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PREVENTION OF ELECTRICAL SYSTEMS IGNITION OF AUTOMOTIVE CRASH FIRE

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16 Abstract

Fire occurs in only about 0.5 percent of all injury-producing automobile accidents. These fires result in death to 1 out of 8 persons involved. The two most probable ignition sources for automotive crash fires are sparks from damaged electrical systems and friction sparks generated by the impact.

Approximately 200 passenger vehicles of 1000- to 6000-pound curb weight were examined on dealer lots and in wrecking yards to assess the probability of damage to electrical system components. Based on the results of this survey, it was concluded that automobile fires due to crash-damaged electrical systems can be reduced by a combination of the following: (1) relocating components and wiring away from vulnerable areas, (2) shielding of components and wiring against impact damage, and (3) incorporation of an impact-sensitive device to inert the electrical system.

A suggested safety standard for automotive electrical systems incorporating these methods is presented, along with recommendations for future study to reinforce the provisions of this standard.

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1. INTRODUCTION

The occurrence of fire in automobile accidents, although virtually insignificant from a statistical viewpoint, results in a totally disproportionate number of deaths and injuries to the occupants involved. Available data indicate that fires result in a fatality rate approximately seven times that of all other automobile accidents yet fire occurs in only about 0.5 percent of all passenger automobile accidents.

If a fire is to occur, two basic components are required: (1) an ignitible fuel/air mixture and (2) an ignition source. In automotive crash fires the primary fuel source is gasoline from ruptured fuel tanks and/or lines. The ignition source may be either electrical sparks from damaged electrical components or friction sparks created by contact of the vehicle with the roadway or some obstruction. While it may be technically feasible to partially or completely control the fuel and ignition sources, design criteria for each is necessary.

A continuing effort to reduce the deaths and injuries resulting from automotive accidents is being conducted by the U. S. Department of Transportation, National Highway Safety Bureau. As part of this effort, a contract entitled "Prevention of Electrical System Ignition", FH-11-7347, was awarded Dynamic Science, a Division of Marshall Industries. This contract called for the accomplishment of three tasks as follows:

Task 1 - Acquisition of Automotive Electrical System Pre and Postcrash Data

Task 2 - Evaluation of Potential Methods for Pacification of Automotive Electrical Systems

Task 3 - Preparation of Design Guide for Future Automotive Electrical Systems

Sixty-six 1967 through 1970 model automobiles were examined on dealer lots during Task I effort to obtain data on electrical and fuel system component locations. The data were then compiled and a diagram prepared showing typical component locations for each of the following general classifications of automobiles:

- Front engine passenger cars
- Front engine station wagons
- Rear engine passenger cars

- Light vans
- Pickup trucks

Numerous automobiles representative of these same classifications were also examined in local wrecking yards to determine the amount and type of component damage resulting from typical accidents.

Using the data gathered from the automobile examinations along with individual estimates of probable fuel spillage, the probability of ignition due to damaged electrical system components was evaluated for various types of accidents.

In Task 2, potential methods of pacifying the electrical system were examined. Methods considered included shielding, component relocation, use of impact sensing devices to inert the electrical system, and combinations of these methods.

In Task 3, the results of the previous two tasks were combined to formulate suggested design criteria to reduce the probability of postcrash fire ignition due to electrical system failure. These design criteria are presented in the form of a design guide.

Performance criteria for crashworthy automotive electrical systems were then formulated and incorporated into a proposed motor vehicle safety standard.

Conclusions were drawn based on the results of the three tasks and recommendations for future study are made herein.

2. CONCLUSIONS

Based on the results of this study, the following conclusions are drawn:

1. Although postcrash fires occur in less than one percent of all injury-producing accidents involving passenger cars, the fatality rate in automotive postcrash fires is over seven times the fatality rate in accidents where fire did not occur.

2. Although data relating to the cause of automotive postcrash fires is very limited, it appears that the two most likely sources of ignition are sparks from damaged electrical systems and friction sparks created by impact.

3. From a postcrash fire ignition viewpoint, the most hazardous components in the automotive electrical system are the high capacity components such as the battery. voltage regulator, alternator/generator, starter solenoid, and the wiring associated with these components. These components and their wiring are often located near the exterior of the vehicle where they are vulnerable to damage.

4. Any electrical component or wiring located near the exterior of the vehicle may be considered a potential source of fire ignition.

5. The battery is a particularly hazardous component from the fire ignition standpoint for two reasons. First, the battery is capable of producing a spark even when disconnected from the electrical system and/or partially destroyed. Second, the battery is often located near the exterior of the vehicle where it is vulnerable to damage.

6. The postcrash fire ignition potential of present automotive electrical systems can be substantially reduced through a combination of the following methods:

   a. Relocating electrical components and wiring as far as possible from the exterior of the vehicle.

   b. Shielding components and wiring in non-conductive, impact-resistant containers to protect them from damage.

c. Providing an impact-sensitive device which will inert the electrical system in a severe impact or roll-over.

7. Further study and testing is needed to more accurately define the minimum acceleration environment necessary to insure actuation of an electrical system inerting device while precluding inadvertent actuation under normal operation.

8. A safety standard is needed to set forth minimum requirements for the performance of automotive electrical systems to reduce the fire ignition potential of these systems.

9. Testing should be conducted to reinforce the requirements set forth in the above mentioned standard.

3. RECOMMENDATIONS FOR FUTURE STUDY

The percentage of automobile accidents resulting in fire is low but the catastrophic results of these fires makes automobile crash fire protection imperative. Since one of the prime fire ignition sources is the automobile electrical system, this system must be rendered incapable of functioning as an ignition source during or immediately after crash impact. Two of the key steps necessary to accomplish this are: (1) protection of hazardous electrical system components and (2) inclusion of a crash-sensitive inerting device in the electrical system. The following recommendations are considered necessary to the development of these safeguards against electrical system ignition of postcrash fires.

RECOMMENDATIONS

1. Commercially available inerting devices should be tested on an impact sled to determine their operational characteristics and limitations.

2. The probability of inadvertent actuation of inerting devices should be determined by conducting a series of controlled road tests involving severe operating conditions.

3. Non-conductive, impact-resistant housings should be developed which will successfully contain and protect electrical system components in the crash environment.

4. A series of full-scale automobile crash tests should be conducted to determine the effectiveness of protecting and inerting the electrical system during crash situations. These tests could be readily "piggy backed" on crash tests conducted for other studies.

5. The results of the preceding tests should be used to further reinforce the proposed standard for crashworthy automobile electrical systems.

6. A thorough analysis and test of crashworthy fuel systems should be conducted in parallel with the crashworthy electrical system program to minimize the postcrash fire hazard. Special emphasis should be made to evaluate the crashworthy performance of evaporative emission control devices during this fuel system evaluation.

7. From an economics viewpoint, it would be desirable to conduct a cost-effectiveness study to determine the costs associated with implementing a crashworthy electrical system in future vehicles.

DISCUSSION

The above recommendations present a comprehensive approach to the development of crashworthy automobile electrical systems. The first two recommendations will accumulate necessary, but presently unavailable, data on the inertia switches currently manufactured for use in automobiles. The third recommendation will generate a new and critical method of shielding the electrical system components. The program will culminate in full-scale crash tests of complete crashworthy electrical systems. The results of this program will furnish a sound data base for a crashworthy automobile electrical system standard. It should be noted that although the emphasis is placed on the electrical system in these recommendations, further work is required to provide a crashworthy fuel system and thus eliminate postcrash fuel spillage.

Two separate testing programs are necessary to evaluate the inertia switches. One program would obtain the operational characteristics of the devices. Information on actuating G levels, actuation times, and sensitivity to various impact directions would be obtained from tests conducted on a high-speed sled.

The second testing program would obtain data on the inadvertent actuation of the sensing switches. Controlled road tests would be conducted during which the test vehicles containing the switches are driven at varying speeds under severe operating conditions. These conditions should include panic stops from high speeds, rapid accelerations, and driving over railroad tracks, bumpy roads, curbs, and dips. Instrumenting the test vehicles to record operating accelerations would allow the precise determination of the minimum G level desirable for actuating the switches.

The development of crash-resistant component housings could be initiated concurrently with the inertia switch testing. After suitable material and design criteria are established, prototype containers would be fabricated for testing.

A limited series of full-scale automobile crash tests would be necessary to fully evaluate the effectiveness of a crashworthy electrical system. The automobiles would not only contain the inertia switches and protective component housings discussed above, but would also incorporate additional crash-worthy measures, such as relocated components and extra length electrical wires. Front, rear, and side-impact crashes, as well as roll-overs would be conducted under controlled conditions with automobiles which have been fully instrumented to record the acceleration levels experienced during the crash. A side benefit of such a series of tests would be the generation of additional crash impact acceleration data which could be used in the design of other crashworthy features and components. In fact, the full-scale tests proposed here could be "piggy backed" on other crash tests conducted by the National Highway Safety Bureau. A natural program would be to superimpose this test program on one associated with the design and development of a crashworthy fuel system.

The results of the preceding tests would be used to reinforce the suggested design criteria presented in this report.

The recommended cost analysis is thought necessary to establish a baseline for determining the ultimate expense to the automotive buyer to provide this safety feature.

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4. ADVANTAGES AND DISADVANTAGES OF THE PROPOSED CRASHWORTHY ELECTRICAL SYSTEM FOR AUTOMOBILES

Advantages:

1. The provision of a crashworthy electrical system in passenger vehicles will result in a reduction of postcrash fires ignited by damaged electrical components.

2. A crashworthy electrical system will have increased reliability due to the extra protection afforded to the wiring and components and the better workmanship required to produce a system which will comply with the provisions of the design guide.

3. The impact sensing device included in a crashworthy electrical system could incorporate a manual control to inert the electrical system easily for repairs or in case of electrical fire not caused by accident impact.

Disadvantages:

1. The provision of a crashworthy electrical system will no doubt increase the per unit cost of the vehicle due to the requirement for extra protection materials and the provision of the impact sensing device. In addition, labor costs may very well increase due to the better workmanship required to properly install such a system.

2. The requirement for encasement of electrical components in the crashworthy electrical system may pose some servicing and repair difficulties by reducing the accessibility of such components (Reference 3). The crashworthy electrical system can be defeated by unauthorized repairs performed either by the owner or by mechanics employed by persons other than the vehicle dealer (Reference 4). Postcrash fire could still result from a very severe accident which damaged wiring and/or by the occupant restoring power to the electrical system following an accident in which wiring or components were damaged and spilled fuel was present.

5. PROBLEM DEFINITION

5.1 STATISTICAL EVALUATION

The rapidly growing number of injuries and fatalities caused by automobile accidents has caused a great deal of attention and effort to be focused on the structural crashworthiness of automobiles. However, because of the low incidence of postcrash fires, little effort has been directed toward the fire problem. Although fire accident statistics are scarce, available data indicate that fires erupt in 0.2 to 0.9 percent of injury-producing accidents (References 1 and 2). Based on an average of 0.5 percent, this means that of the 1968 total of 1,346,800 fatal and disabling accidents (Reference 3) approximately 6700 accidents resulted in postcrash fires.

These numbers tend to obscure the catastrophic effects of fire accidents. A California Highway Patrol study of 11,855 injury-producing accidents revealed that 1 out of 58 victims died in all the accidents, while 1 out of 8 victims died in those accidents involving fire (Reference 2). Thus, accidents with fire represented a hazard over seven times as great as accidents without fire.

A more detailed analysis of the fire accident data by type of accident, although based on a limited number of statistics, provides some insight into the fire problem. The data were extracted from approximately 35,000 cases of accidents involving passenger cars in which at lease 1 person was injured or killed (Reference 2). The data include a total of 156 fire accident cases which were analyzed.

Figure 1 presents the distribution of all accidents and of fire accidents according to three categories: (1) front impact, (2) rear impact, and (3) roll-over accidents. In the study cited, these three categories accounted for 97 percent of the total accidents and all of the fire accidents. The high incidence of fires in roll-over and rear impact accidents should be noted. Although roll-over accidents occurred with only one-third the frequency of front impact accidents, the same percentage of fire accidents occurred in both categories. Rear impact collisions, although accounting for only 5 percent of the total accidents, contributed to 17 percent of the fire accidents.

The extent of fire damage by impact type is presented in Figure 2. Eighty percent of all roll-over fire accidents resulted in extreme damage to the automobile, with the fire engulfing the front, rear, and interior of the vehicle. In

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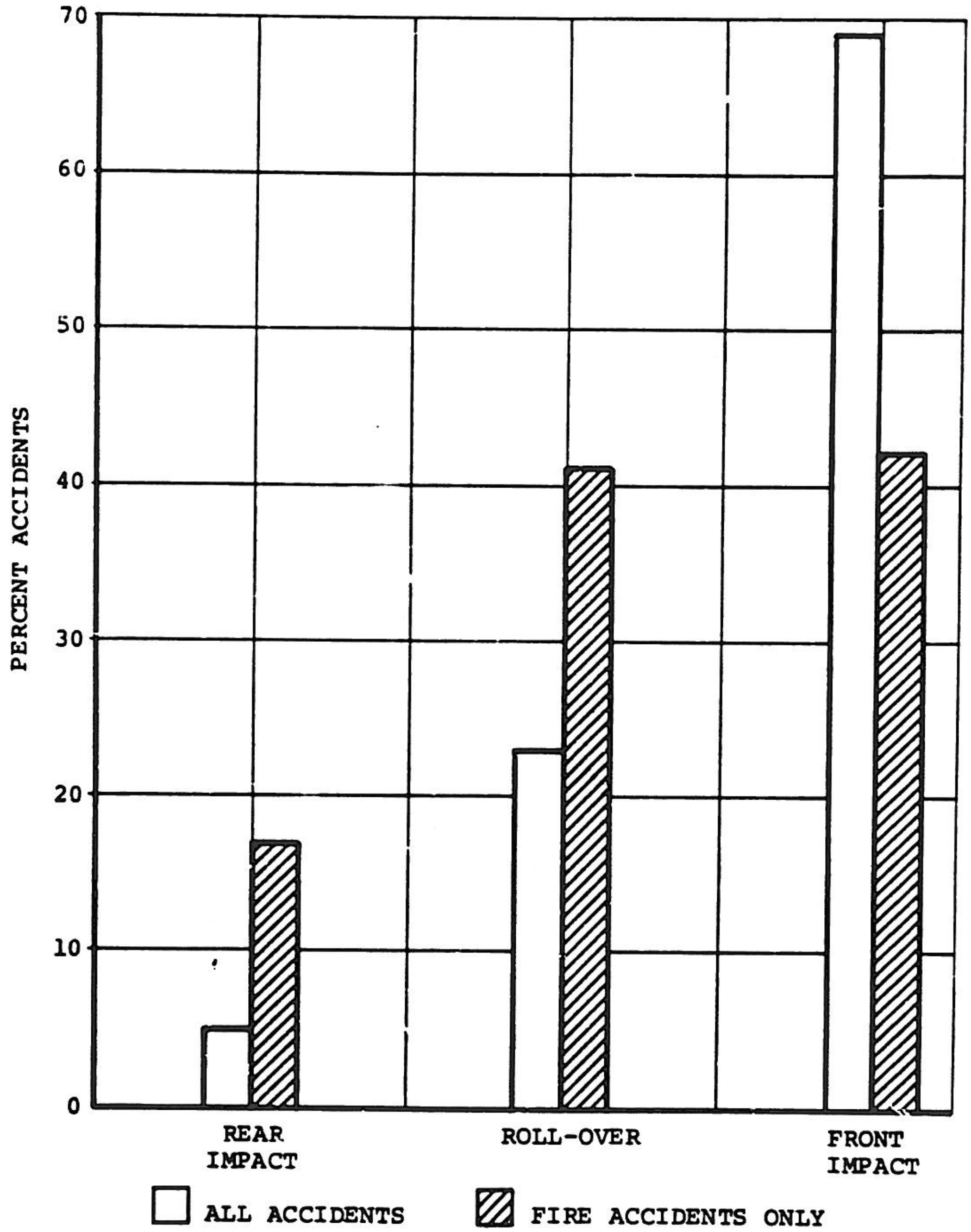


Figure 1. Distribution of Accidents by Impact Type (Based on data in Reference 2).

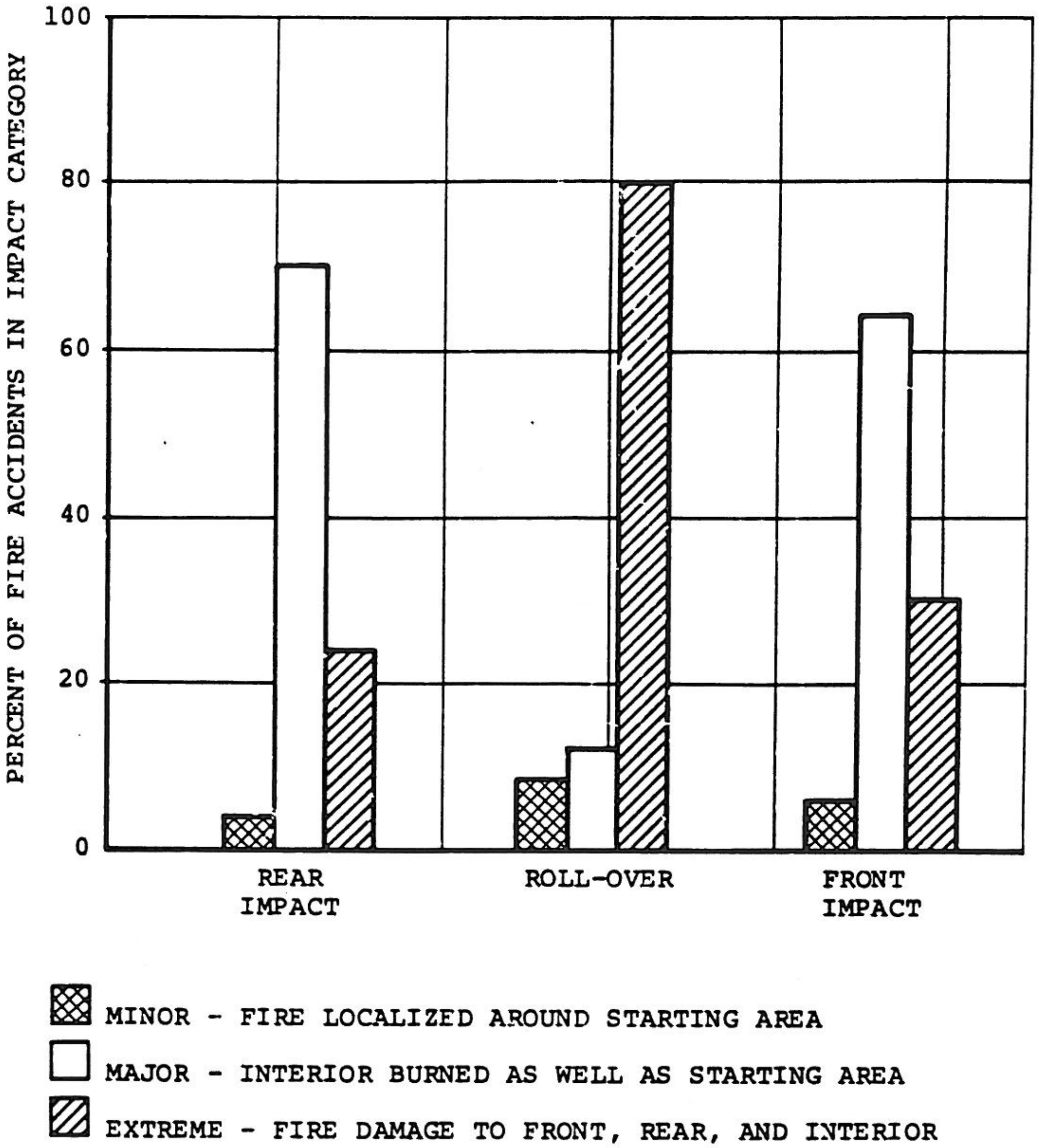


Figure 2. Distribution of Fire Damage by Impact Type (Based on data in Reference 2).

comparing this figure with the 30 percent and 25 percent incidence of extreme damage in front and rear impacts, respectively, the severity of the roll-over accident with respect to fires is again illustrated.

The distribution of burn injuries by impact type is presented in Figure 3. Roll-over accidents accounted for almost 82 percent of all the burn fatalities, although the incidence of fire in roll-over accidents was no greater than for front impact accidents. Rear impact fire accidents accounted for almost as many burn injuries and fatalities as did front impacts, although front impact fire accidents occurred with 2-1/2 times the frequency of rear impact fire accidents.

Although statistics on automobile crash fire accidents are scarce, detailed analyses of the wreckages are even more scarce. In addition, most of the vehicles are so badly damaged that it is difficult to isolate the origin of the fire. However, the following general data have been observed (Reference 4):

1. Most fires in front impact accidents are reported as starting in the engine area.

2. Most fires in rear impact accidents are reported as starting in or about the fuel tank.

3. There is no indication of any difference in fire susceptibility between front and rear engine cars.

5.2 FUEL SOURCES

Fuel sources include the fuel tank and fuel system components. A detailed survey of 1966-1968 automobile fuel systems (Reference 4) showed that the tank was located in the rear trunk compartment for front engine cars and in the front compartment for almost all rear engine cars. Several station wagons had the fuel tank mounted outside the left side frame members, shielded from direct impact only by the body metal of the left rear wheel housing and the quarter panel. Typical fuel system arrangements are shown in Figure 4

The tanks are made of soft sheet steel, usually 24 gauge thickness. The usual manufacturing process involved two stamped pieces joined with continuous-seam welds.

Massive fuel spillage results when fuel tanks fail during an accident. Ruptures produced by both actual and simulated crashes attest to this. A complete series of controlled rear impact crash tests showed that the fuel tanks were deformed,

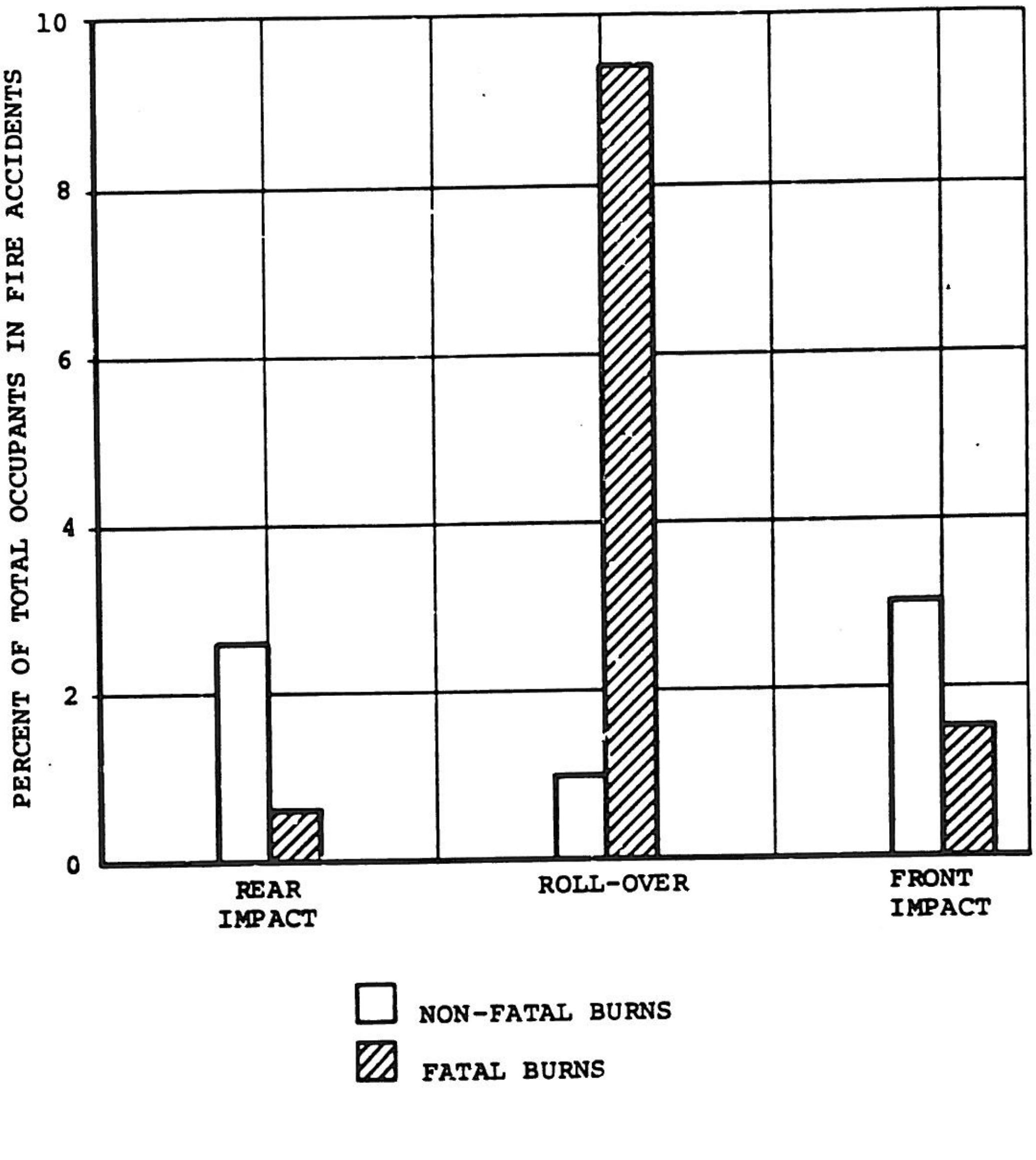


Figure 3. Distribution of Burn Injuries by Impact Type (Based on data in Reference 2).

