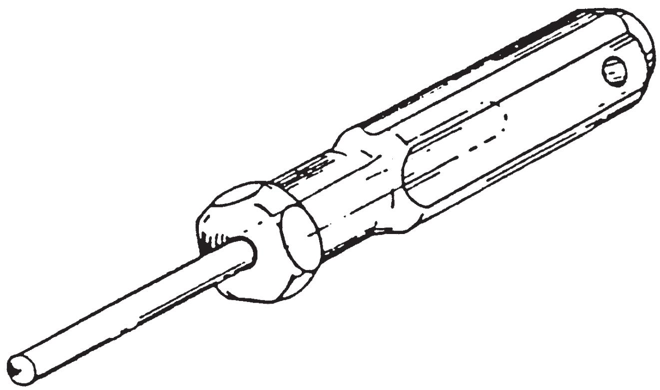
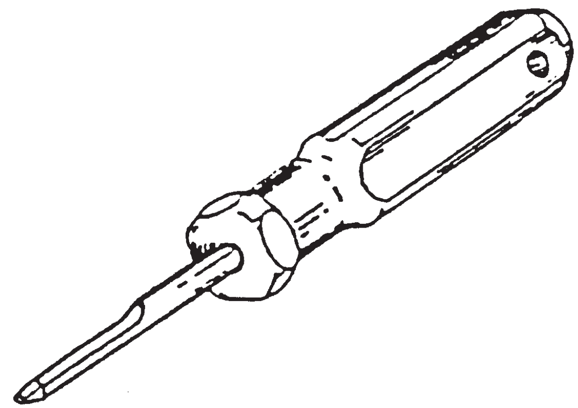
Electrical System – Appendix II – Available Tools

TERMINAL REMOVAL TOOL
This tool is designed to remove Weather Pack and Com-Pack I Terminals from connectors.



TERMINAL REMOVAL TOOL
This tool is designed to remove Micro-Pack Terminals from connectors.



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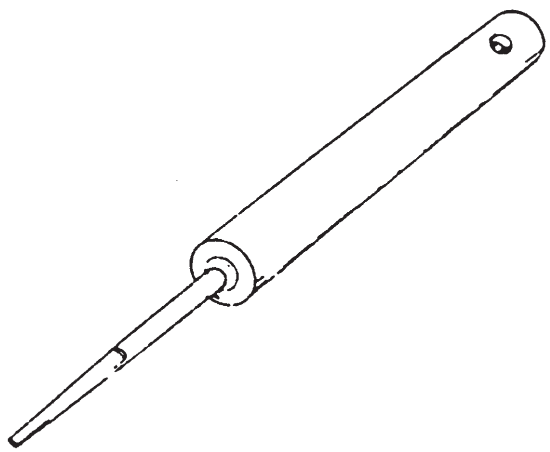
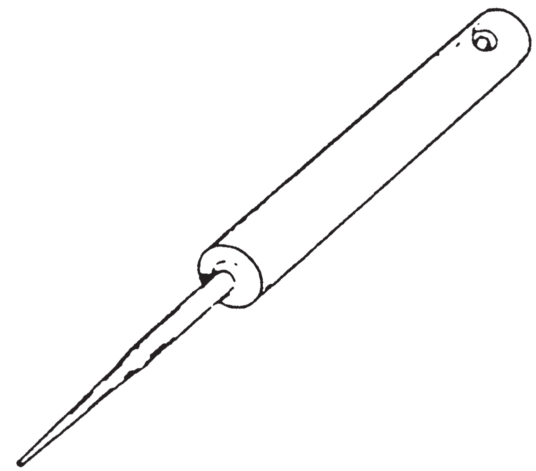
Electrical System – Appendix II – Available Tools

STANDARD TERMINAL REMOVAL TOOLS

These tools are designed to remove terminals from various connectors. Use the appropriate size pick to avoid damage to the terminal being removed.



Wide Pick
Use with 56 Series male and female terminals.