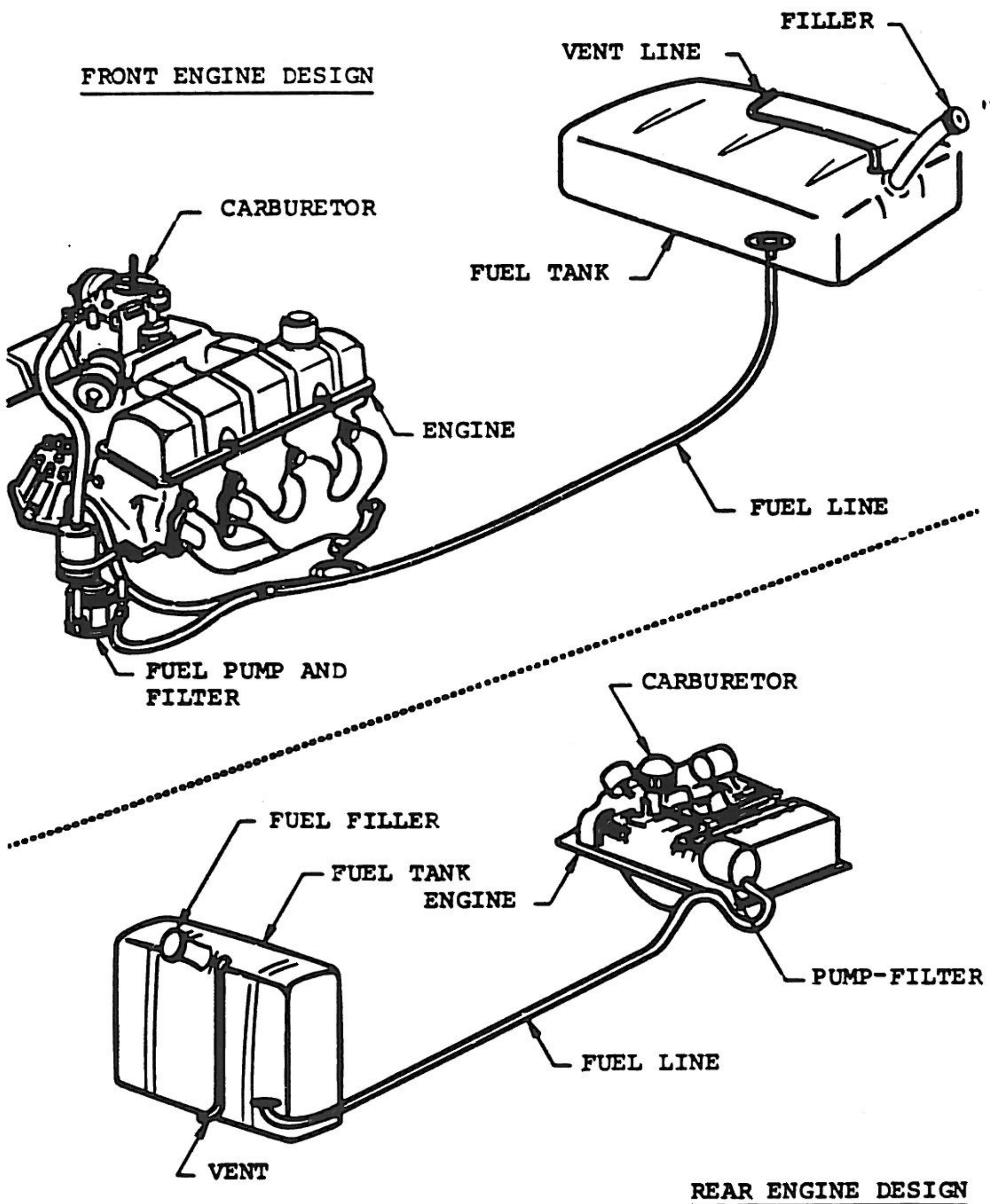


Figure 4. Typical Automobile Fuel Systems.

punctured, or split during the impact (Reference 5). The velocity of the striking car determined the amount of tank damage, as illustrated in Figure 5.

During one test a stationary car was struck in the rear by another car traveling 55 mph. By the time the rear-ended car had advanced 2 feet, gasoline could be seen spurting from the rear wheel area. By the time the rear-ended car had traveled about 8 feet, gasoline had erupted forward to the front wheel area and had spread out several feet on each side of the car. During this test, an igniter had been provided 40 feet ahead of the initial impact point and 8 feet to the side. The gasoline cloud reached the igniter within 0.6 second after impact resulting in a catastrophic fire which enveloped both cars.

The filler neck is another source of serious fuel spillage. The filler neck can be pulled from the fuel tank during impact although the tank itself is not badly damaged. This was demonstrated during the impact test series described in Reference 5. An actual accident case, also described in Reference 5, resulted in the fatal burning of 3 of the 4 occupants of a station wagon when the filler spout pulled free of the tank, which was only slightly dented, allowing fuel to drain into the passenger compartment.

Fuel system components located in the engine compartment are the fuel pump and carburetor. Direct impacts on either of these components by heavy objects torn loose during the crash, such as the battery, or by extensive structural deformation following impact with the other vehicle or fixed objects, could lead to failure and subsequent fuel spillage. In the event of a roll-over fuel may spill from carburetor openings even when the carburetor is not damaged.

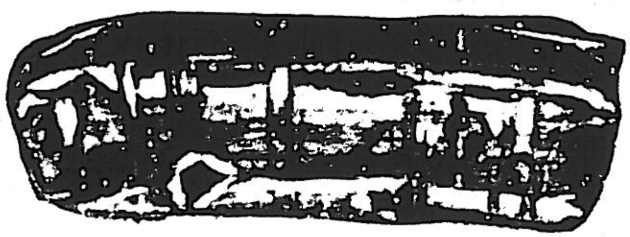
Fuel lines may also be cracked or broken during crash impact. Failure of the tank-to-fuel-pump line could lead to spillage of the entire fuel tank contents.

The fuel tank vent line generally does not contribute to fuel spillage except during roll-over accidents. During a roll-over it is possible for fuel to spill from the tank through the vent line.

5.3 ELECTRICAL IGNITION SOURCES

The electrical systems of modern automobiles are complex and distributed extensively throughout the automobile structure. Most of the circuits are protected by fuses from overloads and subsequent heating or short circuiting. Unfortunately, from a fire hazard standpoint, the high-energy

TYPICAL 30 MPH TANK DAMAGE



TANK PUNCTURED BY STABILIZER BOLT AT 40 MPH

PRODUCTION TANK BURST OPEN DURING 55 MPH COLLISION

Figure 5. Representative Fuel Tank Failures for Three Speeds of Impact (Taken from Reference 5)

circuits with the greatest ignition potential are not protected. These circuits, shown in Figure 6, are: (1) the battery-ignition coil circuitry, (2) the battery-alternator (or generator) circuitry, and (3) the battery-starting motor circuitry.

Because of the extensive number and length of wires in an automobile, the probability of some of these wires being cut or pulled loose during an accident is fairly high, especially during severe impacts. Sparks generated when the wires are severed or when severed wires contact grounded structure may lead to a fire. During a series of tests conducted by the FIAT Auto-Avio Research Laboratory (Reference 6), the open-circuiting of a wire followed by an extra-current spark produced ignition of gasoline/air mixtures in a high percentage of cases. This percentage was found to be in direct relationship to the energy of the spark. Other laboratory studies have indicated that the minimum energy for spark ignition of a stoichiometric mixture of hydrocarbons and air is approximately 0.15 millijoule (Reference 7), or 0.00015 watt-sec.

The FIAT researchers also tried to ignite flammable gasoline/air vapors with overheated wires. In no case was ignition reported, even when the wire was red hot. However, when a heated wire finally melted and broke, with consequent sparking, ignition did take place.

The battery is a constant source of electrical power - a constant postcrash fire ignition hazard. The FIAT researchers found that even when the battery was practically destroyed, with loss of electrolyte, the voltage and output capacity were still available.

The headlight filament is another possible ignition source. Data on automobile headlights are not available, however, there are data available on aircraft landing lights. Temperatures high enough to ignite gasoline may exist for at least 0.75 to 1.5 seconds after the lighted bulb is smashed and the filament broken (Reference 7). During full-scale aircraft crash tests, fuel ignition by broken landing lights occurred 0.6 seconds after initial impact of the aircraft wing against a pole barrier. Although automobile headlights are not as powerful as aircraft landing lights, a definite possibility exists that lighted headlights could still function as an ignition source.

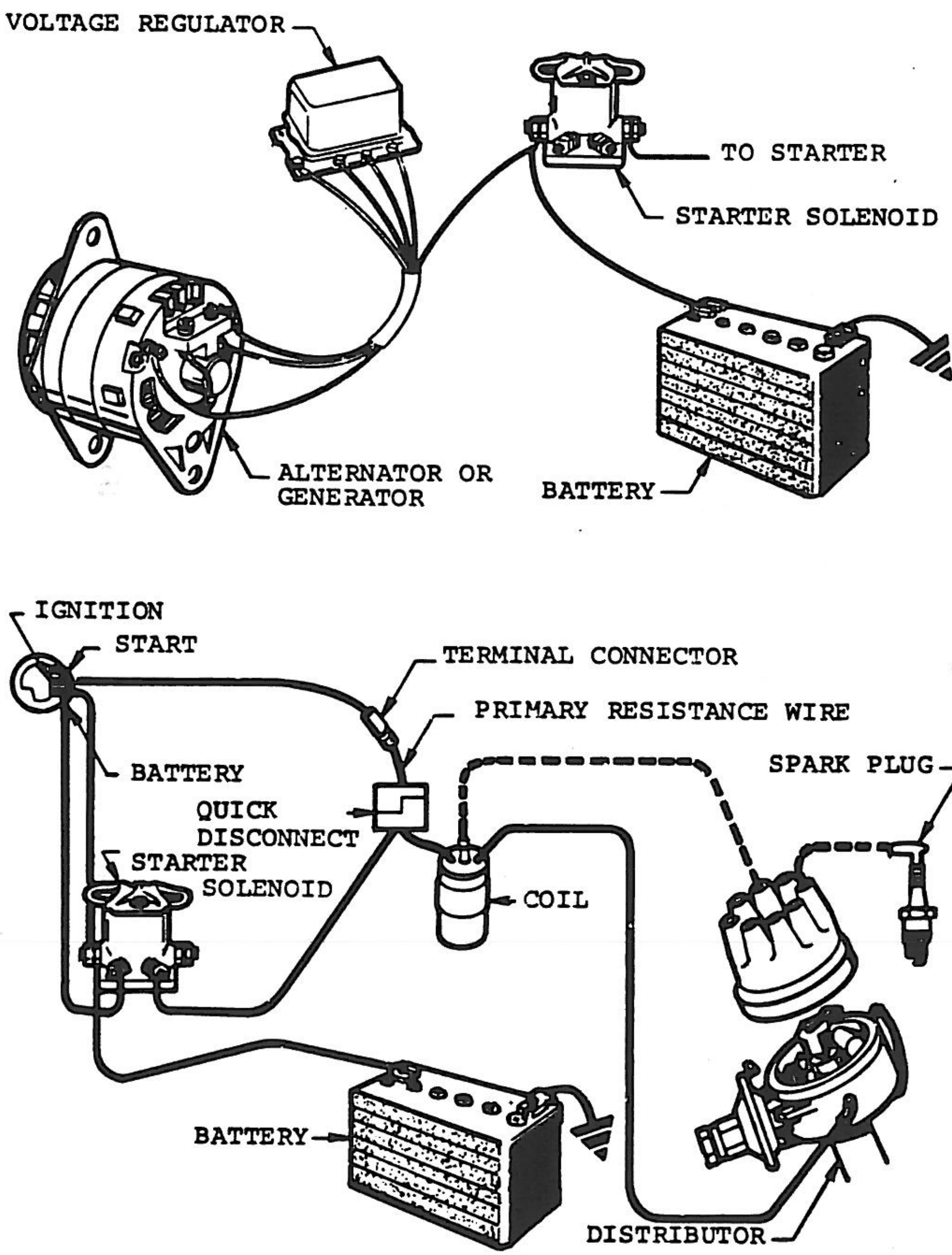


Figure 6. Typical Automobile High-Energy Electrical Circuits.

5.4 SUMMARY

The roll-over accident seems to be the most serious with respect to automobile crash fires. Not only do roll-over accidents result in fires more often than other types of accidents, but these fires also result in greater damage to the automobile and account for the greatest number of fatalities. Several causal factors figure in these results. Structural damage in roll-over accidents is usually extensive and often severe. This damage can extend to the fuel tank and other fuel system components, resulting in appreciable fuel loss. Fuel may also be spilled from the carburetor and fuel tank vent line during the roll-over. The entrapping of occupants because of extensive structural damage also contributes to the high fatality rate in roll-over accidents.

The rear impact collision ranks as the second highest fire hazard type because of the high percentage of these accidents that result in fire. This is probably due to the rearward position of the fuel tank in the majority of cars. Fuel tanks in the rear suffer moderate to catastrophic damage in rear end impacts, depending on the speed differential between the impacted and impacting cars. Such tank failures result in massive fuel spillage, leading to a high incidence of fires and contributing to the severity of the fires.

Front end impacts, although accounting for 69 percent of the injury-producing accidents, do not result in more fire accidents than roll-over accidents. The incidences of burn injuries and fatalities for front end impacts are less than for rear impacts and roll-over accidents. This would indicate that the fire spreads at a slower rate into the interior of the automobile in front end accidents. It is also possible that structural damage in front end collisions does not preclude occupant egress to the extent that it does in the other categories.

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6. ELECTRICAL AND FUEL SYSTEM CONFIGURATIONS

6.1 GENERAL

In order to evaluate the postcrash fire ignition potential due to electrical system failure, it was necessary to determine the location of potential failure points in the electrical system with respect to possible fuel sources in typical passenger vehicles. Five types of vehicles were selected for investigation.

- Front Engine Passenger Cars
- Front Engine Station Wagons
- Rear Engine Passenger Cars
- Light Vans
- Light Trucks (Pickups)

Within these five classifications, 66 vehicles representing a cross-section of models produced by domestic and foreign manufacturers were examined and the location of potentially hazardous components determined. The vehicles, mostly 1967 through 1970 models, were examined in detail on local dealer lots. Spot checks of 1960 through 1965 models were also made.

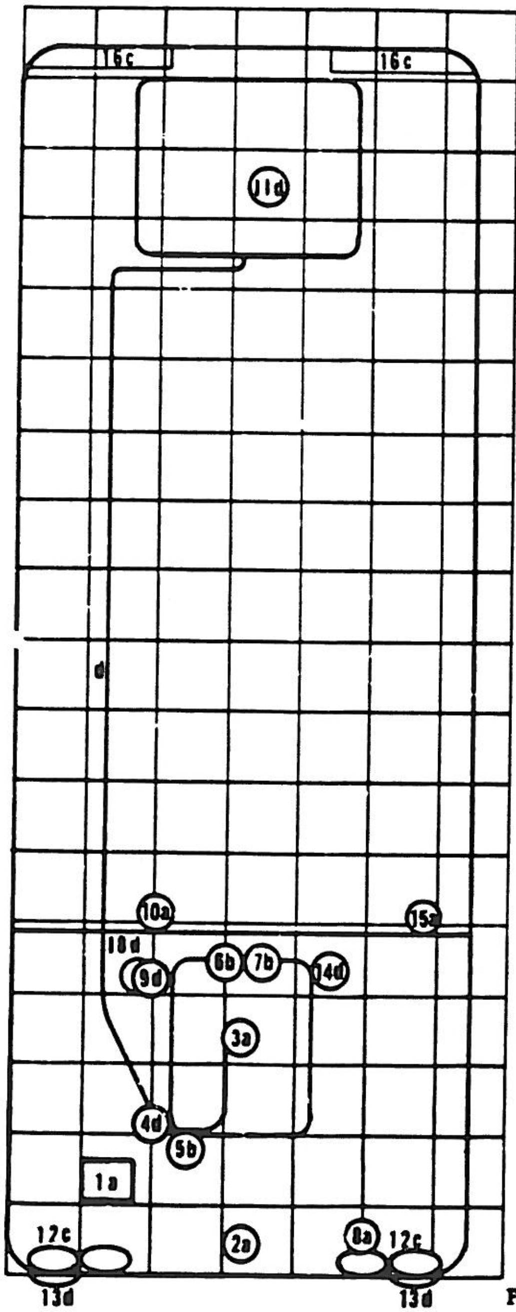
The data collected were recorded on the form shown in Figure 7 and compiled to show the location of each component in each classification of vehicle. Using this information, a composite diagram of the entire system was prepared for each vehicle classification showing zones where electrical system components are found.

The following paragraphs present an in-depth discussion of the electrical and fuel systems for each aforementioned vehicle type.

6.2 FRONT ENGINE PASSENGER CARS

This classification of automobile comprises the majority of passenger vehicles in use today. Forty-four vehicles of this type, which included V-8 and 6-cylinder engines, were examined on dealer lots. Figures 8 and 9 show typical engine compartments of these cars where most major electrical components are located. Considerable similarity in component layout was noticed in vehicles of the same make but different model year. However, there was some variation in layout between vehicles of different makes. Figure 10 is a diagram

S-A-M-P-L-E



MAKE Chevrolet
Impala

CLASS
- Truck ☐
- Van ☐
- FE Pass Car ☒
- RE Pass Car ☐
- FE Sta. Wagon ☐

AGE
- New 1969 ☒
- Used ☐

FIRE
- Yes ☐
- No ☐
- UNK ☐
- N/A ☒

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alt./Gen.
6. Distributor
7. Coil
8. V. Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Park & Dir. Lights
14. Oil Filter
15. W. S. Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

Location (Height relative to Engine)
- a. above top
- b. top
- c. middle
- d. bottom

☒ DEALER LOT SURVEY
☐ WRECKING YARD SURVEY

Figure 7. Component Location Data Sheet.

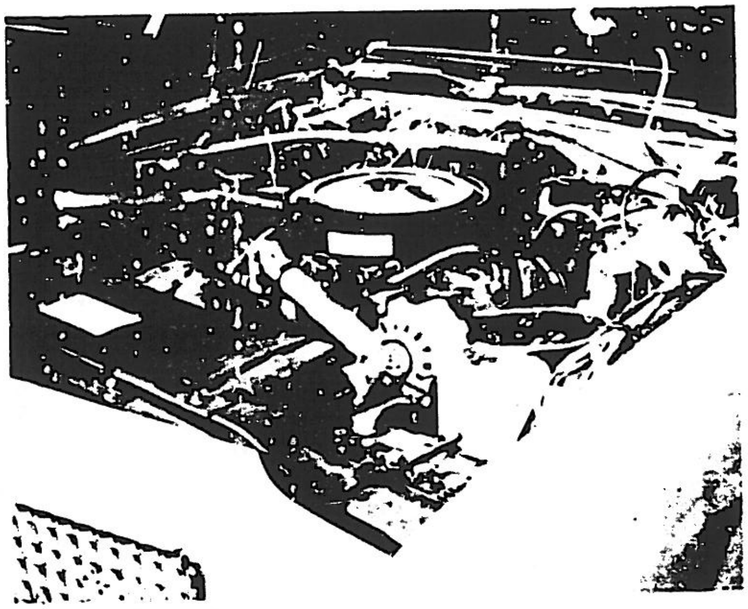


Figure 8. Engine Compartment of Typical V-8 Front Engine Passenger Car.

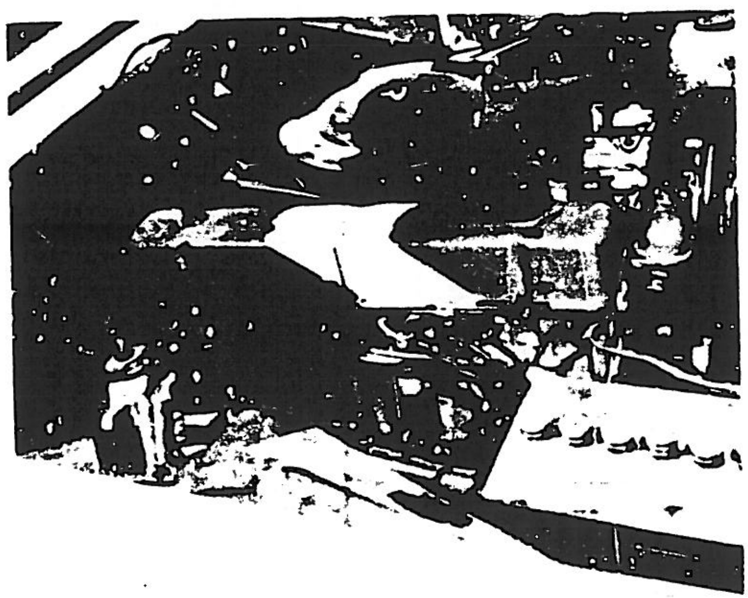
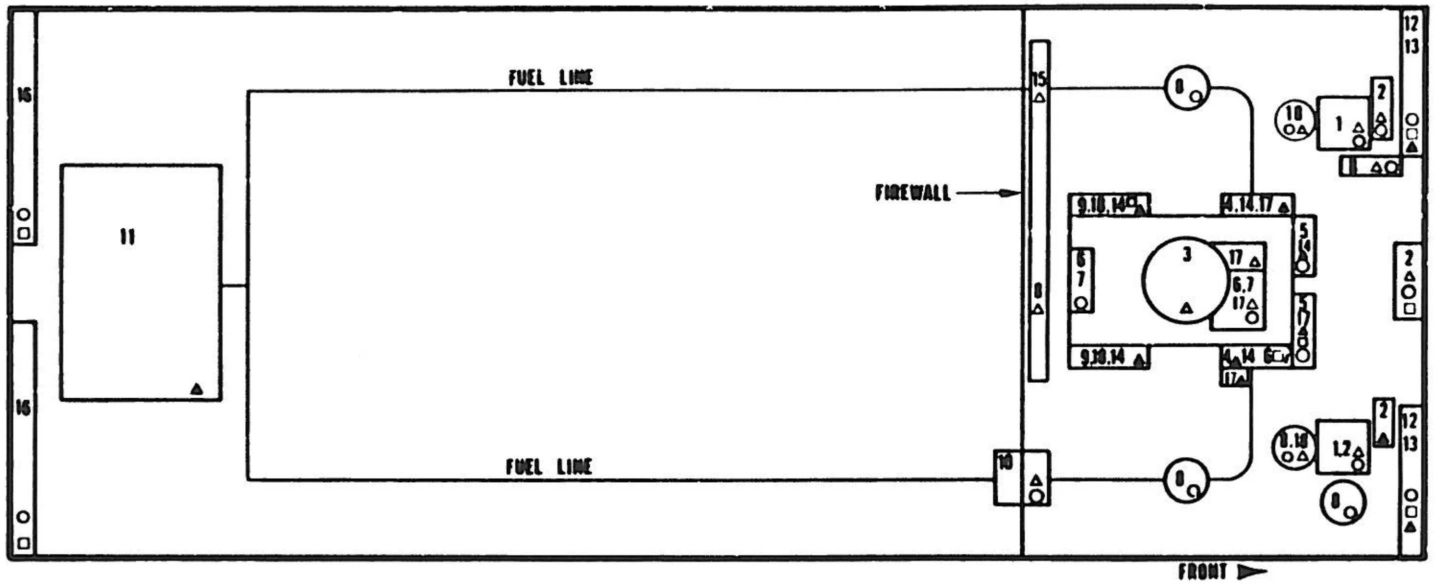


Figure 9. Engine Compartment of Typical 6-Cylinder Front Engine Passenger Car.



LOCATION (HEIGHT RELATIVE TO ENGINE)

△ ABOVE TOP
○ TOP
□ MIDDLE
▲ BOTTOM

COMPONENT IDENTIFICATION

1. BATTERY
2. HORN
3. CARBURETOR
4. FUEL PUMP
5. ALTERNATOR/GENERATOR
6. DISTRIBUTOR
7. COIL
8. VOLTAGE REGULATOR
9. STARTER
10. HEATER BLOWER
11. FUEL TANK
12. LIGHTS
13. PARKING & DIRECTIONAL LIGHTS
14. OIL FILTER
15. WINDSHIELD WIPER MOTOR
16. TAIL LIGHTS
17. FUEL FILTER
18. STARTER SOLENOID

Figure 10. Component Location Zones - Front Engine Passenger Cars.

of the zones in which specific components may be found in typical front engine passenger cars. Figures 11 through 20 show individual component locations.

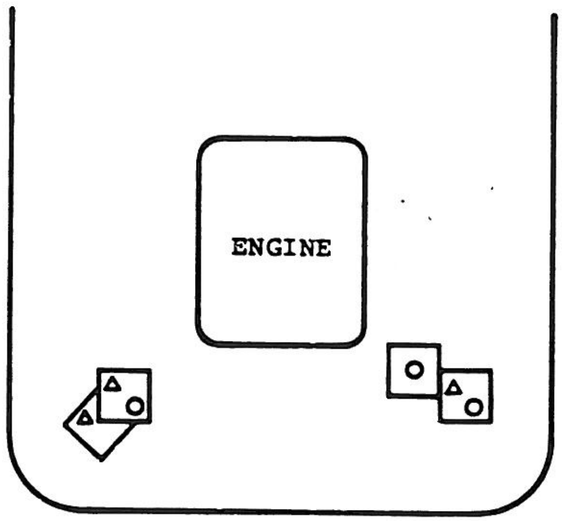
6.2.1 Primary Hazards of the Electrical System. Any electrical component has postcrash fire ignition potential and components located near the periphery of the vehicle possess the highest potential. As can be seen from Figure 10, peripheral components include batteries, starter solenoids, alternators/generators, voltage regulators, lights, and horns, along with associated wiring. The most hazardous of these would be the batteries, starter solenoids, and voltage regulators because they are intended to furnish or carry large electrical loads, and because of these large loads, the circuitry associated with them is normally unfused. Damage to these components could result in repeated sparking.

6.2.1.1 Batteries and Battery Cables. The battery itself is probably the most hazardous single component in any automotive electrical system because of its sparking potential, even when partially destroyed. In front engine passenger cars the battery is very vulnerable to damage because it is located well forward near the outside of the engine compartment (Figure 11). In some extreme cases, the battery is mounted directly behind the grillwork, subject to damage in even a relatively minor accident.

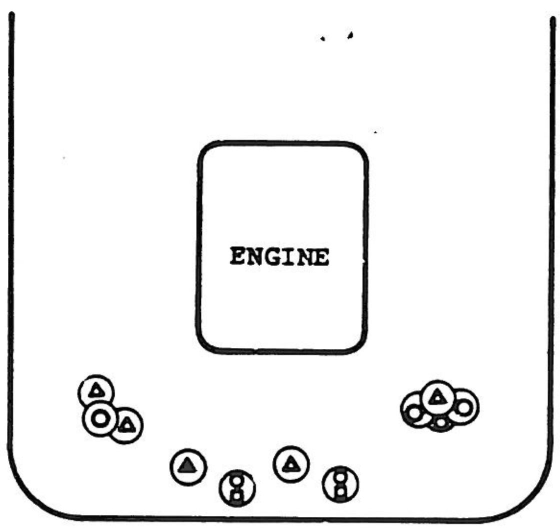
Most batteries have the contact posts exposed on the top of the battery, and no insulation is provided to prevent sparking should the power terminal come in contact with a ground source. One vehicle examined contained a new type battery in which the terminal posts are on the side of the battery at the rear. This terminal location, combined with the battery location just ahead of the splash guard, increases the probability of battery sparking in a moderate frontal or front-quarter impact since even small displacement of either the battery or the splash guard will allow contact of the terminals with the metal splash guard.

Battery cables are heavy and well insulated due to the high electrical loads imposed on them. Their terminal ends are uninsulated in most cases. Should the end of the power cable come in contact with grounded structure, a spark would be produced.

6.2.1.2 Starter Solenoids. Starter solenoids, as shown in Figure 20, are usually found in two general locations, either close to the battery or directly on the starter motor. The solenoid itself is a rugged device which is not readily damaged. The terminals connecting it to the battery and the



BATTERIES



HORNS

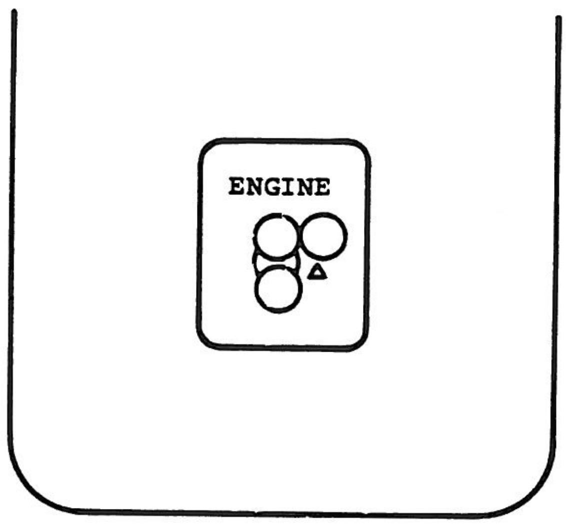
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

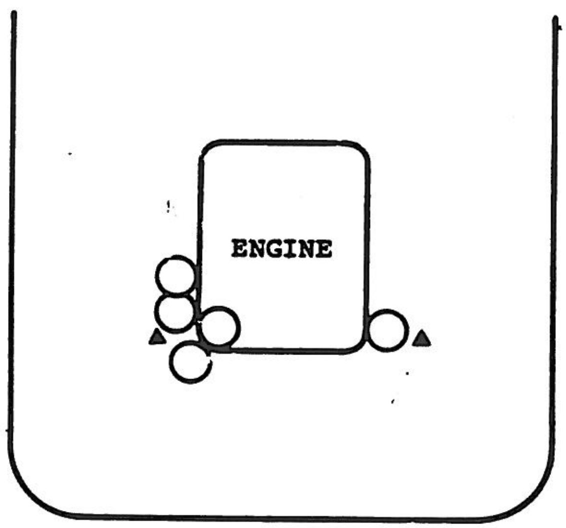
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 11. Battery and Horn Locations - Front Engine Passenger Cars.



CARBURETORS



FUEL PUMP

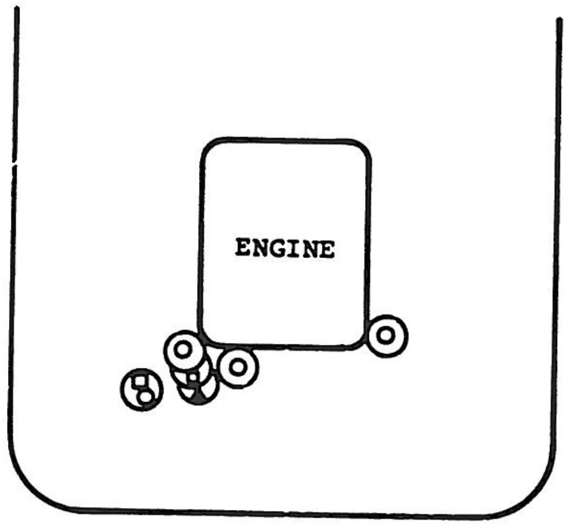
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

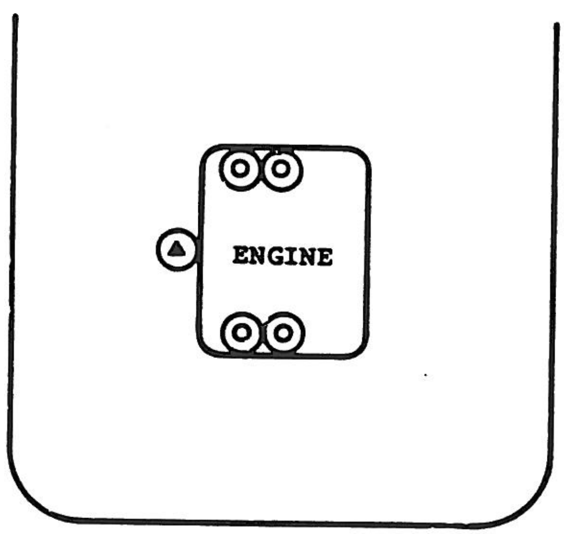
LOCATION (Height relative to engine)

- △ Above top
- O Top
- □ Middle
- ▲ Bottom

Figure 12. Carburetor and Fuel Pump Locations - Front Engine Passenger Cars.



ALTERNATOR/GENERATOR



DISTRIBUTOR

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- O Top
- □ Middle
- ▲ Bottom

Figure 13. Alternator/Generator and Distributor Locations - Front Engine Passenger Cars.

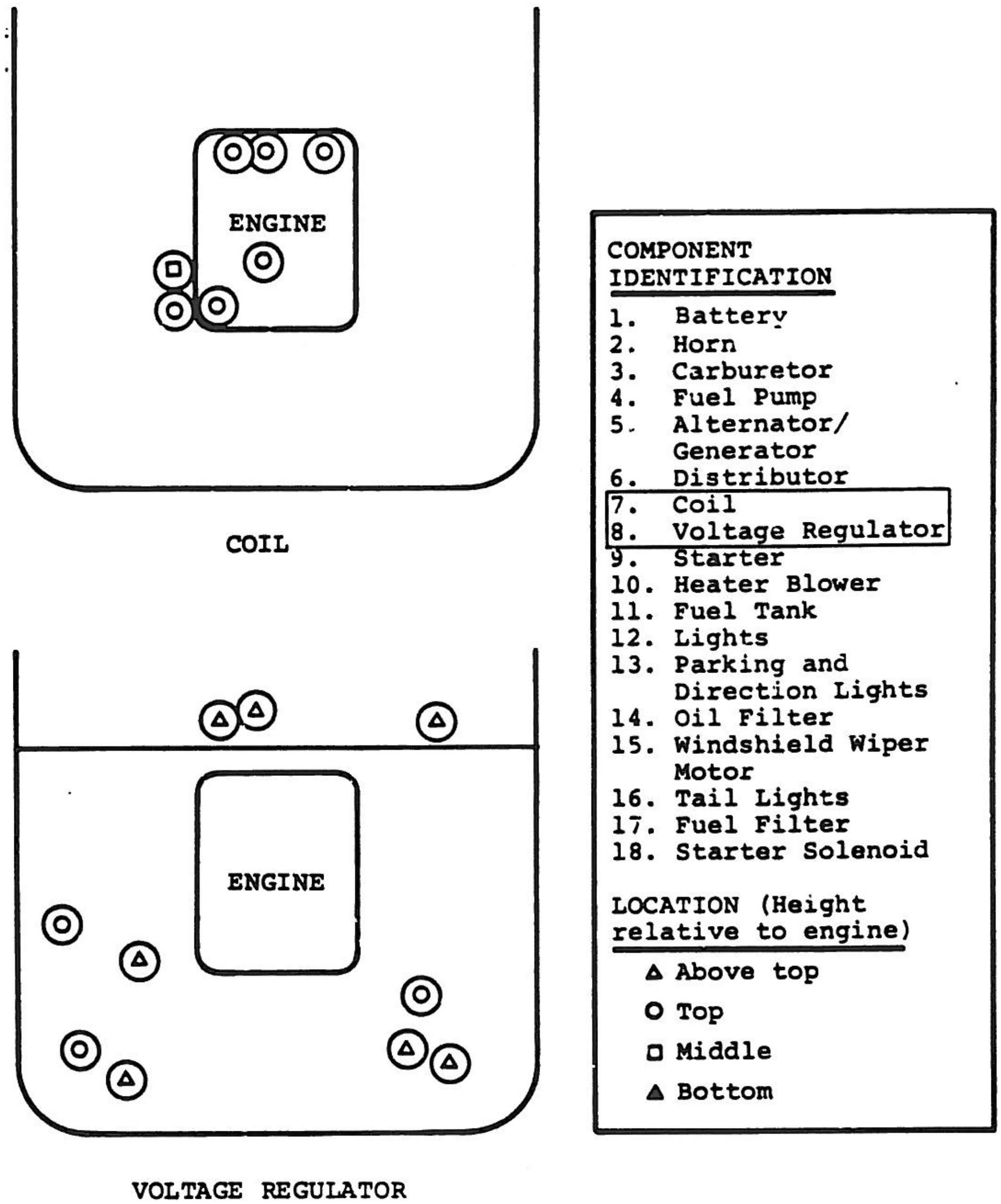
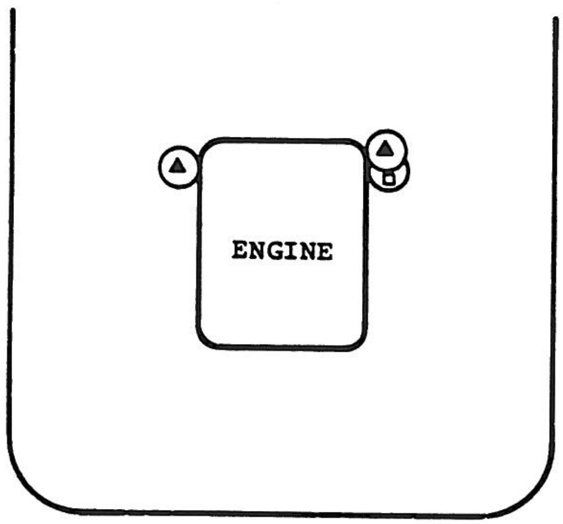
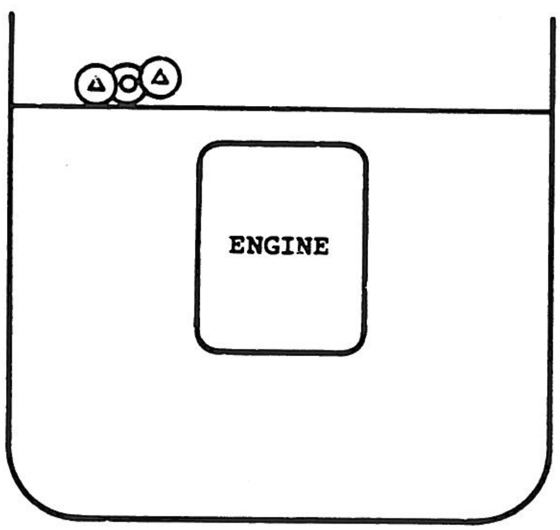


Figure 14. Coil and Voltage Regulator Locations - Front Engine Passenger Cars.



STARTER



HEATER BLOWER

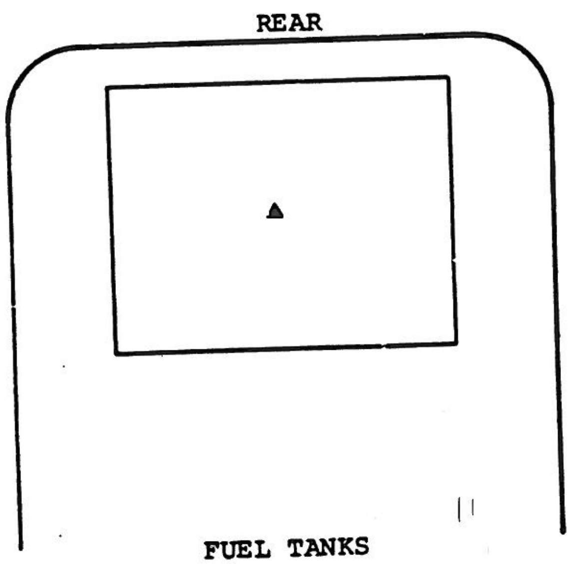
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 15. Starter and Heater Blower Locations - Front Engine Passenger Cars.



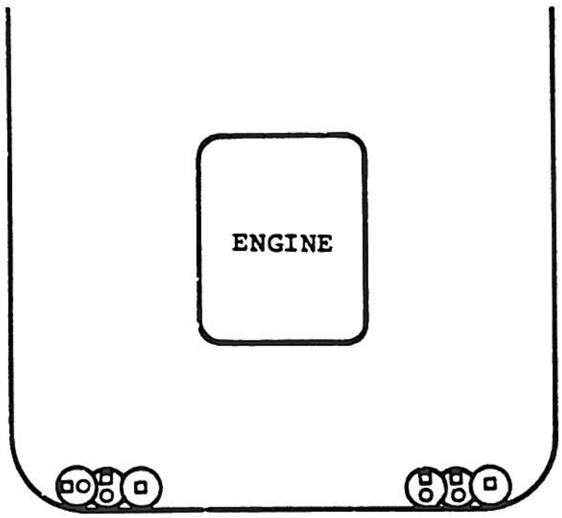
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

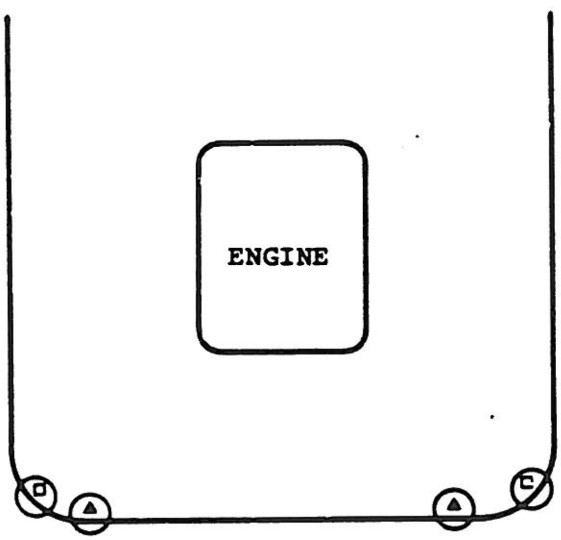
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 16. Fuel Tank Location - Front Engine Passenger Cars.



LIGHTS



PARKING AND DIRECTION LIGHTS

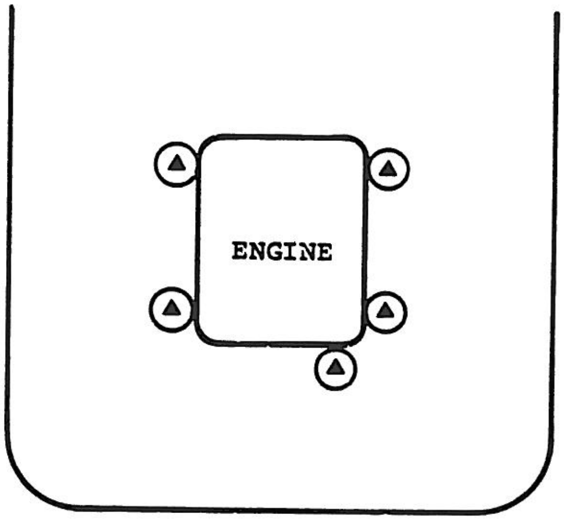
COMPONENT
IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

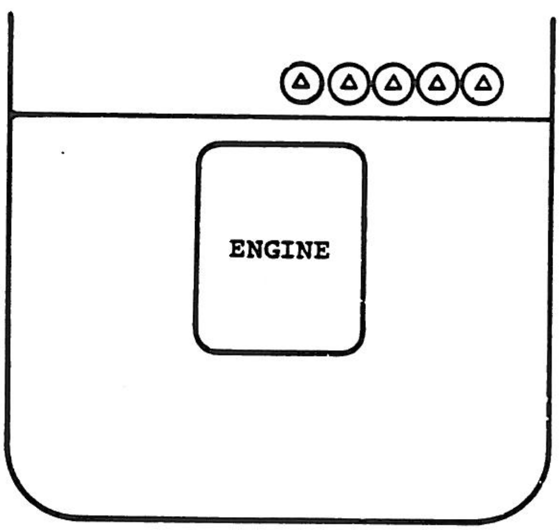
LOCATION (Height relative to engine)

- △ Above top
- O Top
- □ Middle
- ▲ Bottom

Figure 17. Front Light Locations -
Front Engine Passenger Cars.



OIL FILTER



WINDSHIELD WIPER MOTOR

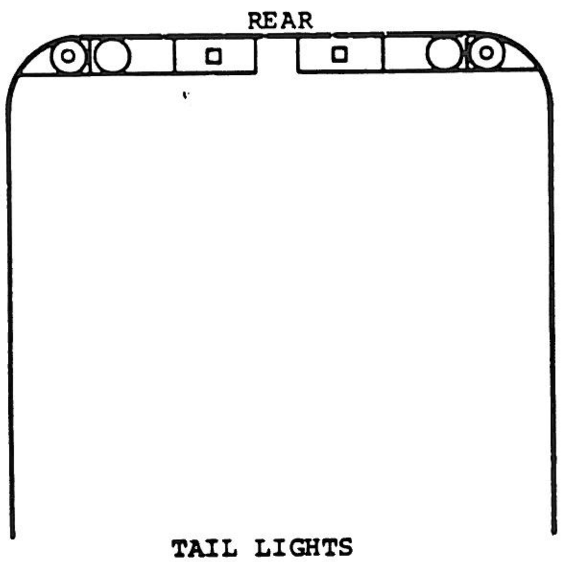
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 18. Oil Filter and Windshield Wiper Motor Locations - Front Engine Passenger Cars.



COMPONENT
<u>IDENTIFICATION</u>

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/
   Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and
    Direction Lights
14. Oil Filter
15. Windshield Wiper
    Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height
<u>relative to engine)</u>

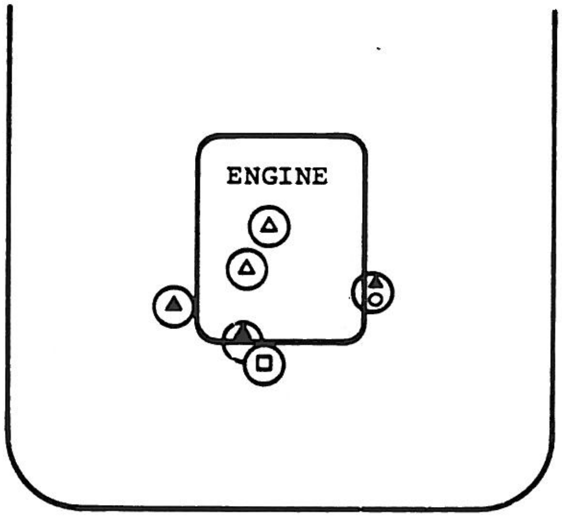
△ Above top

○ Top

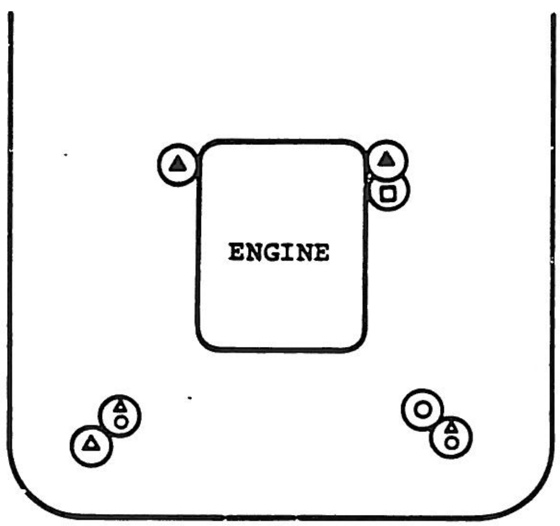
□ Middle

▲ Bottom

Figure 19. Tail Light Locations -
Front Engine Passenger Cars.



FUEL FILTER



STARTER SOLENOID

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 20. Fuel Filter and Starter Solenoid Locations - Front Engine Passenger Cars.

starter (in the case of remote solenoids), however, are usually exposed and capable of sparking if sufficient displacement of the battery or adjacent sheet metal occurs. Particularly vulnerable are solenoids adjacent to the battery since they are located well forward and toward the outside of the engine compartment. Less vulnerable are the solenoids located on the starter since they are to the rear and center of the engine compartment.

6.2.1.3 Voltage Regulators. Voltage regulators are located at random in the engine compartment, see Figure 14. Like the solenoid the voltage regulator, especially the new solid-state type, is itself relatively difficult to damage. The terminals for the associated circuitry, however, are usually exposed, and constitute a sparking potential. In many cars the regulator is mounted either on the forward bulkhead or on the splash guard adjacent to the radiator where it is vulnerable to shorting due to sheet metal displacement.

In some vehicles, the regulator is located on the splash guard, close behind the battery. This sometimes places the regulator, starter solenoid, and battery all in the same area, creating a high sparking potential. In a few vehicles the voltage regulator is located on the splash guard midway back in the engine compartment. In this location, the regulator itself is less vulnerable to frontal impacts but the terminals may short circuit due to sheet metal deformation or associated wiring displacement.

Regulators are also mounted on the firewall at the rear of the engine compartment. On the firewall it is least vulnerable to shorting due to sheet metal displacement. The associated wiring may still be torn loose, however, or the terminals short circuited by other displaced components such as carburetor air cleaners.

6.2.1.4 Lights and Associated Wiring. The headlights are the most hazardous of all the lights from a fire ignition standpoint. This is due to two factors. First, the headlights are of higher wattage and, consequently, have a much larger, hotter filament than the other vehicular lights. Secondly, these lights are located on the front of the vehicle with little protection from damage. The heated filaments can probably remain hot enough to ignite fuel for 0.3 to 0.5 seconds after bulb breakage. Vehicle crash tests indicate that appreciable fuel spillage can occur within this length of time.

The wiring associated with the vehicle headlights and other front lights is usually routed from the light switch on the instrument panel, through the firewall, along the left splash guard to the left hand lights, and then across to the right hand lights. The routing from left to right lights varies. Some manufacturers route the wires down below the radiator along the front frame cross member. Others route this wiring ahead of the radiator by clipping it to the framework supporting the radiator. In the latter position the wiring is extremely vulnerable to crushing in a frontal impact.

The wiring to the tail lights is usually routed inside the vehicle body along the left door sill, through the luggage compartment, and then to the rear lights. This routing is vulnerable to damage in side and rear impacts, plus presenting a sparking potential near the fuel tank.

All wiring is usually enclosed by either a tape wrapping or a woven fiber sheathing that does little to protect the wiring during impacts. Numerous sharp edged and irregularly surfaced locations in the routing possess potential for cutting the light wires in a crash.

6.2.1.5 Horns and Associated Wiring. Each front engine passenger car has from 1 to 4 horns. These are located either behind the grillwork and ahead of the radiator or mounted to the bulkhead alongside the radiator (Figure 11). In either position the horns and wiring are vulnerable to damage in a frontal impact. The horn wiring terminals, however, are shielded as long as the wire remains attached since bayonet-type connectors are used with a well insulated female connector on the wire. If the connector is pulled loose, the contacts in the female connector are still protected from grounding.

6.2.1.6 Alternators/Generators and Associated Wiring. Alternators and generators constitute a serious ignition potential because of their large electrical capacity, up to 55 amperes at 12-14 volts in heavy duty models.

The alternator or generator, a very sturdy device, is not particularly vulnerable to damage and is usually located a considerable distance from the front of the vehicle (See Figure 13). Considerable crushing must take place before they become subject to impact. However, the terminals on the alternator or generator case are sometimes exposed and vulnerable to sparking if contacted due to deflection of the mounting bracket, adjacent sheet metal, or other accessories.

Vulnerability of the wiring from the alternator or generator to the voltage regulator depends upon the location of these components with respect to each other.

6.2.2 Secondary Hazards of the Electrical System. Components located rearward in the engine compartment of front engine passenger cars are less vulnerable to damage and are considered secondary postcrash fire ignition hazards. Examples of such components are heater blowers, windshield wiper motors, distributors, ignition coils, and associated wiring.

6.2.2.1 Heater Blowers and Associated Wiring. Heater blowers located in the engine compartment are usually installed on the right side of the firewall (Figure 15). In some models they are located inside the passenger compartment between the instrument panel and the firewall.

The heater blower motor is a sturdy mechanism but its terminals and associated wiring are often exposed and thus have a sparking potential. The heater blower motor is most vulnerable to side impacts where the fenders and/or hood hinges may be displaced far enough to damage the terminals or wiring.

There is a minimum of exposed wiring from the heater blower. Two or three wires lead from terminals on the motor to and through the firewall and then to the blower control switch on the instrument panel.

6.2.2.2 Windshield Wiper Motor and Associated Wiring. These components are usually found on the firewall, either in the center or toward the left side (Figure 18). Like the heater blower, the windshield wiper motor is a sturdy device not particularly vulnerable to damage. The terminals and wires, however, are exposed and vulnerable to damage. These are most vulnerable to side impacts on the left side where the fender metal or hood hinge may be displaced sufficiently to contact the terminals or damage the wiring.

The wiring usually consists of several strands separated for 6 to 8 inches at the ends and then bundled and taped. The bundle is routed through the firewall to the control switch on the instrument panel.

6.2.2.3 Engine Ignition Systems. Major V-8 engine ignition system components (distributor and coil) are located in two general areas, either at the front of the engine block just ahead of the carburetor or at the rear of the engine block just ahead of the firewall (Figures 13 and 14). In either location the coil and distributor are mounted in close proximity to each other and approximately on the centerline of the engine. The wires leading to the spark plugs are then routed from the distributor over the valve covers to the spark plugs.

In either location, the V-8 engine ignition system is not particularly vulnerable to damage. The most hazardous portion of the ignition system from the viewpoint of sparking potential is the high tension wiring consisting of the spark plug wires, and the lead from the secondary tap of the coil to the center of the distributor. These wires must be severed to produce a spark since the ends are well shielded by rubber caps. Since considerable deformation must occur before the ignition system would be damaged, it is probable that the impact required to produce this deformation would also stall the engine. Once this occurs, the only sparking potential remaining is the primary terminal and wire on the coil. Grounding this terminal or the wire will produce a spark and displacement of the coil and/or adjacent components could cause this terminal or wire to be grounded.

The major ignition components of 4- and 6-cylinder engines are usually located on the side of the engine block, midway back in the engine compartment. In this location, the components are vulnerable to damage caused by displacement of other components located nearby and/or sheet metal. In full-size domestic cars with engine compartments sized for large V-8 engines, considerable sheet metal displacement must occur before the ignition system on a 4- or 6-cylinder engine is endangered. In compact cars, or foreign cars normally equipped with 4- or 6-cylinder engines, very little displacement is required to produce damage.

6.2.3 Primary Hazards of the Fuel and Oil System. From the standpoint of fire potential, the primary hazard in the fuel and oil system is the fuel tank due to its capacity (up to 25 gallons on some cars) and its exposed location in the rear of the vehicle just ahead of the rear bumper (Figure 16). The tank and filler pipe are extremely vulnerable to damage from moderate rear and rear-corner impacts. Fuel may be released due to tank rupture and/or filler pipe damage. In addition, rear-mounted fuel tanks may be dislodged from their mountings in any type accident, even though the tank itself is not damaged. When this occurs, the filler pipe may separate resulting in massive fuel spillage.

6.2.4 Secondary Hazards of the Fuel and Oil System. Secondary hazards in the fuel and oil system are the carburetor, fuel filter, fuel pump, fuel lines and oil filter.