Narrow Pick
Use with Pack-Con female, Pin Grip, Edge Board, Metri-Pack male and female Pull-to-Seat and Com-Pack III Terminals

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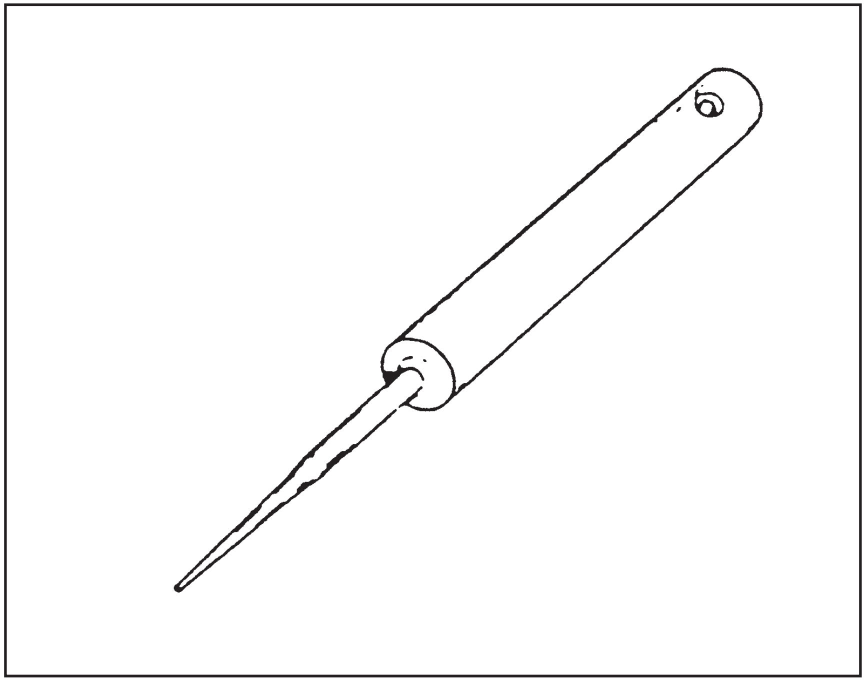
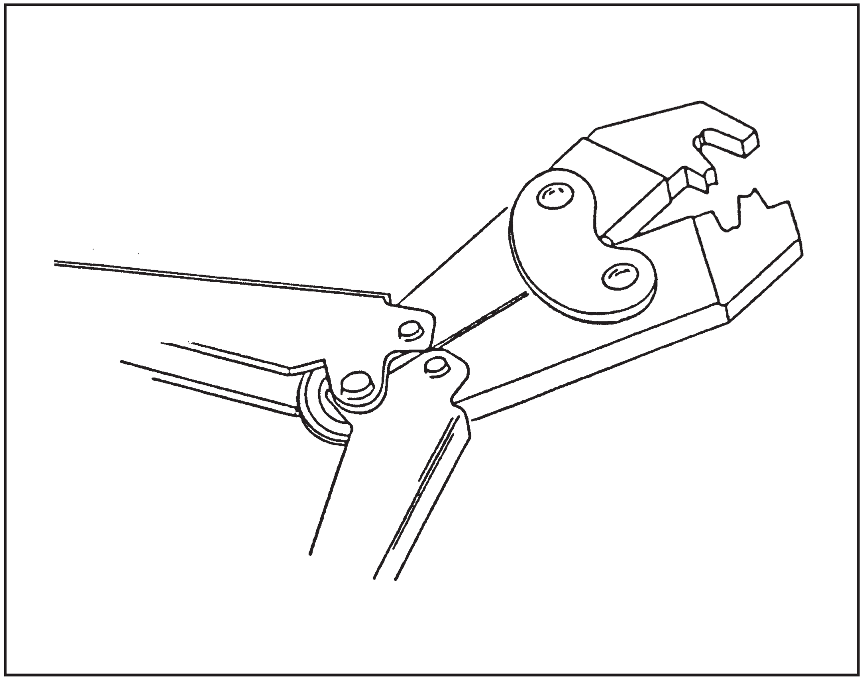
Electrical System – Appendix II – Available Tools

TERMINAL REMOVAL TOOL
This tool is designed to remove Com-Pack II. Molex and AMP terminals from connectors.



STANDARD CRIMPING TOOL
This tool is designed for crimping male and female terminals to 10 through 18-gauge wire and similar splice clips.