6.2.4.1 Carburetors. In V-8 engine vehicles the carburetor is located on top of the engine approximately in the center of the engine compartment (Figure 12). In this location it is well shielded by the mass of the engine block and not particularly vulnerable to damage during impact. Although the carburetor contains a small amount of fuel, this fuel is not likely to be released except in a roll-over accident.

In 6-cylinder and 4-cylinder engines the carburetor is located midway up on the side of the engine block at the center of the engine. In this location the carburetor is vulnerable to damage from side impact. Should damage occur, fuel from the carburetor could be spilled onto the exhaust manifold located under the carburetor. This fuel would then vaporize, creating a readily ignitible fuel/air mixture.

In full-size domestic cars considerable displacement must take place before the carburetor is endangered. In some compact cars and foreign cars the engine compartment is much smaller and lesser displacement could endanger the carburetor.

6.2.4.2 Fuel Pump. The fuel pump may be located on either lower front corner of the engine block (Figure 12). It is vulnerable to damage from front or front-quarter impact, particularly if the impact is with a pole or tree. The fuel pump itself contains only a small amount of fuel, and, since it is usually engine-driven, requires that the engine be operating to deliver fuel. In all probability an impact severe enough to damage the fuel pump would stall the engine before damage to the fuel pump occurred.

An exception to the above exists for the small number of cars that are equipped with electric fuel pumps. These pumps may be located anywhere between the fuel tank and the carburetor. Should a fuel line be severed ahead of the pump, with electrical power still available at the pump, fuel will continue to be delivered until the tank is emptied. This is because the electric pump shuts off only when a specific pressure exists in the line to the carburetor or the electrical circuit is interrupted.

6.2.4.3 Fuel Lines. The fuel line from the fuel tank to the engine-driven pump usually exits the tank at the front, through the sending unit for the gauge, and is then routed to the frame rail on the side of the vehicle corresponding to the fuel pump location. The line is then routed along the inside of the frame rail or sill to the engine compartment. The line from the tank to the engine compartment is normally made from ductile steel tubing with the portion inside the engine compartment composed partly of flexible hose. The amount of hose used will vary from a few inches to several feet, depending upon the manufacturer.

The tubing portion of the tank-to-pump-line is relatively invulnerable to damage for several reasons. First, it is usually well protected by either the frame rail or body sill. Second, the ductile tubing will usually bend and/or collapse if impacted. Even if severed the ends will collapse, limiting fuel flow.

The hose portion of the line is vulnerable to damage by cutting and by failure of connections in tension. The hose is normally connected to the tubing simply by slipping the hose over the tubing and securing it with either a spring clamp or a crimped metal band. This type connection can easily be failed by tension loading. Some vehicles use short flexible hose between the fuel line and the pump with threaded connections on each end. This type is less vulnerable to tension failure and, because the hose is usually of a braided material, less vulnerable to cutting failure.

The line from the engine-driven pump to the carburetor is usually routed from the pump around the front of the engine block and up to the carburetor. This routing is used to avoid passing the fuel line over the exhaust manifold, thereby reducing the possibility of vapor lock due to overheating the fuel. The vulnerability of this line is variable, depending on the exact routing of the line and the proximity of other components, such as alternators or air conditioning compressors. In most vehicles the line is routed close to the block and is well protected by the water pump pulley and shaft. In some vehicles with 6-cylinder engines, where the fuel pump and carburetor are on opposite sides of the block, the line is routed directly up and over the top of the engine. This routing places the line well back in the engine compartment where it is less vulnerable to front impacts. Severe side impact could produce sufficient deflection to damage the line, however.

The line from the pump to the carburetor does not usually employ hose, unless an in-line fuel filter is used, and is made entirely of ductile steel tubing with threaded fittings at each end.

6.2.4.4 Fuel Filters. Two types of fuel filters are normally used, the canister type and the in-line type.

The canister type is located on the fuel pump and consists of a disposable filter element housed in a light metal screw-on canister. This type, common on newer vehicles, may contain as much as a half-pint of fuel.

The in-line filter may be located at any point in the pump-to-carburetor line, although it is usually found on top of the engine close to the carburetor (Figure 20). Two types of in-line filters may be encountered. On older vehicles the filter element may be housed in a heavy glass bulb. Newer vehicles have the filter element encased in a light metal container which is entered in the fuel line with short rubber hoses on each end.

The canister type filter is easily damaged because of its light construction. Its location on the fuel pump makes it vulnerable to frontal impact, but fairly well protected by front suspension components against side impacts.

The vulnerability of in-line filters will vary with their type and location. The older type with the glass bulb is extremely vulnerable regardless of location. The glass bulb can be easily broken on impact by contact with its immediate surroundings due to flexing of the fuel line. The newer metal case types are less vulnerable to damage, particularly when they are located on top of the engine adjacent to the carburetor.

6.2.4.5 Oil Filters. Oil filters in front engine passenger cars are located low in the engine compartment near one of the corners of the engine block (Figure 18). Those located at the rear corners are not as vulnerable to damage as those near the front corners. Those filters which mount with the long axis of the element vertical are less vulnerable than those mounted horizontally.

Although the oil is not likely to be ignited in a crash, the filters hold approximately one quart of oil which could serve to feed a fire ignited from another source.

6.3 FRONT ENGINE STATION WAGONS

Front engine station wagon electrical and fuel system configurations differ very little from front engine passenger cars. Mechanically the same components are used with the only major difference being the design of the bodywork. Figure 21 shows a typical station wagon engine compartment. Figure 22 presents a diagram of component location areas while Figures 23 through 32 show individual component locations. Similarity in layout of passenger cars and station wagons can be seen by comparing Figures 10 and 22.

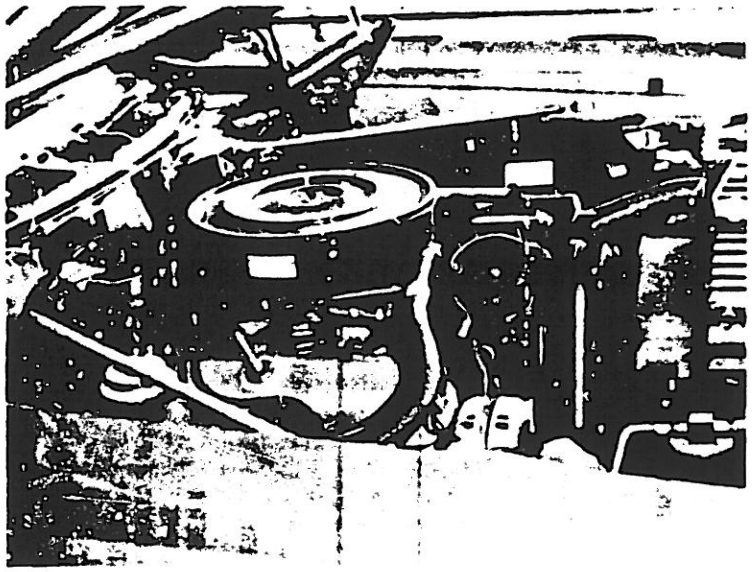


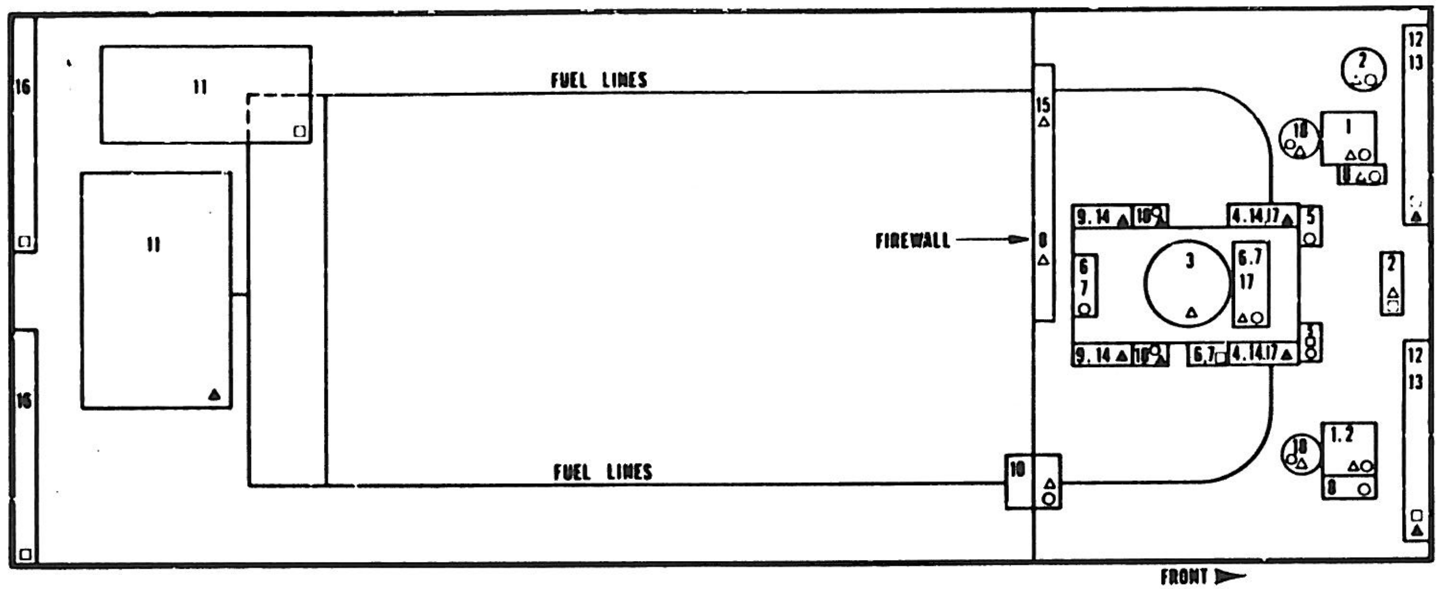
Figure 21. Engine Compartment - Typical Front Engine Station Wagon.

The only significant difference in electrical and fuel system component layouts between front engine passenger cars and station wagons is the fuel tank location. While some station wagons locate the fuel tank in the rear under the body, as in passenger cars, a few models locate the tank in the left rear fender (Figure 28). This location makes the tank extremely vulnerable to rear and side impacts since it is protected only by the body metal.

All other observations previously made concerning front engine passenger cars apply to front engine station wagons.

6.4 REAR ENGINE PASSENGER CARS

Rear engine passenger cars represent a significant portion of the vehicles in use though only a few manufacturers are represented. These vehicles are, with one exception, of foreign manufacture and configurations change very little from year to year. Four such vehicles representing a cross section of this type car were examined. Figure 33 shows a typical rear engine compartment. Figure 34 presents a diagram of component location areas and Figures 35 through 51 show individual component locations.



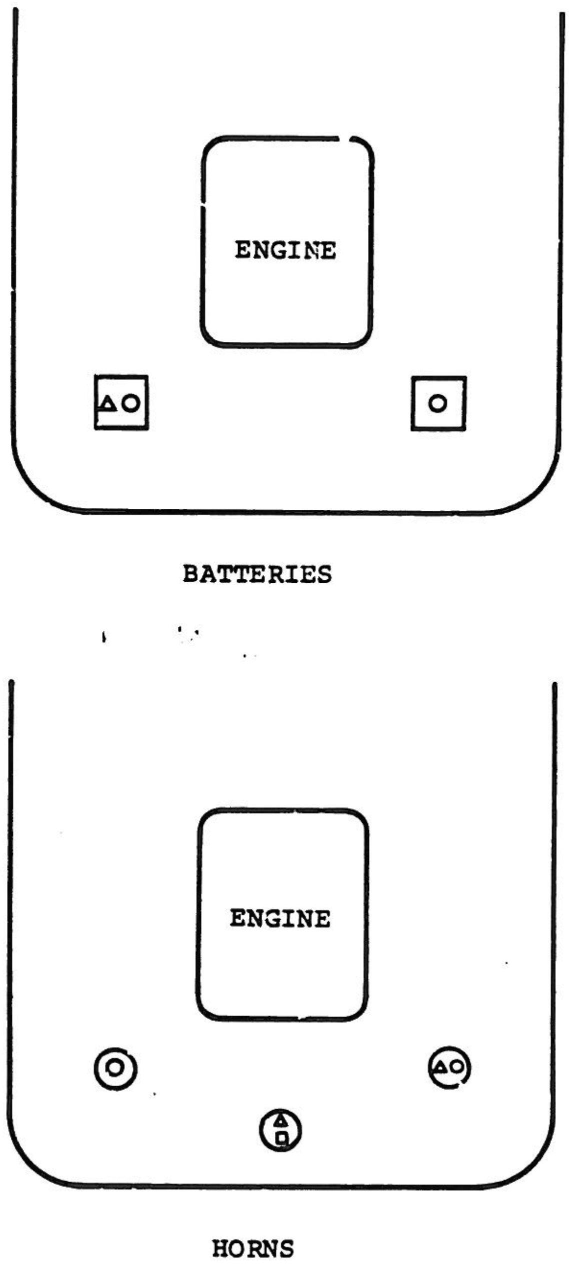
LOCATION (HEIGHT RELATIVE TO ENGINE)

- △ ABOVE TOP
- ○ TOP
- □ MIDDLE
- ▲ BOTTOM

COMPONENT IDENTIFICATION

1. BATTERY
2. HORN
3. CARBURETOR
4. FUEL PUMP
5. ALTERNATOR/GENERATOR
6. DISTRIBUTOR
7. COIL
8. VOLTAGE REGULATOR
9. STARTER
10. HEATER BLOWER
11. FUEL TANK
12. LIGHTS
13. PARKING & DIRECTIONAL LIGHTS
14. OIL FILTER
15. WINDSHIELD WIPER MOTOR
16. TAIL LIGHTS
17. FUEL FILTER
18. STARTER SOLENOID

Figure 22. Component Location Zones - Front Engine Station Wagons.



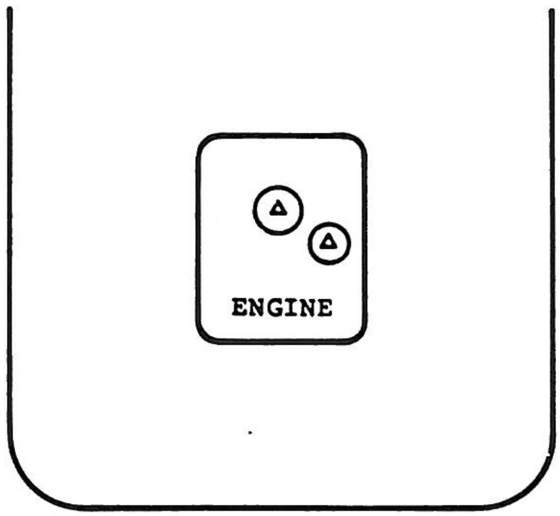
COMPONENT IDENTIFICATION

1. **Battery**
2. **Horn**
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

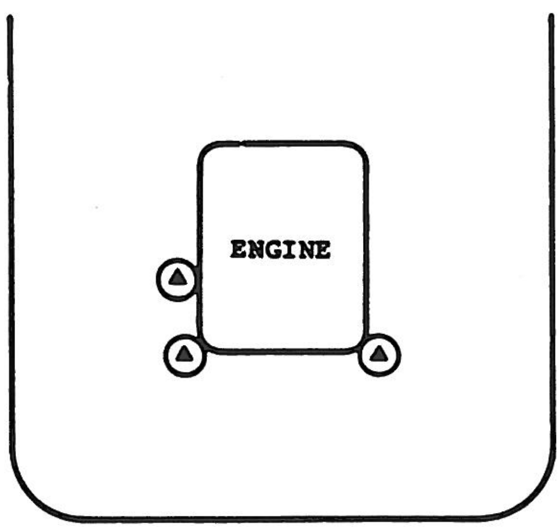
LOCATION (Height relative to engine)

△ Above top
○ Top
□ Middle
▲ Bottom

Figure 23. Battery and Horn Locations - Front Engine Station Wagons.



CARBURETORS



FUEL PUMPS

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

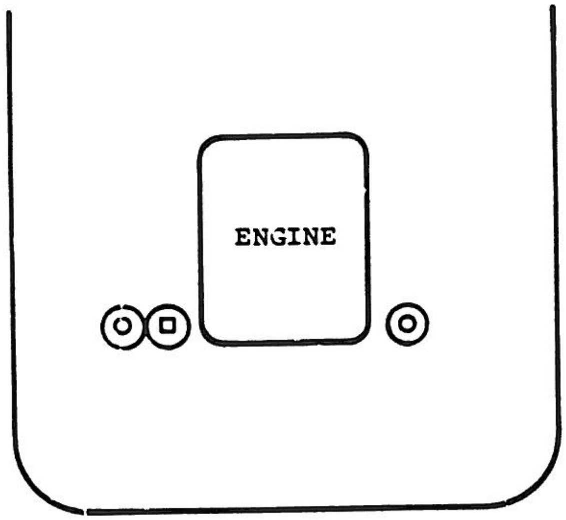
△ Above top

○ Top

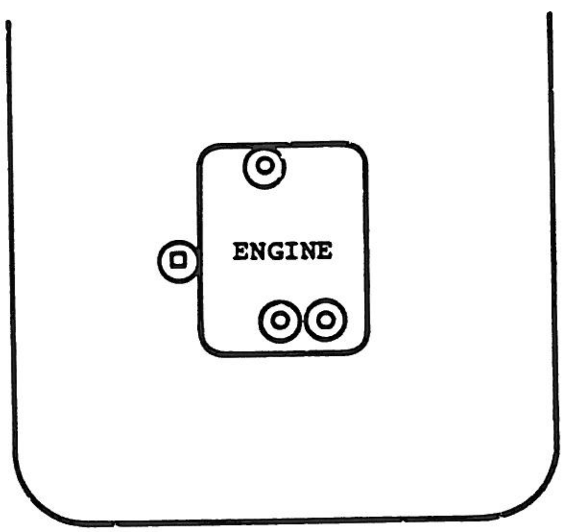
□ Middle

▲ Bottom

Figure 24. Carburetor and Fuel Pump Locations - Front Engine Station Wagons.



ALTERNATOR/GENERATOR



DISTRIBUTORS

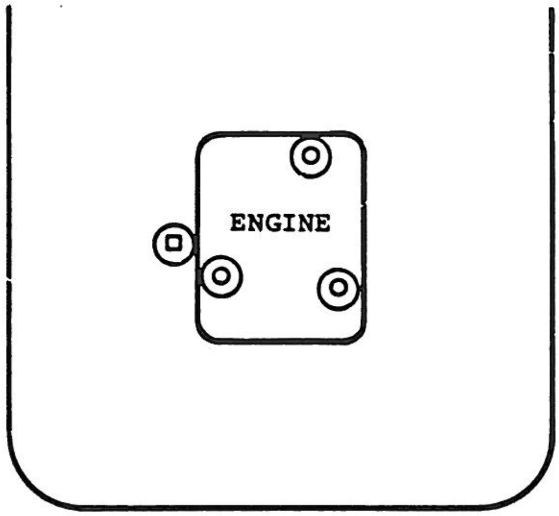
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

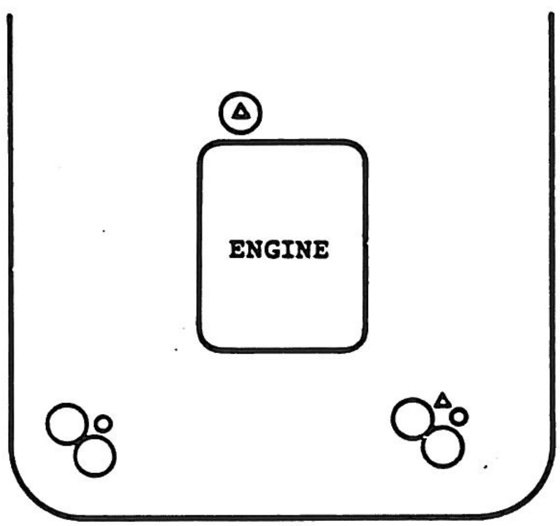
LOCATION (Height relative to engine)

△ Above top
○ Top
□ Middle
▲ Bottom

Figure 25. Alternator/Generator and Distributor Locations - Front Engine Station Wagons.



COILS



VOLTAGE REGULATORS

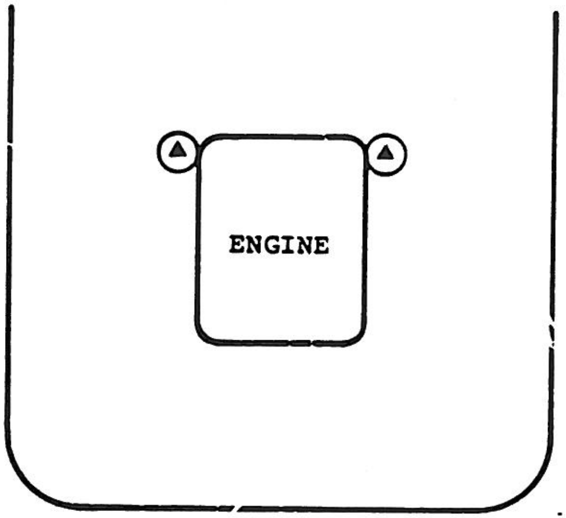
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

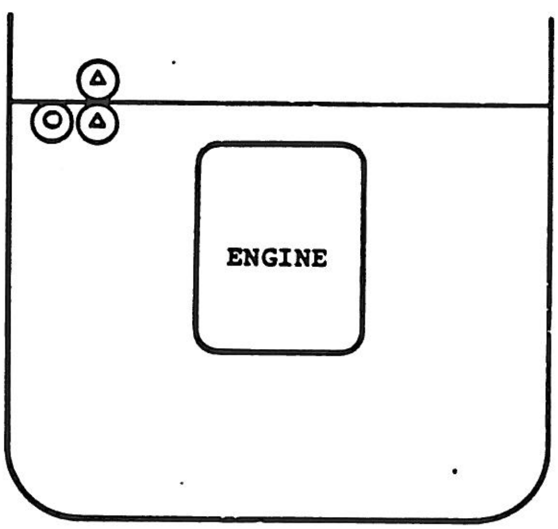
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 26. Coil and Voltage Regulator Locations - Front Engine Station Wagons.



STARTER



HEATER BLOWER

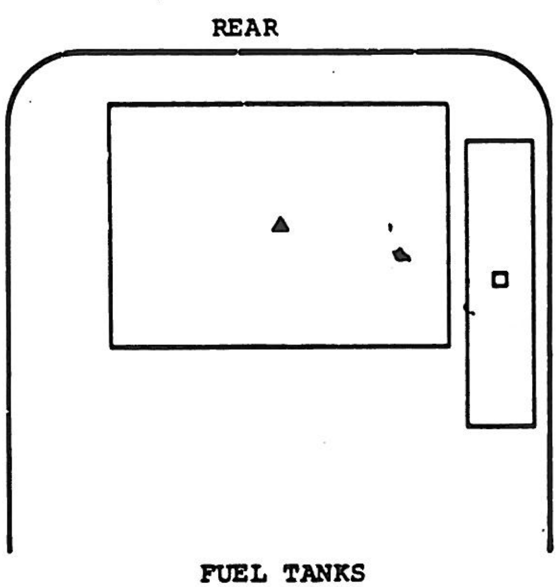
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 27. Starter and Heater Blower Locations - Front Engine Station Wagons.



COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 28. Fuel Tank Locations - Front Engine Station Wagons.

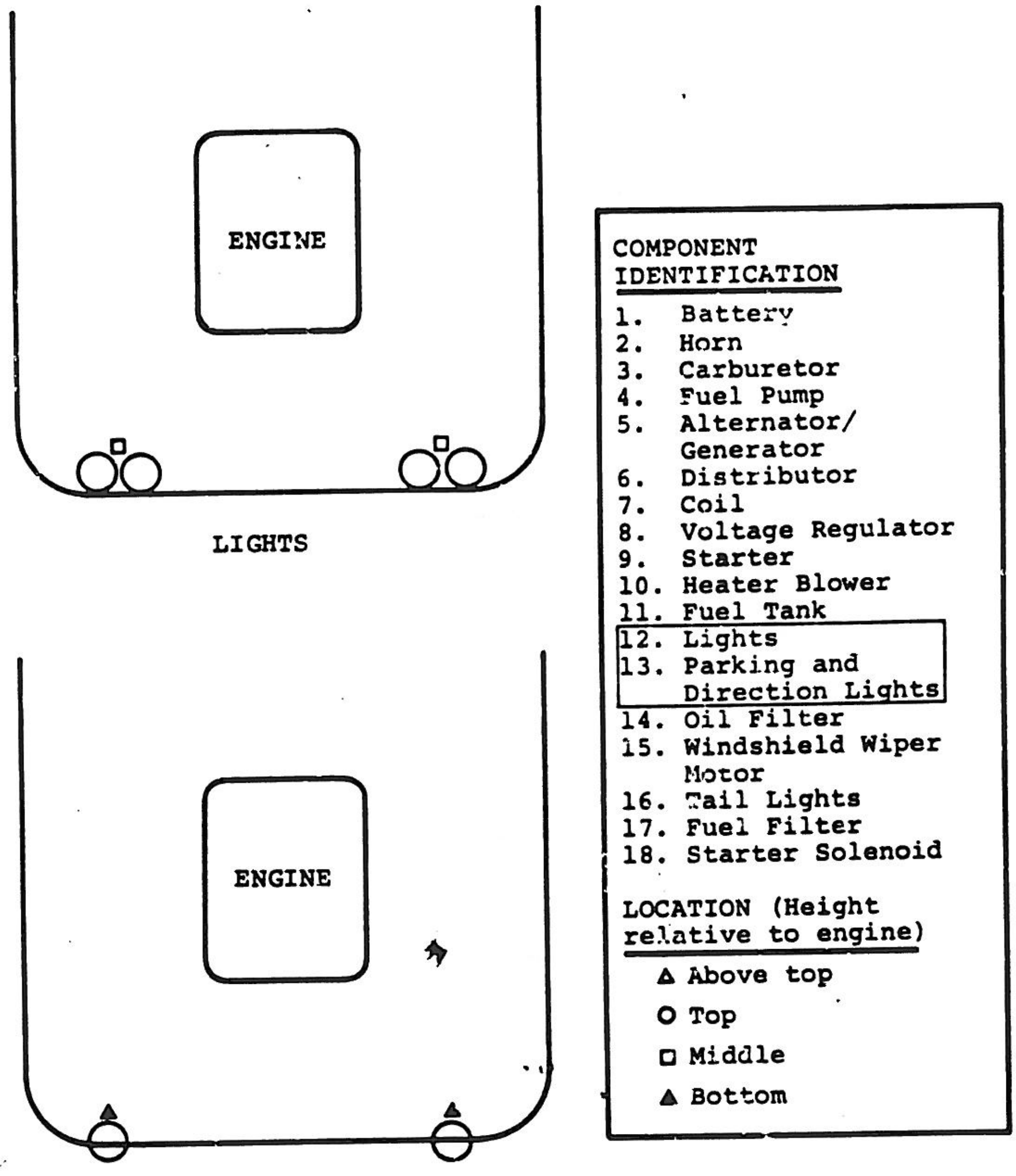
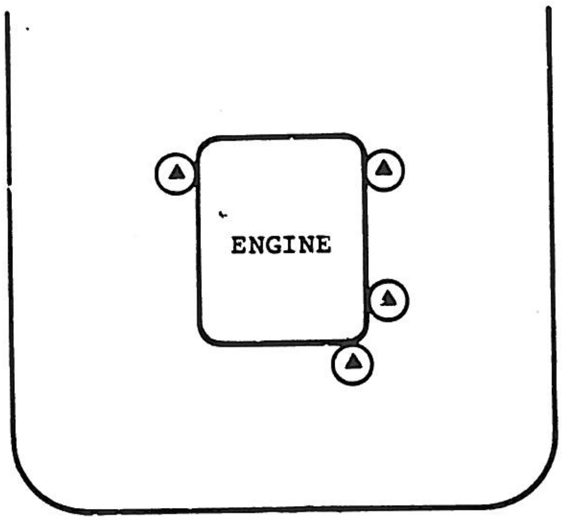
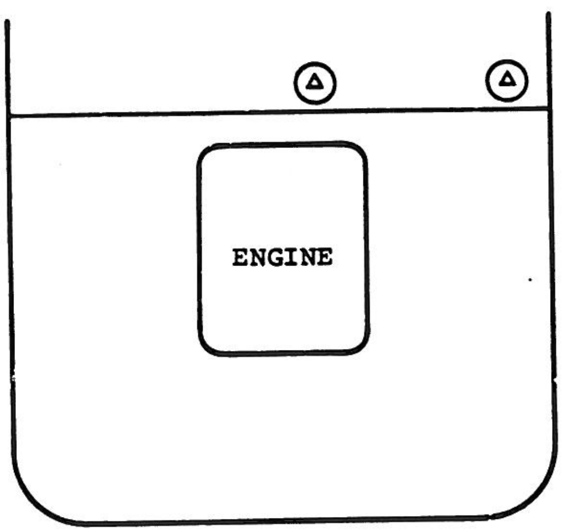


Figure 29. Front Light Locations - Front Engine Station Wagons.