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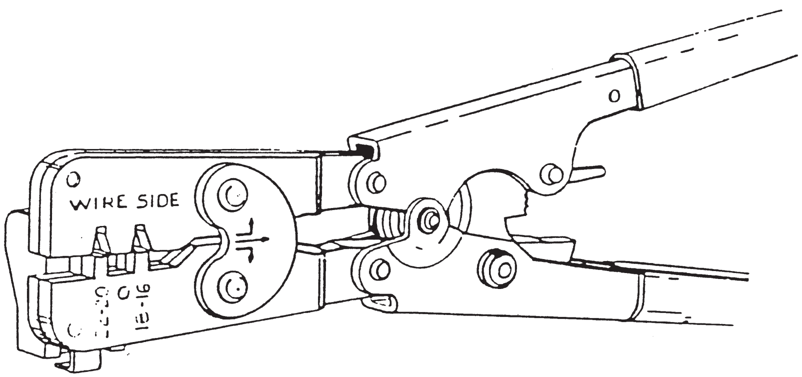
Electrical System – Appendix II – Available Tools

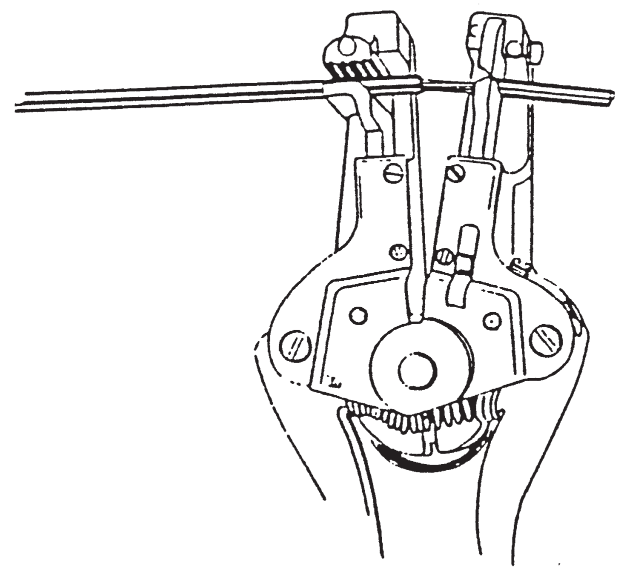
CRIMPING TOOL

This tool is designed for crimping male and female Weather Pack terminals (and seals) to 14 through 20 gauge wires.



WIRE STRIPPERS

This tool is designed for stripping cable insulation on 8 through 22-gauge wires.



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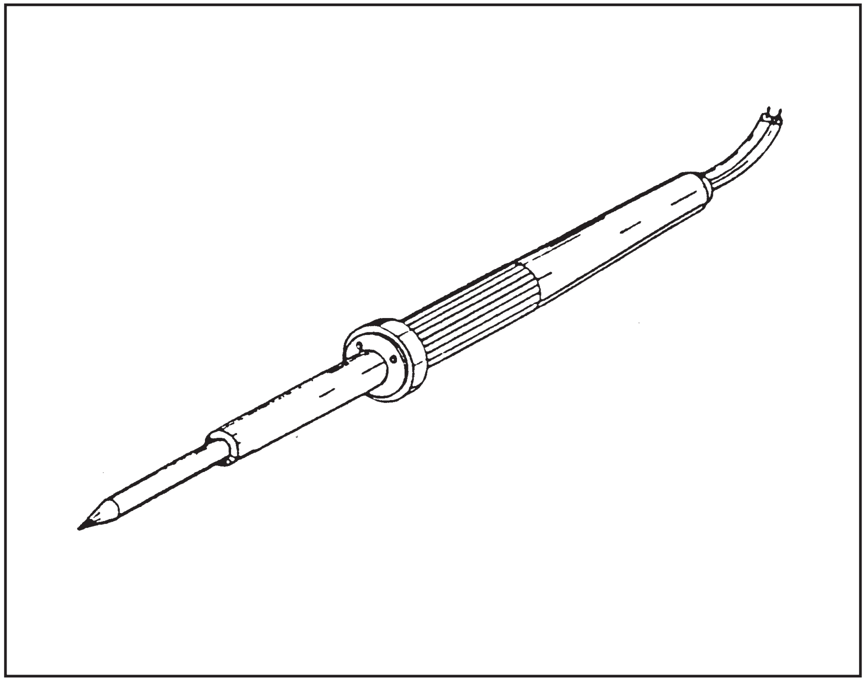
Electrical System – Appendix II – Available Tools

SOLDERING IRON

This tool is designed for apply heat for the soldering of terminal and splice clip applications.



TAPE RIPPER - STANDARD

This tool enables quick removal of tape with no damage to wire.