OIL FILTERS



WINDSHIELD WIPER MOTOR

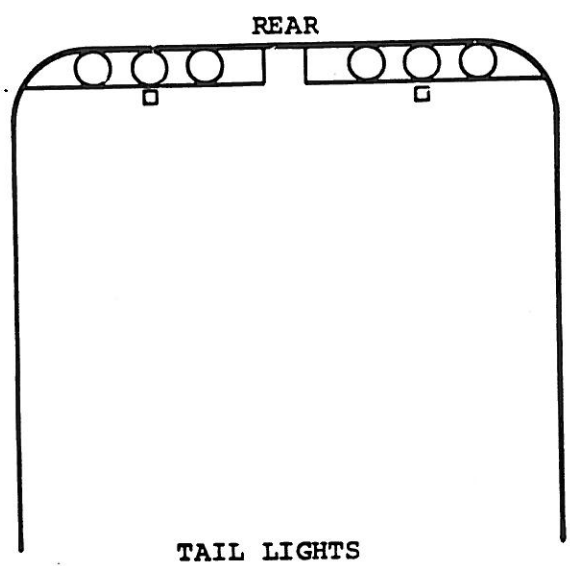
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- O Top
- □ Middle
- ▲ Bottom

Figure 30. Oil Filter and Windshield Wiper Motor Locations - Front Engine Station Wagons.



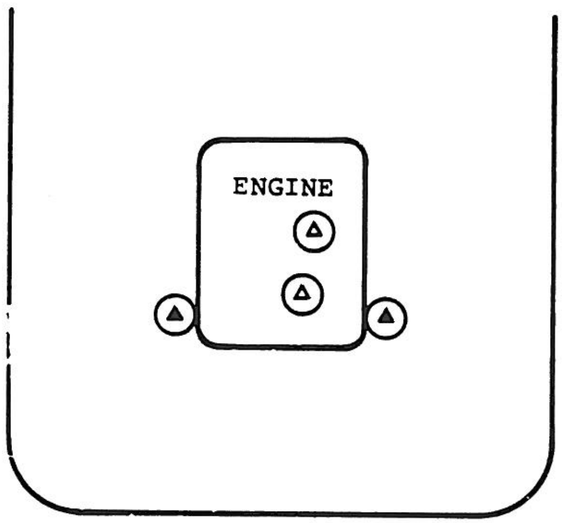
COMPONENT
IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

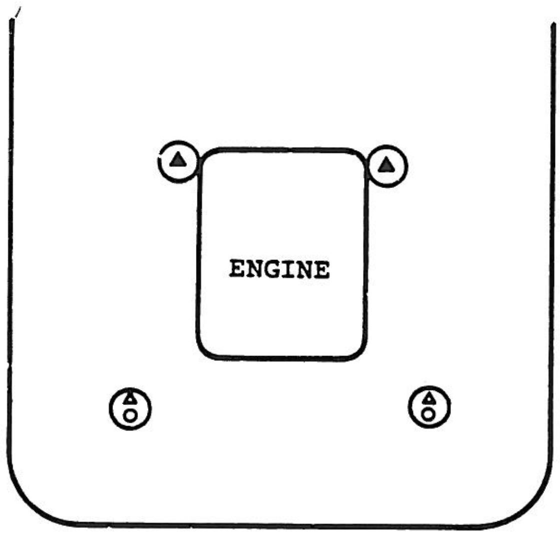
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 31. Tail Light Locations - Front Engine Station Wagons.



FUEL FILTER



STARTER SOLENOID

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 32. Fuel Filter and Starter Solenoid Locations - Front Engine Station Wagons.

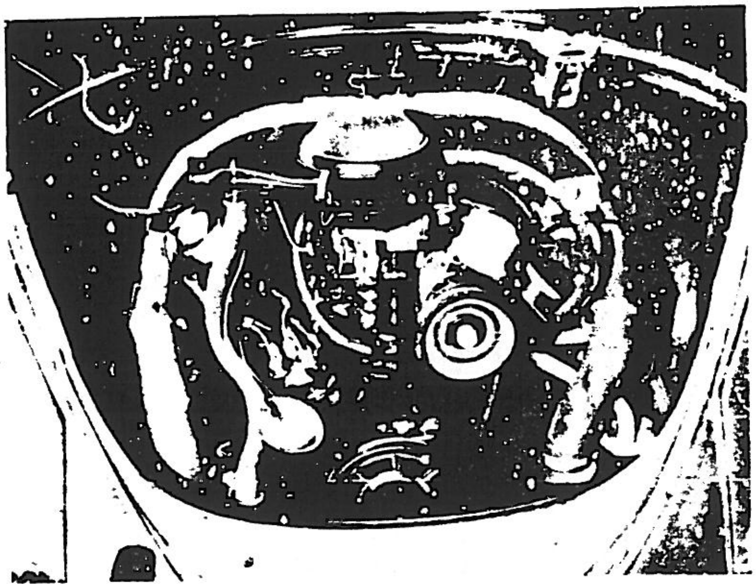
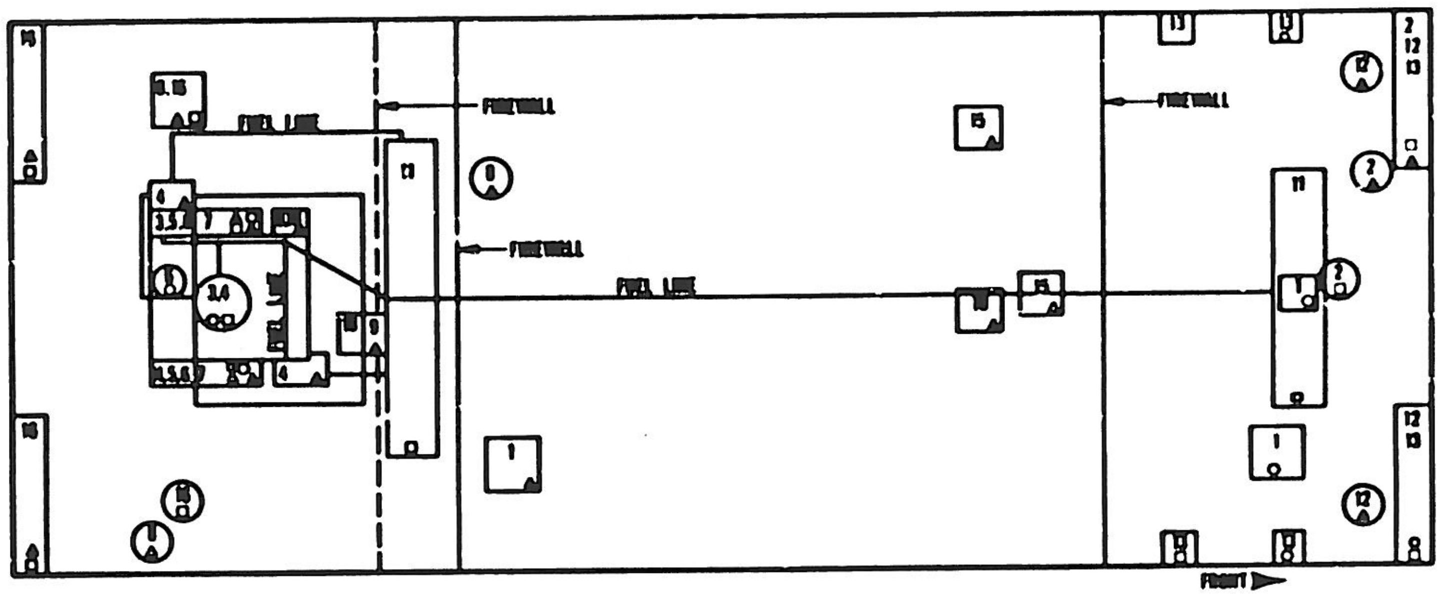


Figure 33. Engine Compartment - Typical Rear Engine Passenger Car.

All models of a particular manufacturer are similar in component location but there is a wide variation in some component locations between vehicles of different manufacturers. This is especially true of battery and fuel tank locations.

6.4.1 Primary Hazards of the Electrical System. As in other vehicles the primary electrical system hazards from a fire ignition viewpoint are those located near the periphery of the vehicle and, therefore, most susceptible to damage or short circuiting. As shown in Figure 34, these components are: batteries, voltage regulators, lights, ignition coils, alternator/generators, distributors, and associated wiring.

6.4.1.1 Batteries and Battery Cables. In some rear engine passenger vehicles the battery is located inside the passenger compartment beneath the rear seat (Figure 35). In this location the battery is relatively invulnerable to damage in all but extremely severe impacts. In other rear engine passenger cars the battery is located in the front of the car in the luggage compartment (Figure 35) where they are extremely vulnerable to frontal and front-quarter impacts.



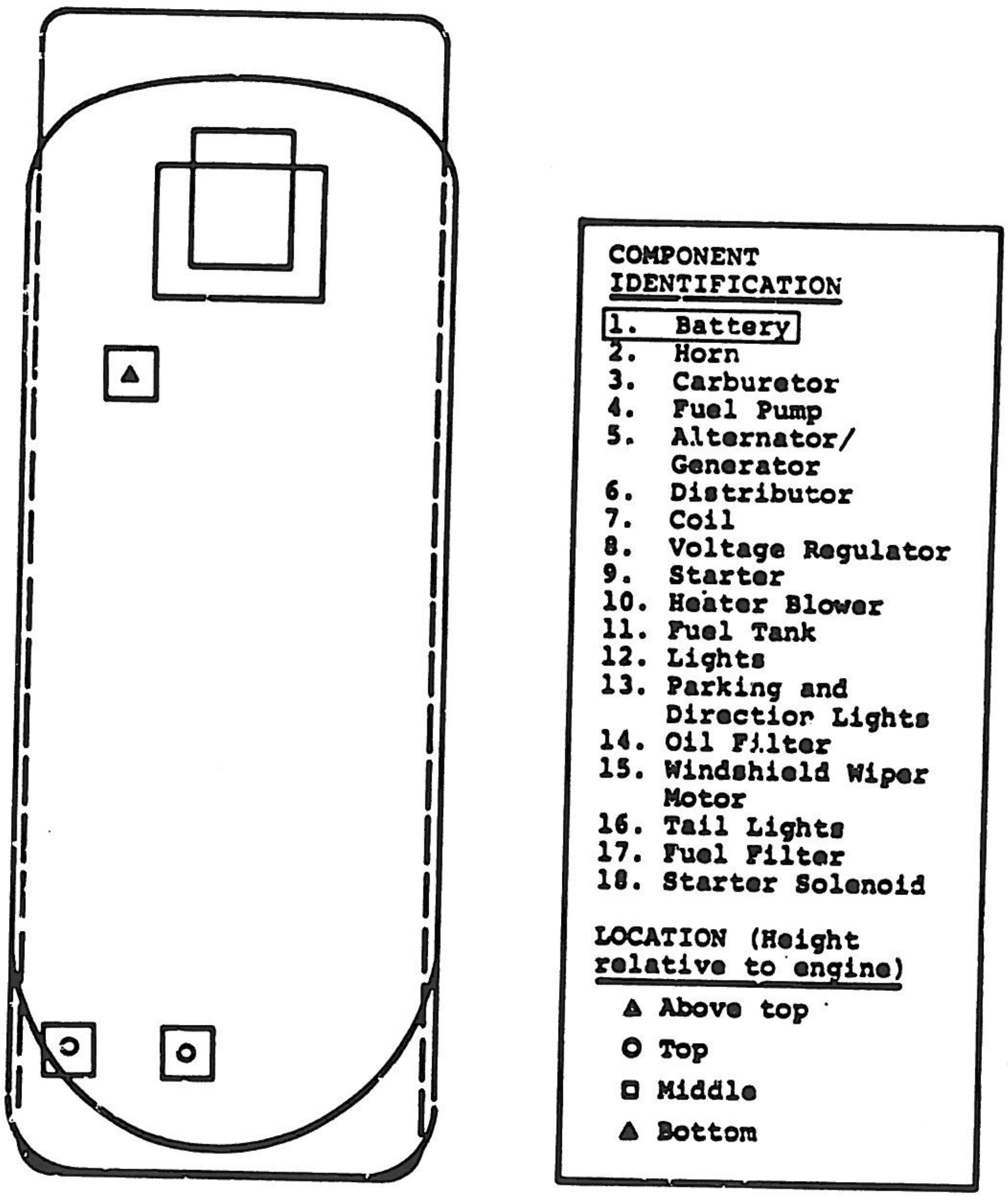
LOCATION (HEIGHT RELATIVE TO ENGINE)

- △ ABOVE TOP
- ○ TOP
- □ MIDDLE
- ▲ BOTTOM

COMPONENT IDENTIFICATION

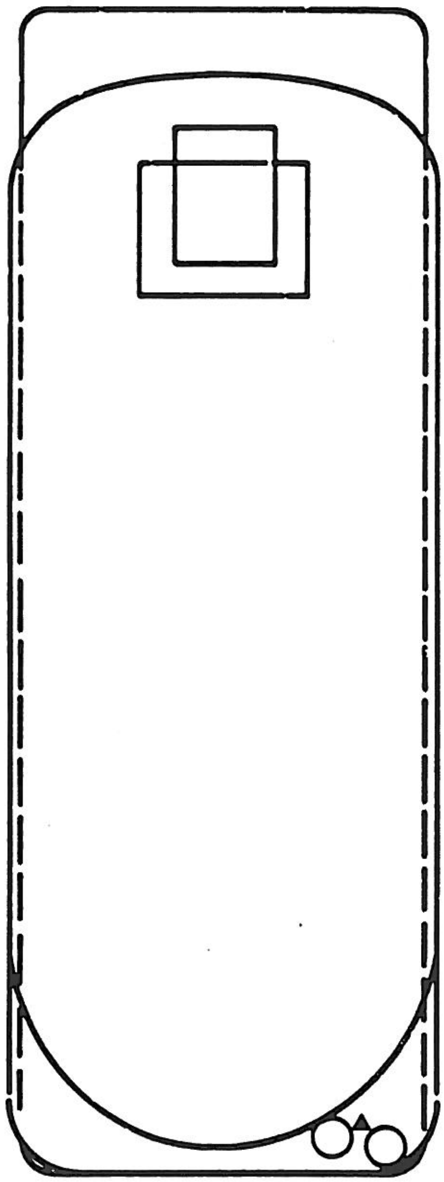
1. BATTERY
2. HORN
3. CARBURETOR
4. FUEL PUMP
5. ALTERNATOR/GENERATOR
6. DISTRIBUTOR
7. COIL
8. VOLTAGE REGULATOR
9. STARTER
10. HEATER BLOWER
11. FUEL TANK
12. LIGHTS
13. PARKING & DIRECTIONAL LIGHTS
14. OIL FILTER
15. WINDSHIELD WIPER MOTOR
16. TAIL LIGHTS
17. FUEL FILTER
18. STARTER SOLENOID

Figure 34. Component Location Zones - Rear Engine Passenger Cars.



BATTERY

Figure 35. Battery Locations - Rear Engine Passenger Cars.



HORN

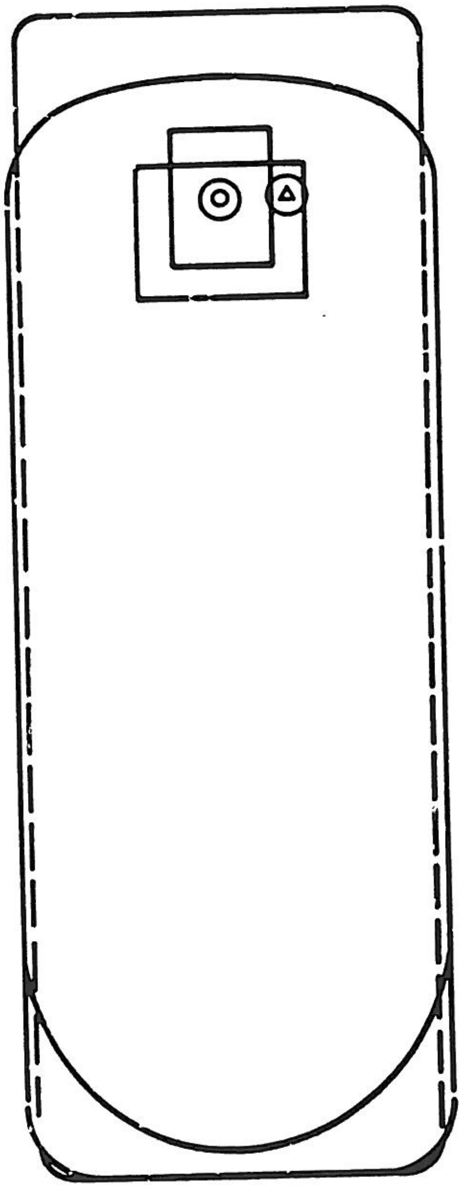
COMPONENT
IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 36. Horn Locations - Rear Engine Passenger Cars.



COMPONENT IDENTIFICATION

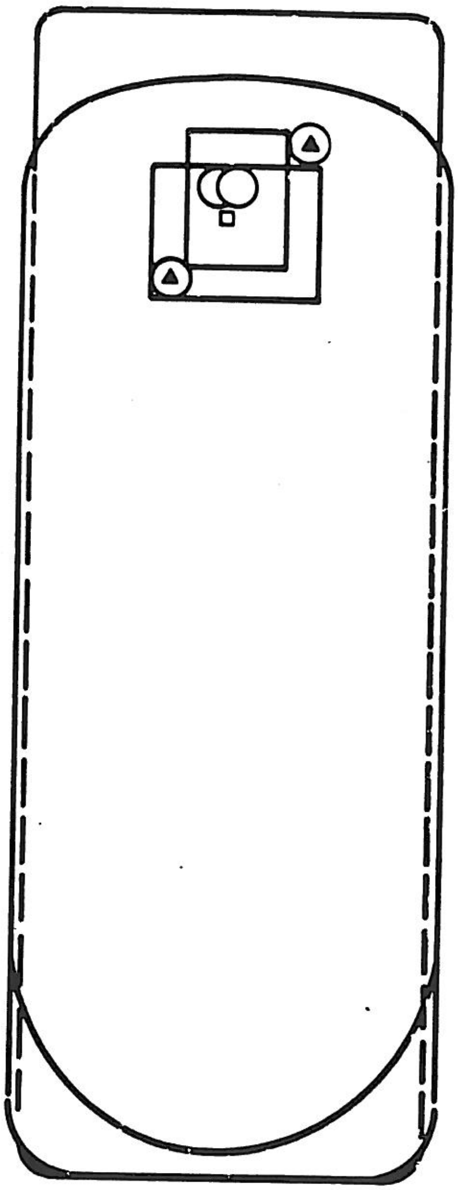
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

CARBURETOR

Figure 37. Carburetor Locations - Rear Engine Passenger Cars.



COMPONENT
IDENTIFICATION

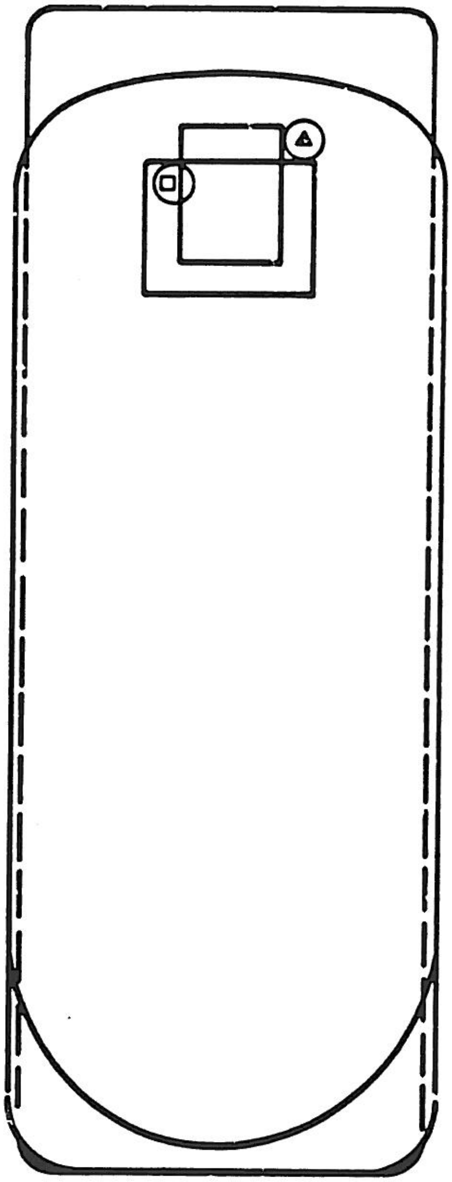
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- ▲ Above top
- ○ Top
- □ Middle
- ▲ Bottom

FUEL PUMP

Figure 38. Fuel Pump Locations - Rear Engine Passenger Cars.



COMPONENT
IDENTIFICATION

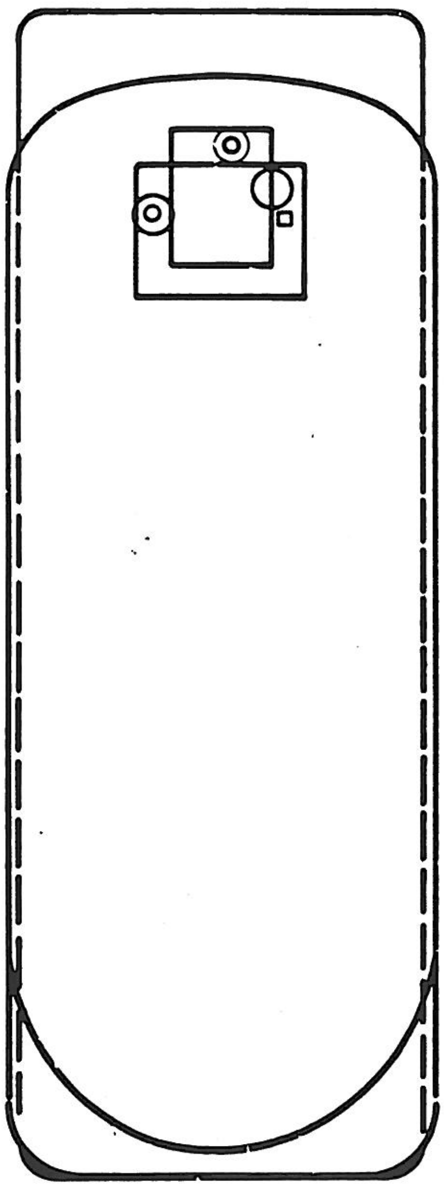
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

GENERATOR

Figure 39. Generator Locations - Rear Engine Passenger Cars.



DISTRIBUTOR

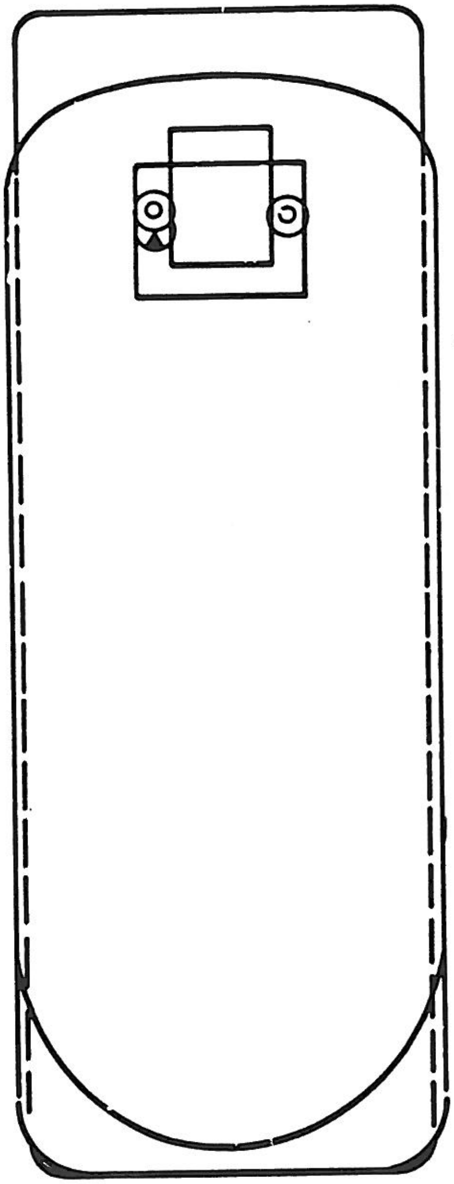
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

△ Above top
○ Top
□ Middle
▲ Bottom

Figure 40. Distributor Locations - Rear Engine Passenger Cars.



COMPONENT IDENTIFICATION

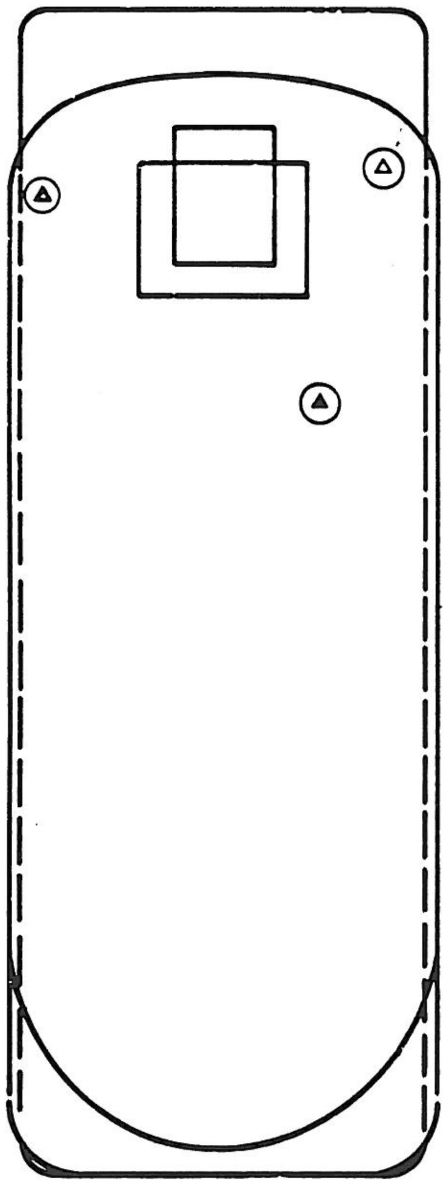
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

COIL

Figure 41. Coil Locations - Rear Engine Passenger Cars.



VOLTAGE REGULATOR

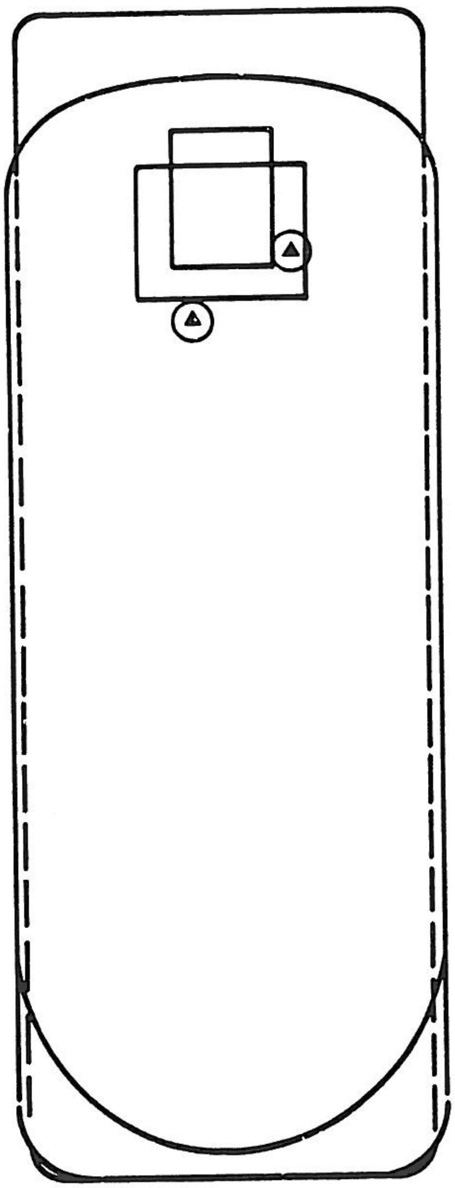
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 42. Voltage Regulator Locations - Rear Engine Passenger Cars.



COMPONENT IDENTIFICATION

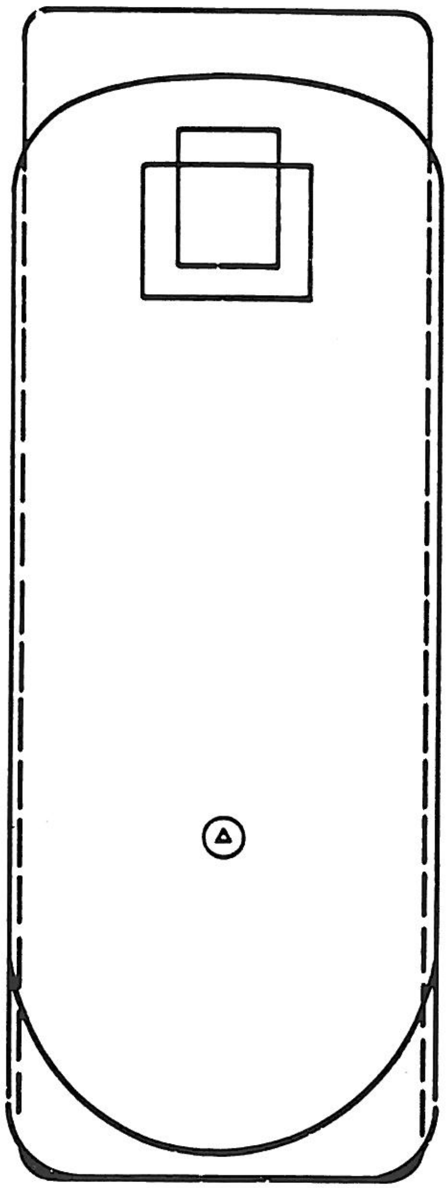
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. **Starter**
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- O Top
- ◻ Middle
- ▲ Bottom

STARTER

Figure 43. Starter Locations - Rear Engine Passenger Cars.



COMPONENT
IDENTIFICATION

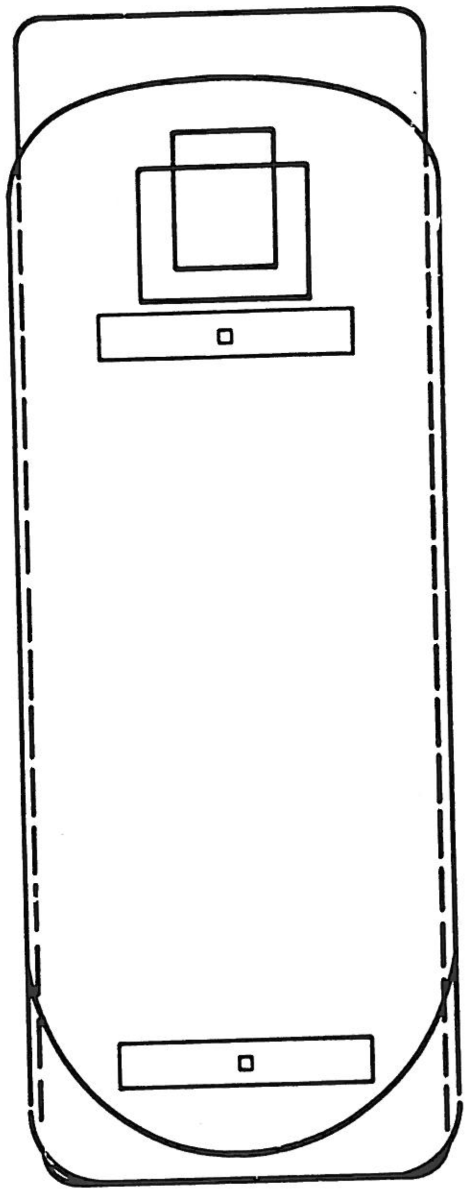
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

HEATER BLOWER

Figure 44. Heater Blower Locations - Rear Engine Passenger Cars.



COMPONENT IDENTIFICATION

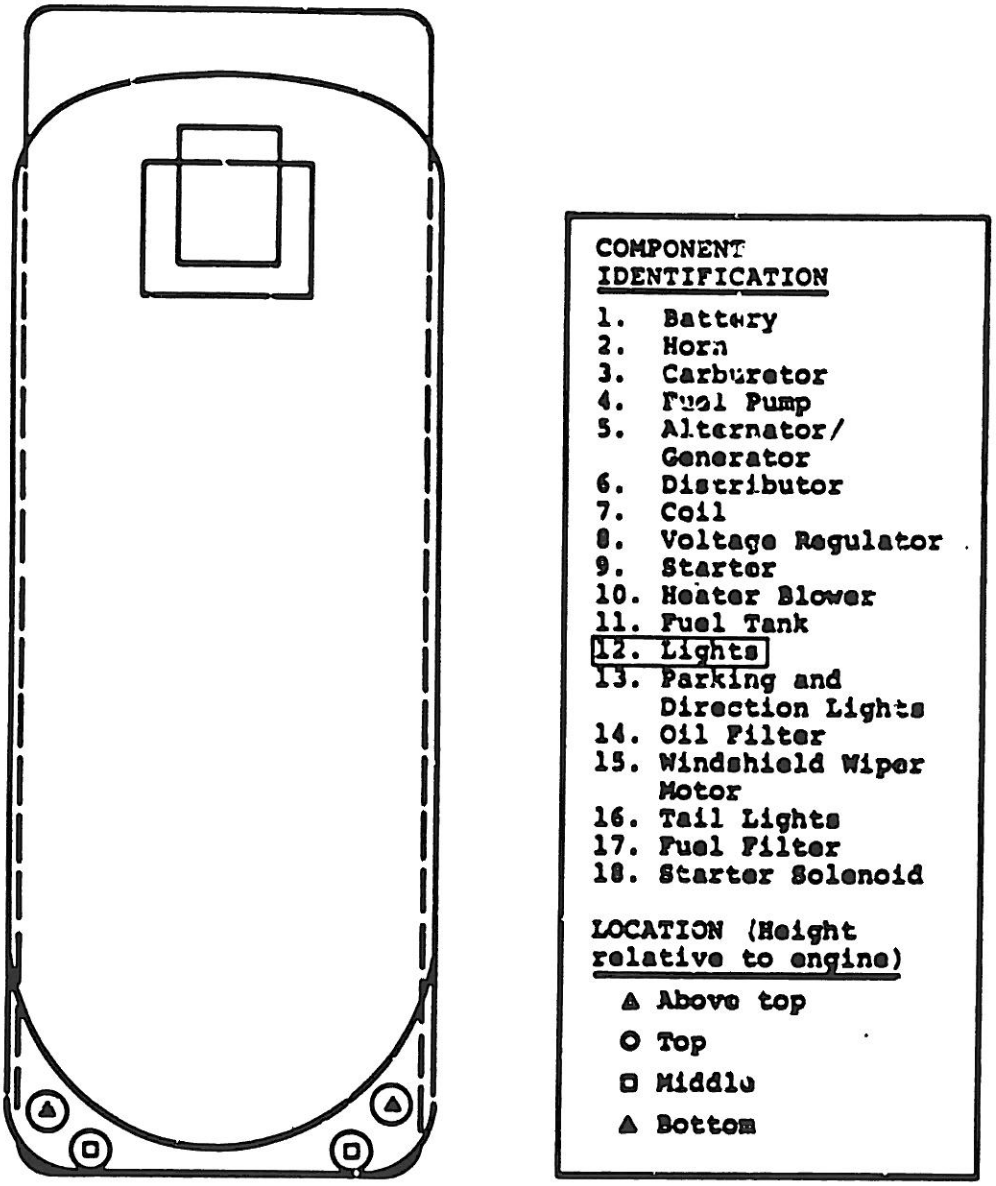
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

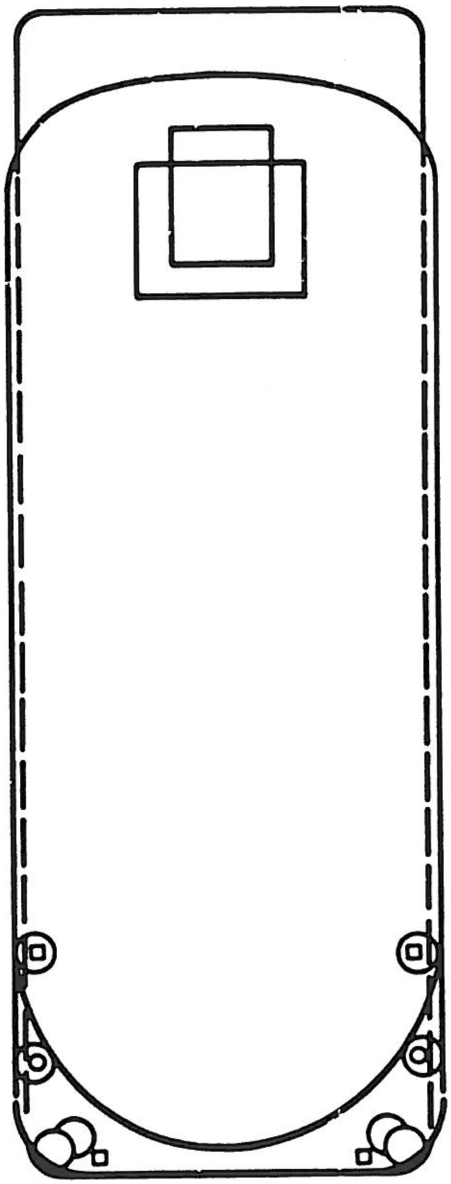
FUEL TANKS

Figure 45. Fuel Tank Locations - Rear Engine Passenger Cars.



LIGHTS

Figure 46. Headlight Locations - Rear Engine Passenger Cars.



COMPONENT
IDENTIFICATION

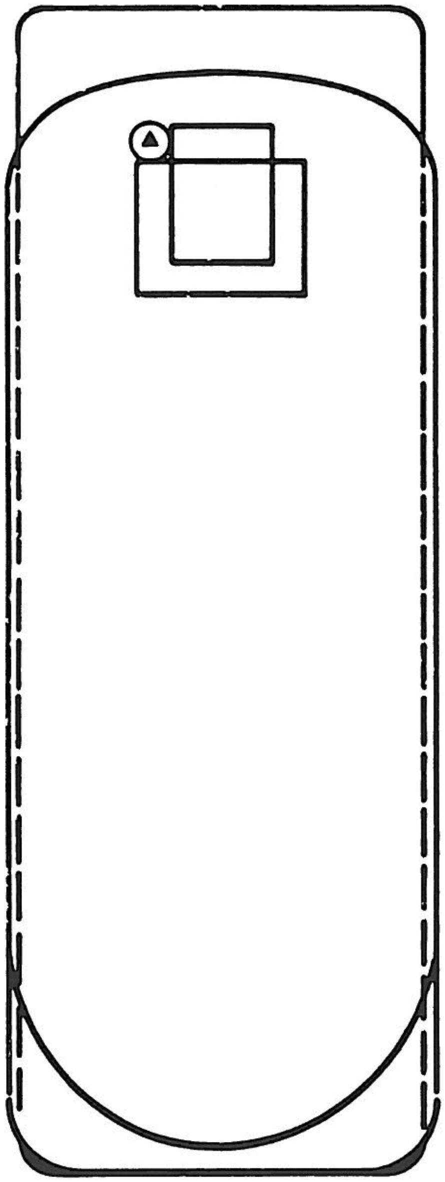
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

△ Above top
○ Top
□ Middle
▲ Bottom

PARKING AND DIRECTION LIGHTS

Figure 47. Parking and Direction Light Locations - Rear Engine Passenger Cars.



COMPONENT
IDENTIFICATION

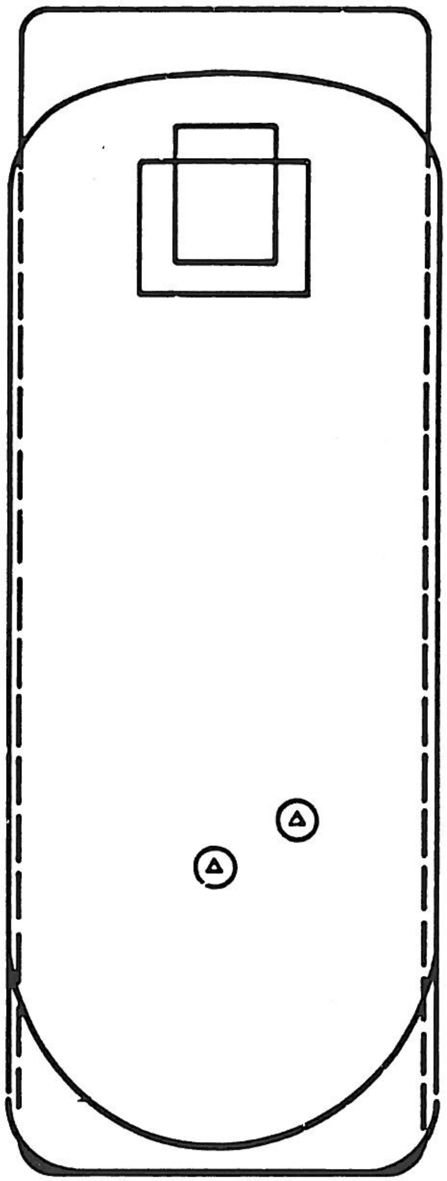
1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

△ Above top
○ Top
□ Middle
▲ Bottom

OIL FILTER

Figure 48. Oil Filter Locations - Rear Engine Passenger Cars.



COMPONENT
IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/
   Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and
    Direction Lights
14. Oil Filter
15. Windshield Wiper
    Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height
relative to engine)

△ Above top

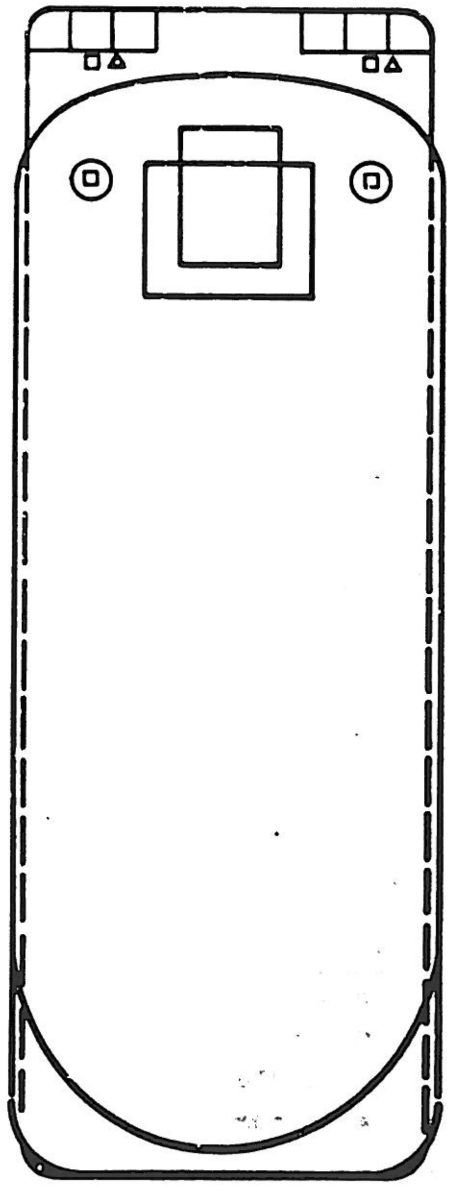
○ Top

□ Middle

▲ Bottom

WINDSHIELD WIPER MOTOR

Figure 49. Windshield Wiper Motor Locations -
Rear Engine Passenger Cars.



COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

▲ Above top

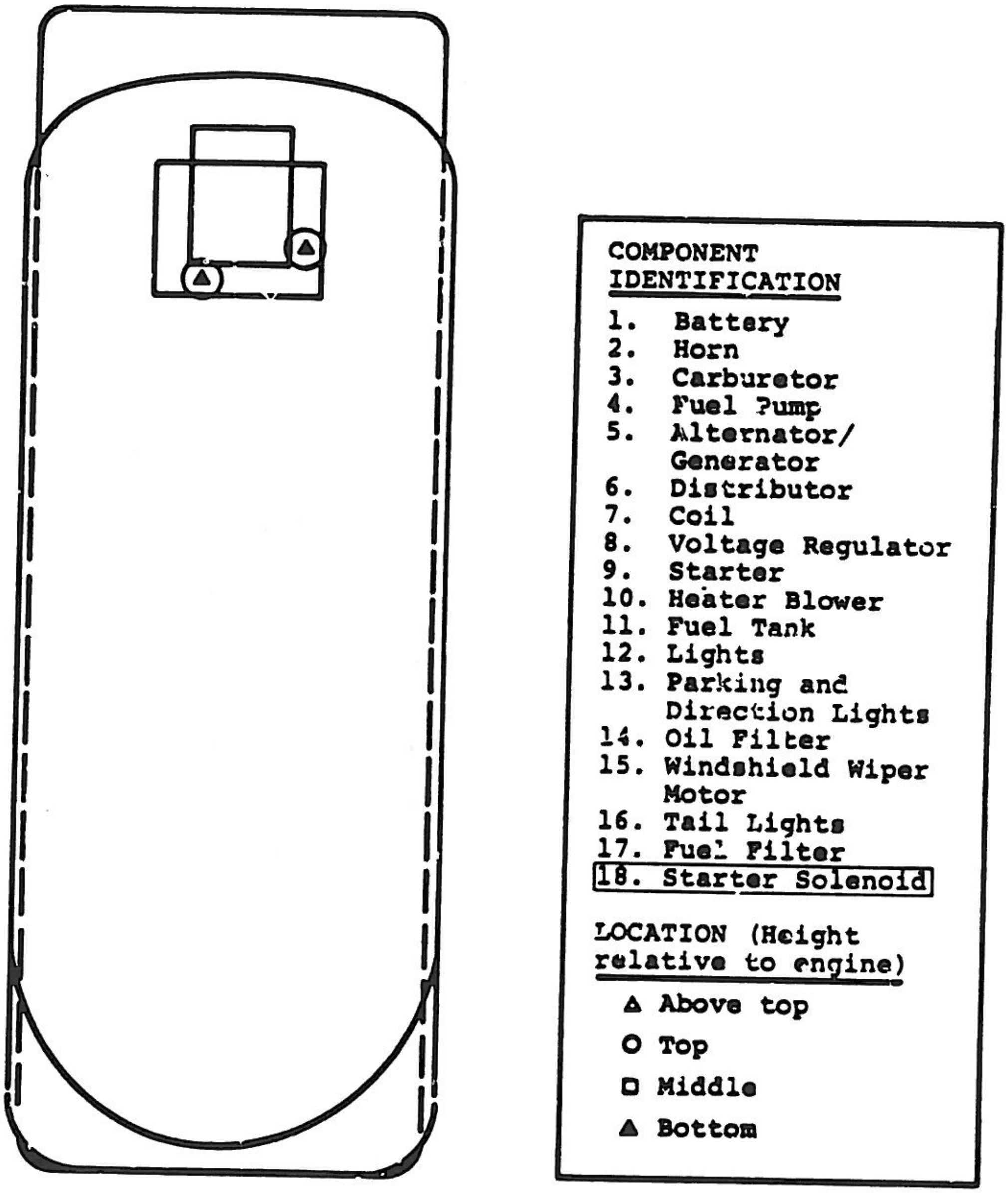
○ Top

□ Middle

▲ Bottom

TAIL LIGHTS

Figure 50. Tail Light Locations - Rear Engine Passenger Cars.



STARTER SOLENOID

Figure 51. Starter Solenoid Locations - Rear Engine Passenger Cars.

The cable from the battery to the starter solenoid is well protected in cars with the battery located in the passenger compartment. The cable is routed well inside the vehicle to the starter solenoid on the starter which is located at the front of the engine compartment. In vehicles where the battery is located in the front luggage compartment the battery cable is extremely long, since it must reach to the starter solenoid in the engine compartment. This cable is normally routed down the center of the vehicle through the tunnel carrying the transmission shift linkage where it is relatively invulnerable to damage from all but extremely severe impacts.

6.4.1.2 Voltage Regulators and Associated Wiring. Voltage regulators may be found in one of two general locations (Figure 42). In cars with the battery located in the passenger compartment the voltage regulator is also located in the passenger compartment, adjacent to the battery where it is well protected from damage.

In vehicles with the battery located in the front luggage compartment the voltage regulator is usually found in the engine compartment mounted on one of the rear quarter panels. Here it is vulnerable to damage or short circuiting due to rear or rear-quarter impacts. Some older models have the regulator mounted on the generator where they are vulnerable to damage. As with any regulator, the primary spark danger lies in short circuiting of exposed terminals.

The vulnerability of the wiring associated with the voltage regulators is a function of the location of the regulator. Regulators located inside the passenger compartment have their wiring located closer to the center of the vehicle than those located on the rear quarter panels and are, therefore, less vulnerable to damage.

6.4.1.3 Ignition Coils. Ignition coils in rear engine cars are frequently located in an exposed position near the rear of the engine (Figure 41). Because of the limited space available in the engine compartment, minor damage to the surrounding sheet metal could cause impingement on the ignition coil and its wiring, producing a spark. The primary terminals on the coil, being uninsulated, are particularly vulnerable.

6.4.1.4 Distributors. The distributor on rear engine vehicles is also very vulnerable to damage in rear impacts, being located within a few inches of the coil (Figure 40). Minor impingement could damage the cap, producing a spark. Since extremely high voltage is involved in this component (20,000 volts and higher), the spark potential is great.

Damaged ignition wiring presents the same hazardous spark potential, although simply pulling the wire loose at the spark plug end will not produce sparking since these terminals are well shielded by a rubber cap.

6.4.1.5 Lights and Associated Wiring. As in other vehicles, the lights present a sparking potential due to their location on the exterior of the vehicle where they are easily damaged. Headlights, due to their size and power requirements are the most dangerous ignition source. The wiring associated with the lights is usually routed near the exterior of the vehicle where it is vulnerable to damage due to sheet metal displacement. In addition, some rear engine vehicles have a terminal strip located just ahead of the instrument panel in the front luggage compartment for accessory wiring. This terminal strip is ordinarily covered by a fibreboard panel of little structural strength. Displacement of sheet metal could easily short circuit these terminals since the terminals are not protected by insulation.

6.4.1.6 Alternator/Generators and Associated Wiring. The alternator or generator is usually mounted toward the rear of the engine compartment above the engine (Figure 39) and is vulnerable to rear impacts. The alternator or generator itself is not easily damaged; however, the terminals may be exposed and short circuited by displacement of body sheet metal or other components.

The wiring associated with the alternator or generator is usually routed from the terminals to the front of the engine compartment, thence to the voltage regulator. Vulnerability is dependent to a large extent on the location of the voltage regulator. Wiring to regulators located in the passenger compartment is less vulnerable than wiring to regulators located in the engine compartment.

6.4.2 Secondary Hazards of the Electrical System. Secondary electrical system hazards consist of starter motors, starter solenoids, horns, heater blower motors, windshield wiper motors, and associated wiring.

6.4.2.1 Starter Motors. The starter motor on rear engine vehicles is usually found on one of the front corners of the engine block (Figure 43), well forward and low in the engine compartment. Considerable displacement must occur before the starter motor or its terminals are endangered. The vulnerability of the wiring associated with the starter motor is primarily a function of the battery location since this determines the length and routing of the cable. See the previous discussion on batteries for possible cable routings.

6.4.2.2 Starter Solenoids and Associated Wiring. The starter solenoid in rear engine cars is mounted directly on the starter motor (Figure 51). Its vulnerability is the same as the starter motor. However, the exposed solenoid terminals are potential spark producers if contacted by collapsing structure.

6.4.2.3 Horns and Associated Wiring. Horns are located close to the front of the car, in or below the luggage compartment (Figure 36). They are vulnerable in this position yet their sparking potential is low since only a single horn with a single wire is usually involved. The terminal on the horn body is a bayonet connector with the insulated female end on the wire. When connected the female connector enshrouds the terminal, protecting it from short circuiting. Even if pulled loose, the contacts in the female connector are shielded within the connector so that grounding of these contacts is unlikely. Only by severing the wire could a spark be produced.

6.4.2.4 Heater Blower Motors and Associated Wiring. Heater blower motors are usually located inside the passenger compartment and are relatively invulnerable to damage (Figure 44). The wiring associated with the blower motor is usually routed along the instrument panel to a terminal strip or fuse panel located on the left side of the passenger compartment under the instrument panel.

6.4.2.5 Windshield Wiper Motors and Associated Wiring. Windshield wiper motors are usually located behind the forward firewall inside the passenger compartment (Figure 49) and are relatively invulnerable to damage. The wiring is usually routed along the inside of the firewall to a fuse panel or terminal strip.

6.4.3 <u>Primary Hazards of the Fuel and Oil System</u>. Primary hazards in the fuel system of rear engine passenger cars are fuel tanks (when front-located), fuel pumps, carburetors, and the lines connecting the fuel tank to the carburetor through the fuel pump. These components are located close to the exterior of the vehicle, vulnerable to damage.

6.4.3.1 Fuel Tanks (Front-Mounted). Fuel tanks in most rear engine passenger cars are usually located in the front luggage compartment immediately behind the front bumper (Figure 45). In this location the tank is extremely vulnerable to damage in a frontal impact. While front mounted tanks normally have about one-half the capacity of domestic cars, the amount of fuel available is still significant. Depending upon the type of impact, damage to such tanks could release rather large quantities of fuel to potential sources of ignition.

6.4.3.2 Fuel Pumps. Fuel pumps on rear engine vehicles are usually located in the rear of the engine compartment (Figure 38) where they are vulnerable to damage in rear impacts. Even though they are engine driven they could be damaged in a relatively minor impact which might not stall the engine. The engine would continue driving the pumps, resulting in extensive spillage. Also, due to the small amount of space available in the engine compartment, electrical system components having a high spark potential may be located immediately adjacent to the pump.

6.4.3.3 Carburetors. Carburetors in rear engine passenger cars are usually located in the approximate center of the engine compartment, above the engine block (Figure 37). They are vulnerable to damage from rear or rear-quarter impacts. The engine block offers little protection since it is small and mounted low in the engine compartment. Another vehicle, impacting from behind, would tend to ride over the engine block. Although the carburetor holds only a small amount of fuel, ignition could initiate chain reaction ignition of other flammables.

6.4.3.4 Pump-to-Carburetor Fuel Lines. The pump-to-carburetor line is often located in the rear of the engine compartment where it can readily be damaged by displacing sheet metal during a rear or rear-quarter impact. The line is normally made of flexible material, such as rubber or neoprene, and may have a cover of braided fabric. This type of line will resist crushing failures but is easily cut by sharp metal edges. The connections used are slip-on connections, i.e., the hose is forced over a short tube and secured with a screw-clamp or a spring clip. These connections are easily broken when tension is applied to the hose.

6.4.3.5 Fuel Tank-to-Fuel-Pump Lines. In vehicles with front-mounted fuel tanks the fuel tank-to-fuel-pump line is routed from the tank to the engine compartment through the tunnel in the center of the car which also contains the transmission control linkage and hand brake cables. The line from the tank to just inside the engine compartment firewall is of ductile steel tubing. Inside the engine compartment the line is flexible hose which is connected to the fuel pump. The connections are the slip-joint and clamp type. These connections can easily be broken by a tension load on the hose. The flexible hose is routed among other displaceable components increasing the likelihood of failure.

In vehicles with rear mounted fuel tanks the ductile steel fuel line exits the tank on the side corresponding to the fuel pump location, and is routed along the rear quarter panel to a point opposite the fuel pump. From this point, the line is connected to the pump by a flexible hose. The ductile line is vulnerable to damage in rear-quarter impacts and the flexible line connections may be pulled loose in rear impacts.

6.4.4 <u>Secondary Hazards of the Fuel and Oil System</u>. Secondary hazards in fuel and oil systems in rear engine vehicles are the rear-mounted fuel tank and the oil filter.

6.4.4.1 Fuel Tanks. Rear-mounted tanks are usually mounted ahead of the engine compartment between two firewalls (Figure 45). In this position, the tank is well protected from rear impact damage by the engine block. Side impact protection is provided by the rear suspension, although a roll-over accident could cause spillage through the vent line.

The filler neck for rear-mounted tanks is usually located in the engine compartment where it is somewhat vulnerable to damage in side or rear impacts. A rear impact followed by a roll-over could produce serious spillage into the engine compartment.

6.4.4.2 Oil Filters. Oil filters are not normally used on rear engine passenger cars. This is mainly due to lack of available space in the engine compartment. In the one instance found where the oil filter was used in a rear engine passenger car, it was mounted in the rear of the engine compartment (Figure 48) where it would be vulnerable to damage from a rear impact. The oil released could serve as fuel for a fire ignited at another source.

6.5 LIGHT VANS

These vehic[illegible] [illegible]ere included in the study not because of the number [illegible]y in use but because of their growing popularity as r[illegible]ional vehicles. Four of these vehicles, representing [illegible]oss-section of manufacturers, were examined on dealer lots. All of these were front engine vehicles. Figure 52 shows a typical light van engine compartment. Figure 53 is a diagram of component location areas and Figures 54 through 63 show locations of individual components.

6.5.1 <u>Primary Hazards of the Electrical System</u>. Primary electrical system hazards in light vans are the components located near the exterior of the vehicle where they are vulnerable to damage. Although component locations vary somewhat

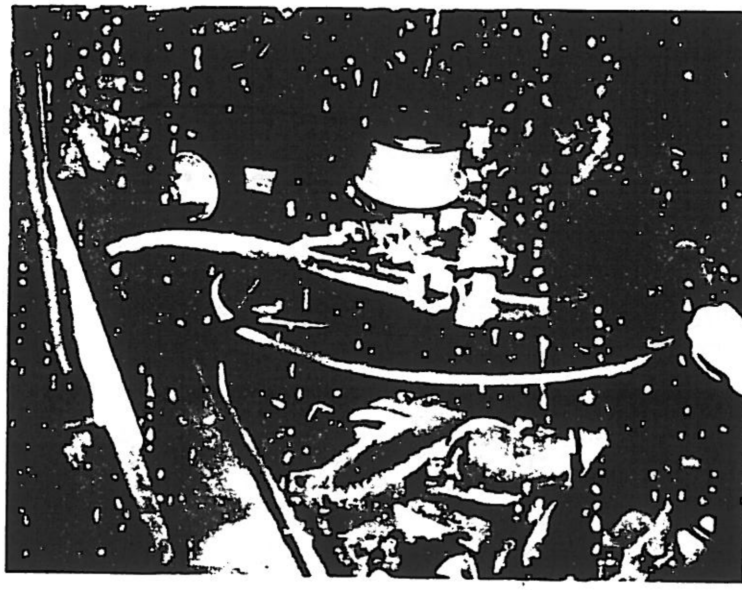
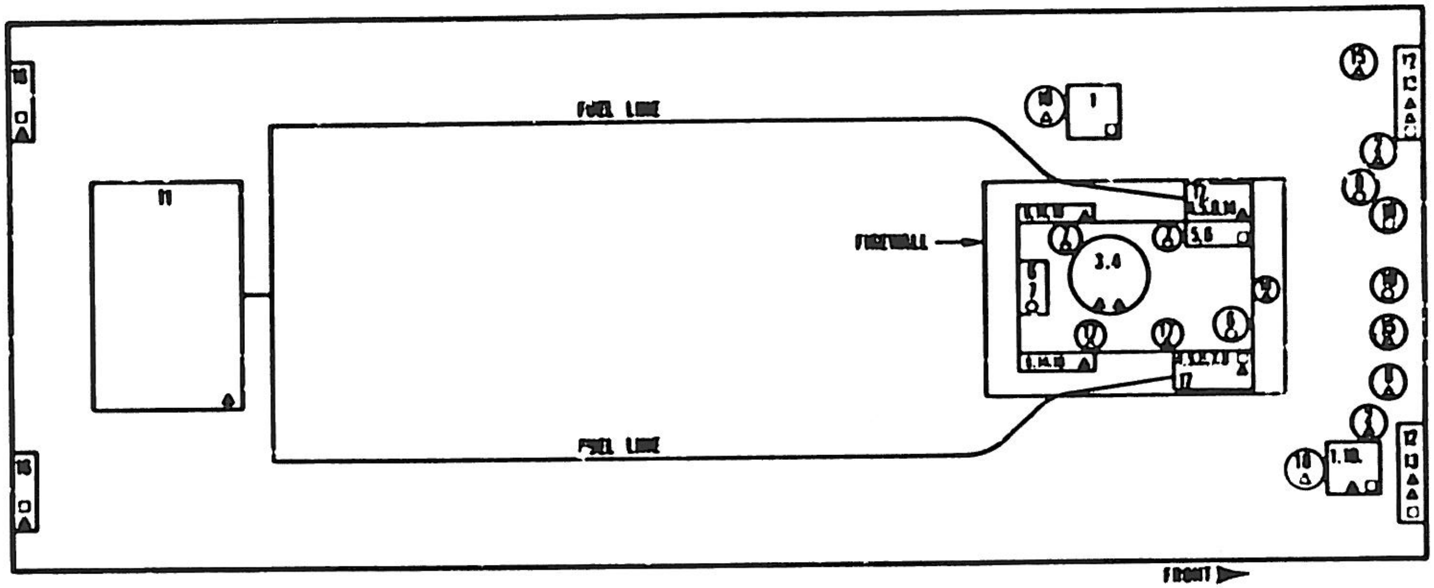


Figure 52. Engine Compartment - Typical Light Van.

between different makes of vans, the more vulnerable components are batteries, horns, voltage regulators, starter solenoids, heater blower motors, windshield wiper motors, lights, and all associated wiring (Figure 53).

6.5.1.1 Batteries. Batteries in vans are located as shown in Figure 54. Those mounted toward the right front of the vehicle are vulnerable to damage in front impacts and side-mounted batteries are vulnerable to damage in side impacts. The terminals may be short circuited by displacing sheet metal or the battery may be displaced or crushed, producing a spark. The cables associated with the battery may be damaged and short circuited, resulting in sparking.

6.5.1.2 Horns and Associated Wiring. The horns and wiring employed in vans have little physical difference from the horns used in front engine passenger cars. In vans the extreme forward location of the horns (Figure 54) makes them vulnerable to damage, resulting in possible sparking due to severed wiring.



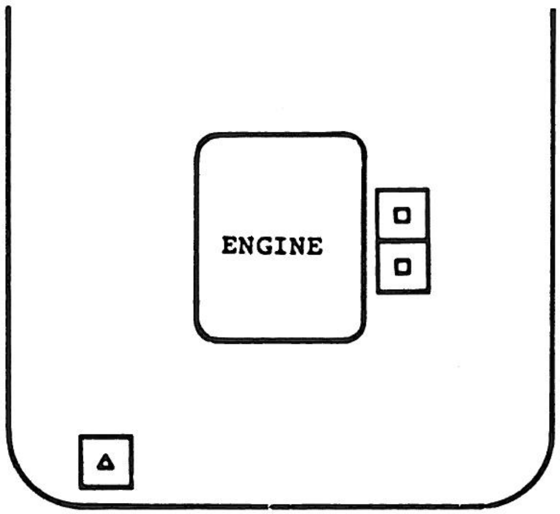
LOCATION (HEIGHT RELATIVE TO ENGINE)

- △ ABOVE TOP
- ○ TOP
- □ MIDDLE
- ▲ BOTTOM

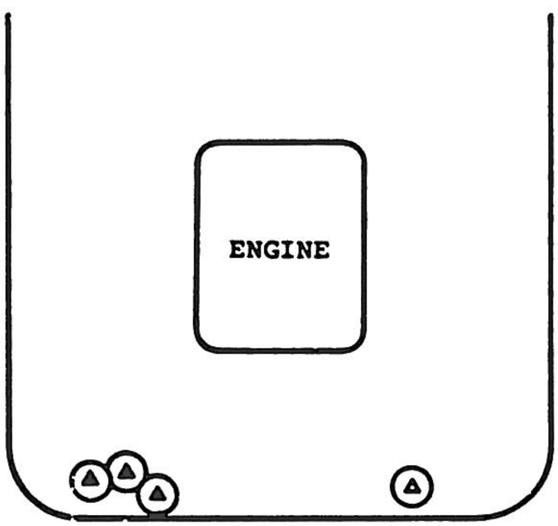
COMPONENT IDENTIFICATION

1. BATTERY
2. HORN
3. CARBURETOR
4. FUEL PUMP
5. ALTERNATOR/GENERATOR
6. DISTRIBUTOR
7. COIL
8. VOLTAGE REGULATOR
9. STARTER
10. HEATER BLOWER
11. FUEL TANK
12. LIGHTS
13. PARKING & DIRECTIONAL LIGHTS
14. OIL FILTER
15. WINDSHIELD WIPER MOTOR
16. TAIL LIGHTS
17. FUEL FILTER
18. STARTER SOLENOID

Figure 53. Component Location Zones - Light Vans.



BATTERIES



HORNS

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

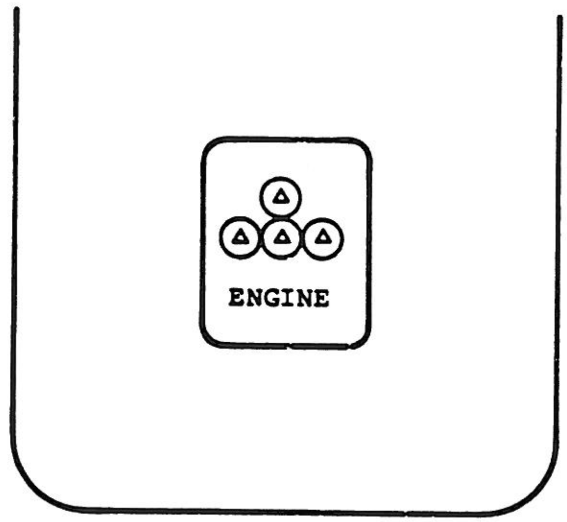
△ Above top

○ Top

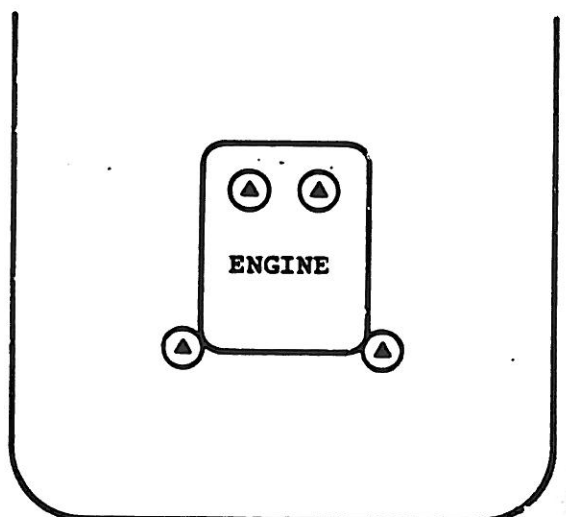
□ Middle

▲ Bottom

Figure 54. Battery and Horn Locations - Light Vans.



CARBURETORS



FUEL PUMPS

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- ▲ Above top
- ● Top
- ■ Middle
- ▲ Bottom

Figure 55. Carburetor and Fuel Pump Locations – Light Vans.

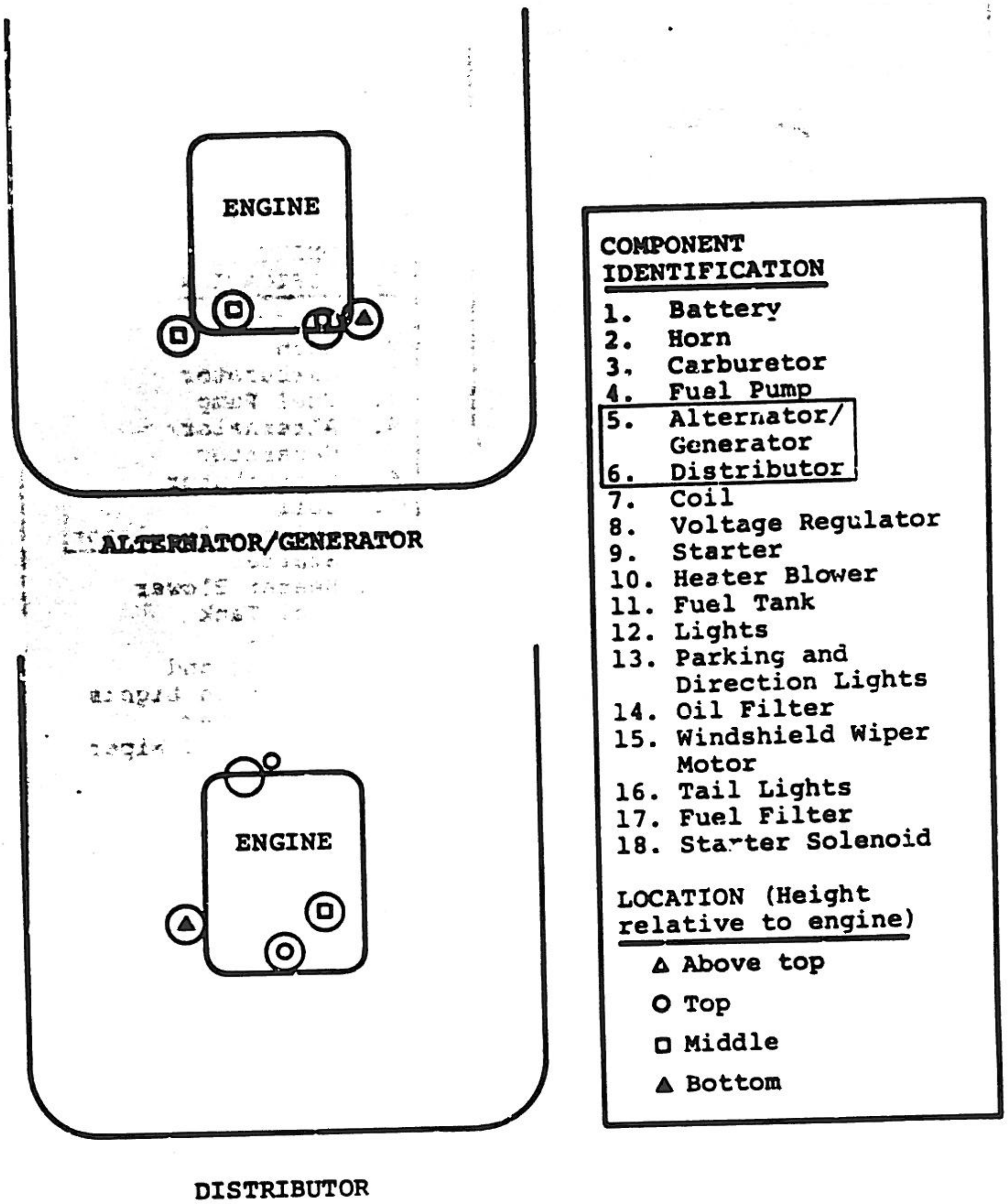
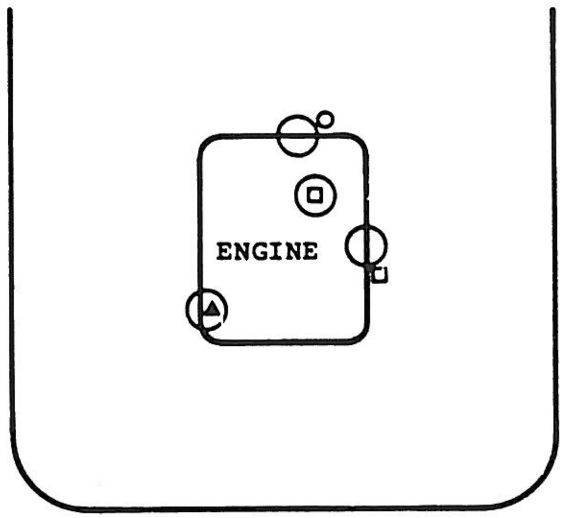
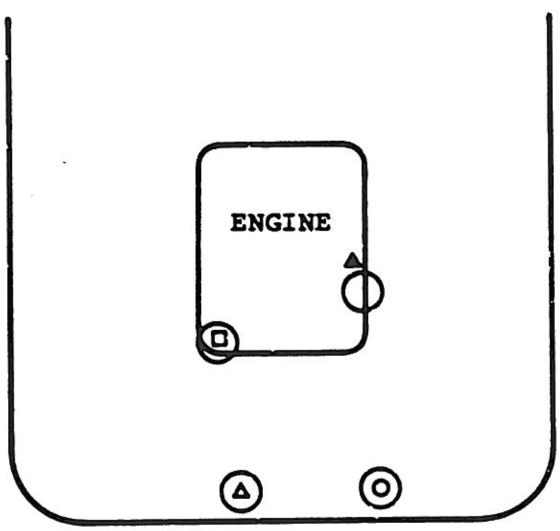


Figure 56. Alternator/Generator and Distributor Locations - Light Vans.



COIL



VOLTAGE REGULATOR

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

△ Above top

○ Top

□ Middle

▲ Bottom

Figure 57. Coil and Voltage Regulator Locations - Light Vans.

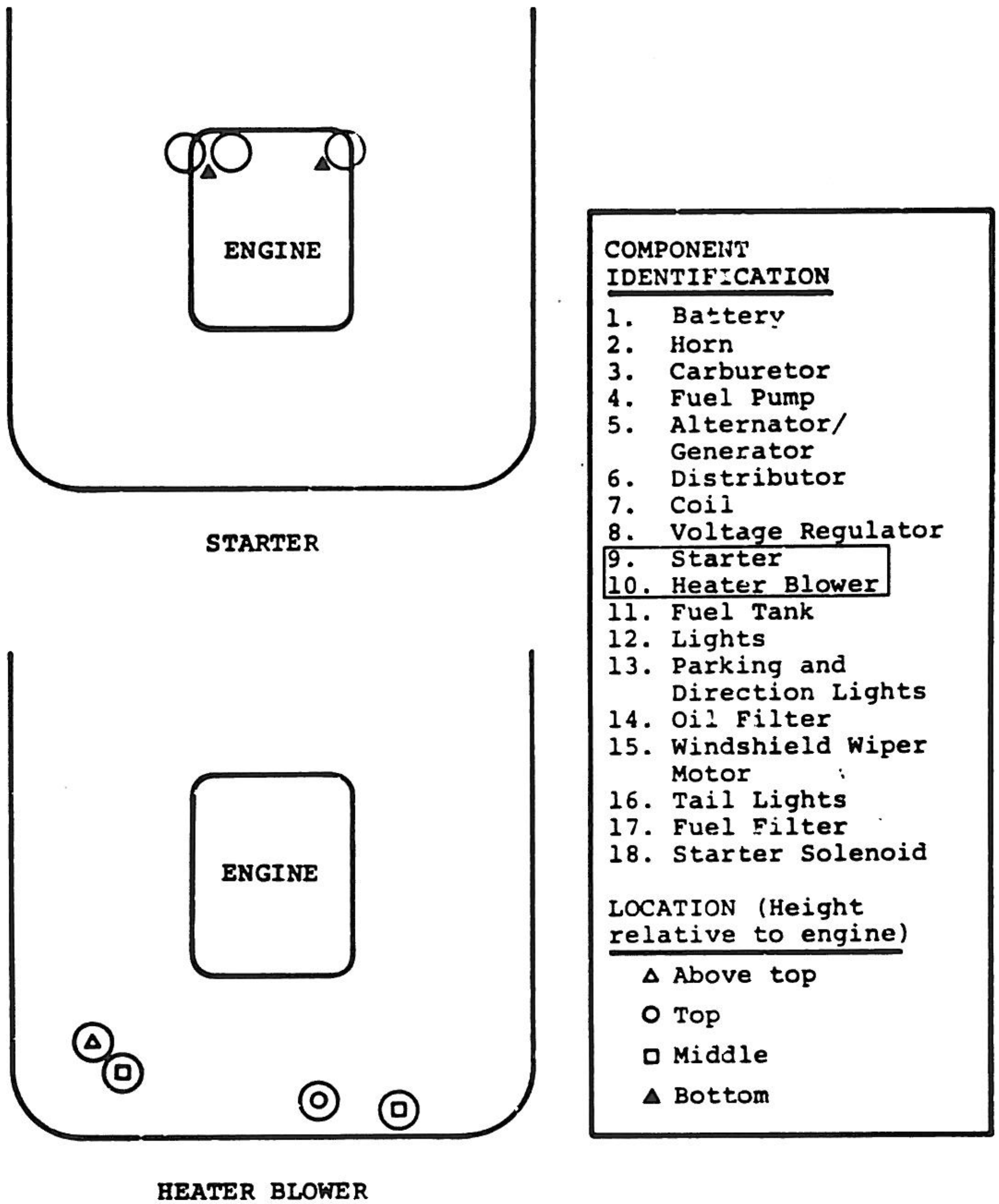


Figure 58. Starter and Heater Blower Locations - Light Vans.

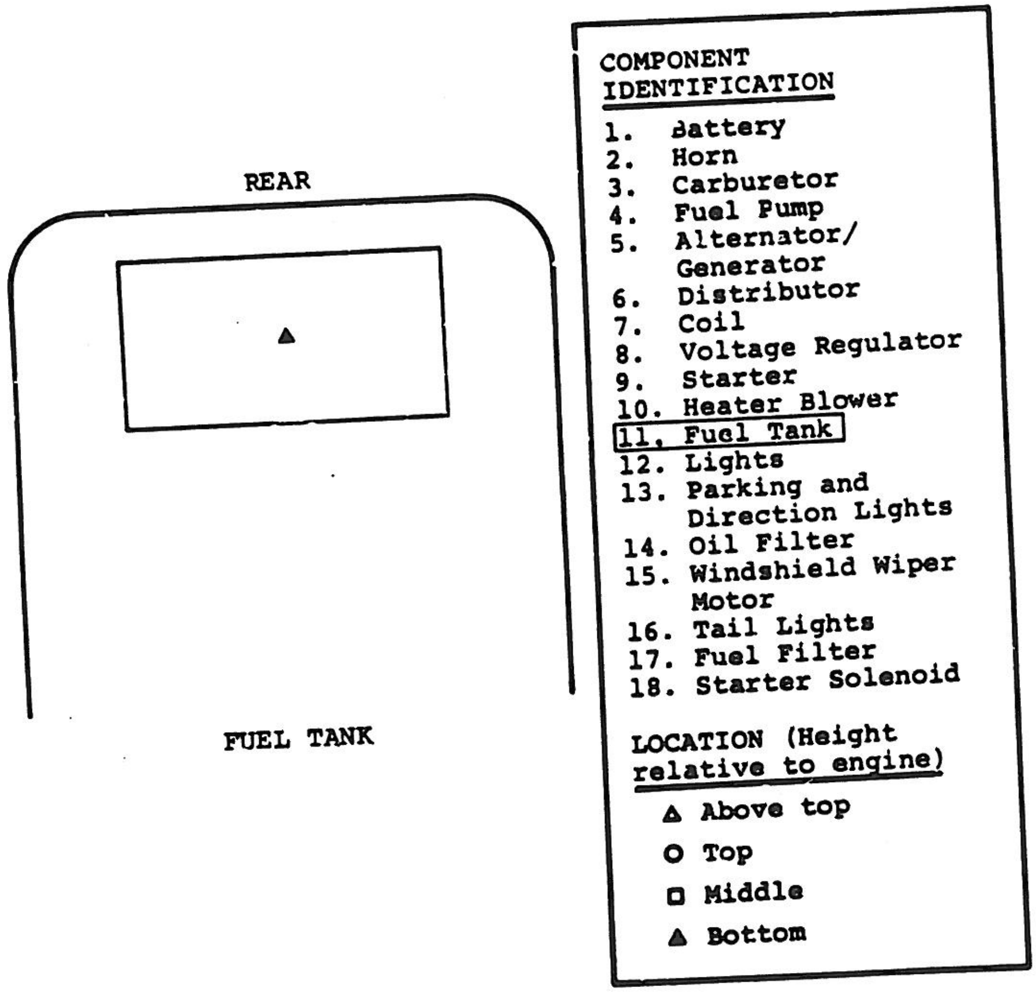
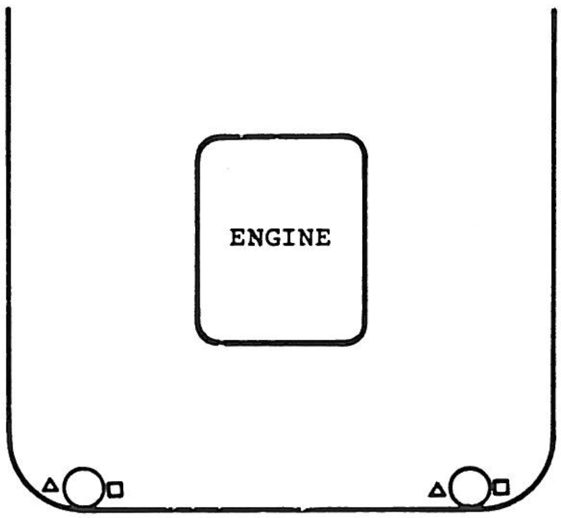
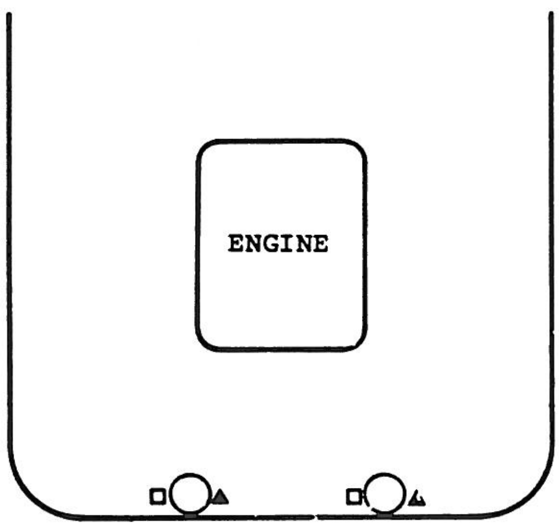


Figure 59. Fuel Tank Location - Light Vans.



LIGHTS



PARKING AND DIRECTION LIGHTS

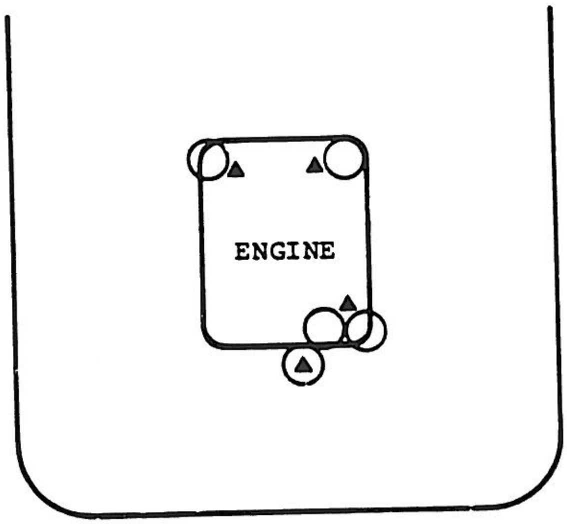
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

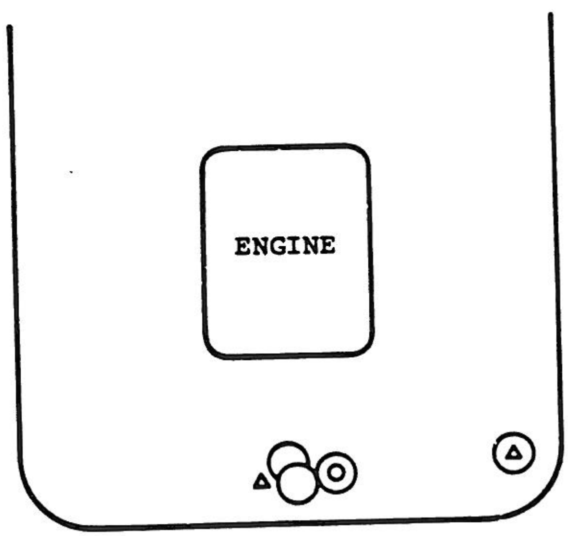
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Botton

Figure 60. Front Light Locations - Light Vans.



OIL FILTER



WINDSHIELD WIPER MOTOR

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

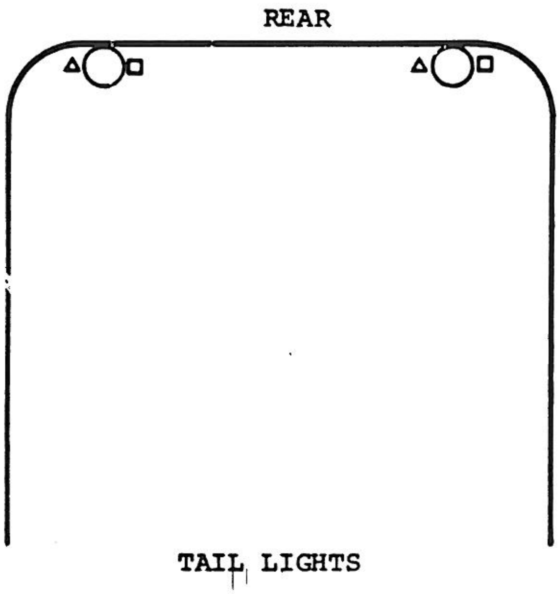
△ Above top

○ Top

□ Middle

▲ Bottom

Figure 61. Oil Filter and Windshield Wiper Motor Locations - Light Vans.



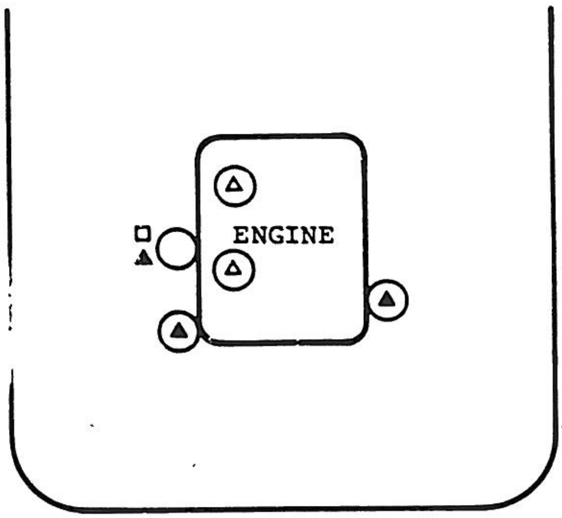
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

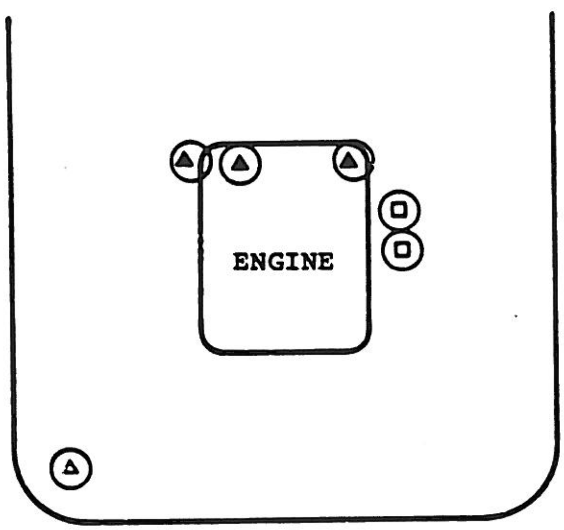
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 62. Tail Light Locations - Light Vans.



FUEL FILTER



STARTER SOLENOID

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 63. Fuel Filter and Starter Solenoid Locations - Light Vans.

6.5.1.3 Voltage Regulators and Associated Wiring. Van voltage regulators are often located well forward (Figure 57), where wiring and terminal damage may occur in even a minor impact due to displacement of adjacent sheet metal. The wiring associated with regulators makes connections to both the battery and the alternator. The routing of this wiring varies, depending on the location of components with respect to each other. For front-mounted regulators the wiring will be vulnerable to damage in front impacts through sheet metal displacement and/or crushing due to entrapment.

6.5.1.4 Starter Solenoids and Associated Wiring. Starter solenoids in light vans may be located near front-mounted batteries (Figure 63) and, when so located, are considered vulnerable to impact damage. Their terminals are usually unprotected and present a sparking potential if short circuited due to sheet metal displacement or contact with other components.

The wiring from front-mounted starter solenoids to the starter may also be vulnerable to damage, depending upon its routing to the starter. In most cases the starter and starter solenoid are located on opposite sides of the vehicle so that the wiring is rather lengthy. In these cases the wires are routed around the front of the engine compartment where they could be damaged sufficiently to produce a spark potential.

6.5.1.5 Heater Blower Motors and Associated Wiring. In light vans the heater blower is located inside the passenger compartment under the instrument panel (Figure 58). This location is vulnerable to damage in front impacts since it is immediately adjacent to the exterior of the vehicle. While the heater blower motor itself is a sturdy device, the wiring from the control switch on the instrument panel lies close to the exterior of the vehicle and is subject to damage.

6.5.1.6 Windshield Wiper Motors and Associated Wiring. Windshield wiper motors in vans are located behind the instrument panel adjacent to the exterior of the vehicle (Figure 61). Thus, wiring and terminals associated with the motor are vulnerable to damage from sheet metal displacement in front impacts.

6.5.1.7 Lights and Associated Wiring. As in any vehicle, the lights in light vans are located on the exterior of the vehicle where they are extremely vulnerable to damage (Figures 60 and 62). While all lights have a spark potential if broken, headlights are the most dangerous due to their higher power requirements and their larger, hotter filaments. The wiring associated with all lights is vulnerable at and close to the lights themselves. Headlight and parking light wiring is extremely vulnerable since its routing leads from the control switch on the instrument panel to the left headlight and then across the front of the vehicle to the right headlight. This routing presents maximum exposure to damage in a front impact.

6.5.2 Secondary Hazards of the Electrical System. Secondary electrical system hazards in vans are those components located toward the center of the vehicle or other positions that are relatively invulnerable to damage. These components include distributors, ignition coils, alternators/generators, starter motors, and starter solenoids mounted on the starter motor.

6.5.2.1 Distributors. Distributors in light vans are mounted as shown in Figure 56. Even those mounted on the front of the engine block are well protected since the engine compartment is several feet behind the front of the van and considerable structure must be crushed before the engine compartment is damaged.

6.5.2.2 Ignition Coils. Ignition coils in light vans are also located in the engine compartment. They are well protected from damage by the engine block and the location of the engine compartment (Figure 57). The exposed terminals of the coil present a spark potential, if short circuited.

6.5.2.3 Alternators/Generators and Associated Wiring. Alternators or generators on light vans are usually mounted down low on the front of the engine block (Figure 56). Considerable sheet metal displacement has to occur before they would be endangered. Only the terminals of these components present a real sparking potential if they are unprotected. The wiring associated with these components connects with the voltage regulator. The vulnerability of this wiring depends on the location of these components with respect to each other.

6.5.2.4 Starter Motors and Associated Wiring. Starter motors in light vans are located on one of the lower rear corners of the engine block (Figure 58) and are relatively invulnerable to damage. Only the terminals present a sparking potential. The vulnerability of the wiring associated with these components is dependent upon the routing from the battery or starter solenoid to the starter motor.

6.5.2.5 Starter Solenoids (Starter-Mounted) and Associated Wiring. Some light vans utilize starters that have the solenoid integrally mounted. Though located on one of the rear corners of the engine block (Figure 63), this type has a constant sparking potential since the cable from the battery is routed directly to the terminal on the solenoid. This terminal, which is usually unprotected, will spark if short circuited.

6.5.3 Primary Hazards of the Fuel and Oil System. The most vulnerable component in the fuel systems of light vans is the fuel tank.

6.5.3.1 Fuel Tanks. Fuel tanks in light vans are mounted at the rear between the frame rails (Figure 59). In this location the tanks are extremely vulnerable to damage from rear and rear-quarter impacts. The filler neck is usually located near the left rear corner of the vehicle, also vulnerable to damage in rear and rear-quarter impacts. The tanks in vans are of medium capacity, usually 16 to 20 gallons.

6.5.4 Secondary Hazards of the Fuel and Oil System. Light van fuel and oil system components considered secondary hazards are those located well within the vehicle or otherwise protected and are relatively invulnerable to damage during all but the most severe impacts. Such components include carburetors, fuel pumps, fuel filters, fuel lines from tank-to-pump-to-carburetor, and oil filters.

6.5.4.1 Carburetors. Engines used by light vans are very similar to those used in front engine passenger cars and carburetor locations on the engine block are also similar (Figure 55). With the engine located well inside the body structure and with no heavy components in the engine compartment to tear loose and strike the carburetor, this component is not likely to be damaged in an accident. The carburetor does contain a small amount of fuel which could spill in a roll-over accident.

6.5.4.2 Fuel Pumps. Light vans employ engine-driven fuel pumps located on one of the lower front corners of the engine block (Figure 55). The pumps are not likely to be damaged in an impact because the engine compartment is located well inside the vehicle, protected by the surrounding structure.

6.5.4.3 Fuel Filters. Fuel filters, when present, are of the in-line type, are located near the carburetor (Figure 63), and are well protected from damage.

6.5.4.4 Fuel Tank-to-Fuel-Pump Lines. The fuel line from the tank to the pump usually exits the tank near the front and is routed over to the frame rail on the side of the vehicle corresponding to the fuel pump location. The line is then routed inside the frame rail to a point near the rear of the engine compartment where it is turned inward toward the fuel pump. Although the line is made of ductile steel, short flexible hoses are usually used to connect the line to the tank and to the fuel pump. The flexible connection at the tank is usually very short. The flexible hose connecting the line to the pump is usually 6 to 8 inches in length. Connections may be made using threaded couplings or slip-on joints held with clamps. The line is well protected for its full length.

6.5.4.5 Pump-to-Carburetor Fuel Line. The fuel line from the pump to the carburetor may be of flexible hose or ductile steel tubing, depending upon the manufacturer. The routing is usually from the pump up and around the front of the engine block, then back along the top of the engine block to the carburetor. This line is not vulnerable to damage because of the amount of deformation which must occur before the line is endangered.

6.5.4.6 Oil Filters. Some light vans have the oil filters mounted low on the side of the engine block (Figure 61). They are well protected from damage during impact since considerable displacement must occur before the filter will be damaged.

6.6 LIGHT TRUCKS

This type vehicle has shown a tremendous increase in popularity over the last several years as combination second cars and recreational vehicles. Although many are in use, the majority are produced by no more than four manufacturers. Five such vehicles, representing a cross section of manufacturers, were examined on dealer lots. Figures 64 and 65 show typical light truck engine compartments. Figure 66 presents a diagram of component location areas and Figures 67 through 76 show the location of individual components.

Comparison of Figures 10 and 66 show that, with exception of fuel tanks, electrical and fuel system component locations are the same for light trucks as for front engine passenger cars. Light trucks carry at least one fuel tank, usually of 20-gallon capacity, inside the passenger compartment behind the seat (Figure 72). This is the standard location provided by the manufacturers. One manufacturer also offers an optional 25-gallon tank mounted inside the frame rail just

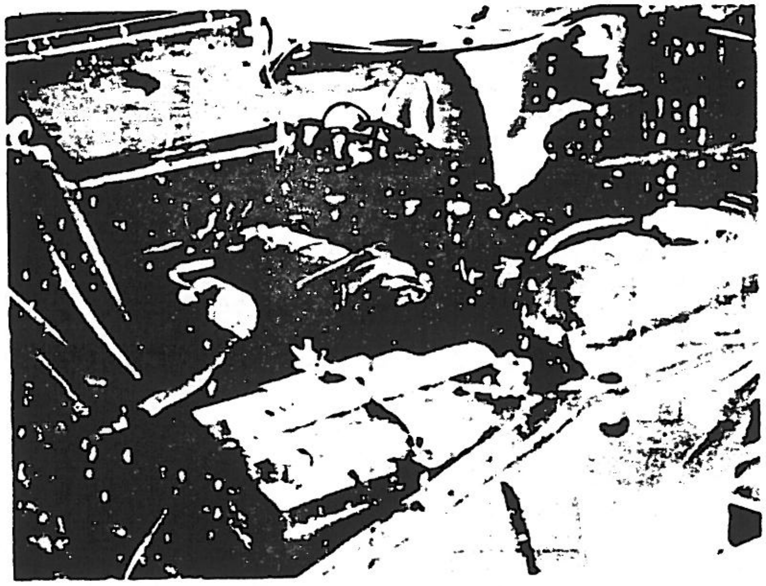


Figure 64. Engine Compartment - Typical V-8 Light Truck.

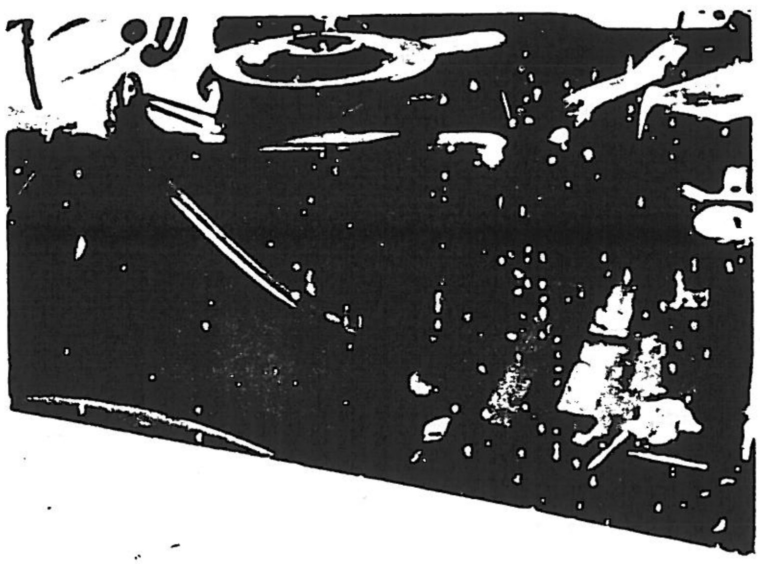
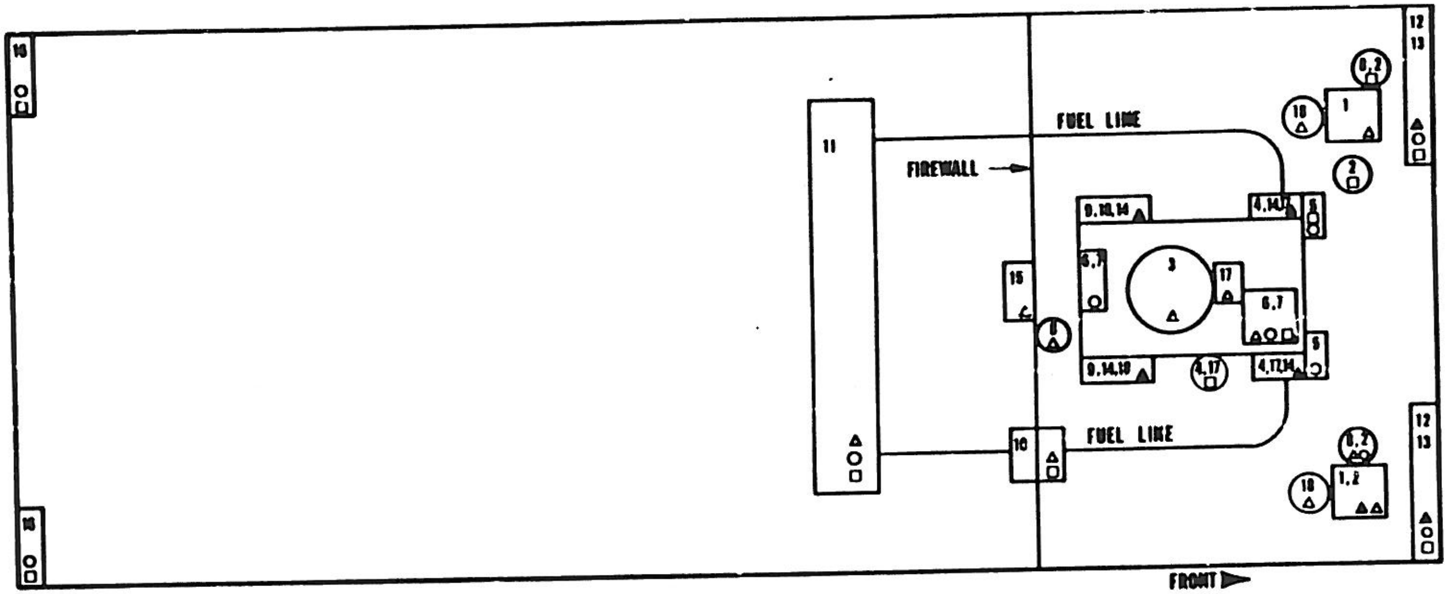


Figure 65. Engine Compartment - Typical 6-Cylinder Light Truck.



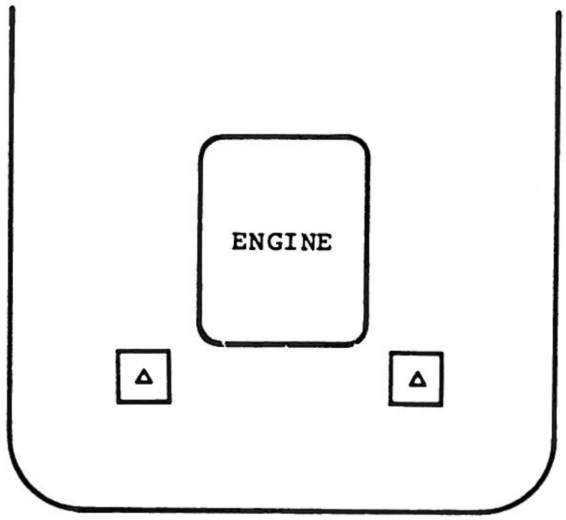
LOCATION (HEIGHT RELATIVE TO ENGINE)

- △ ABOVE TOP
- ○ TOP
- □ MIDDLE
- ▲ BOTTOM

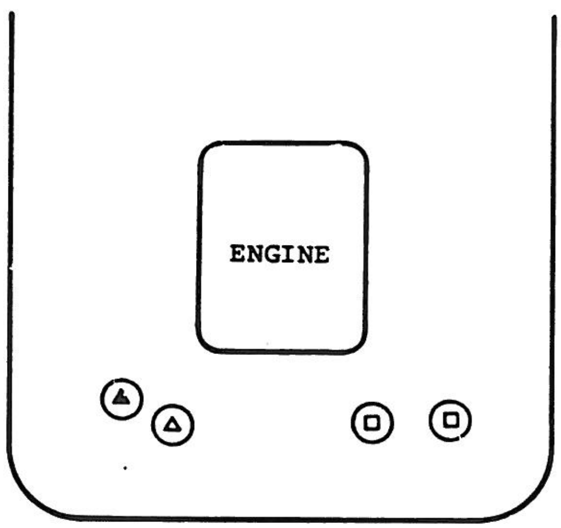
COMPONENT IDENTIFICATION

1. BATTERY
2. HORN
3. CARBURETOR
4. FUEL PUMP
5. ALTERNATOR/GENERATOR
6. DISTRIBUTOR
7. COIL
8. VOLTAGE REGULATOR
9. STARTER
10. HEATER BLOWER
11. FUEL TANK
12. LIGHTS
13. PARKING & DIRECTIONAL LIGHTS
14. OIL FILTER
15. WINDSHIELD WIPER MOTOR
16. TAIL LIGHTS
17. FUEL FILTER
18. STARTER SOLENOID

Figure 66. Component Location Zones - Light Trucks.



BATTERIES



HORNS

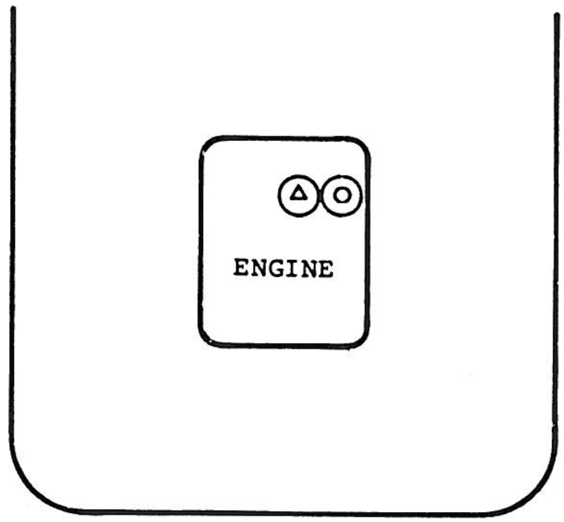
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

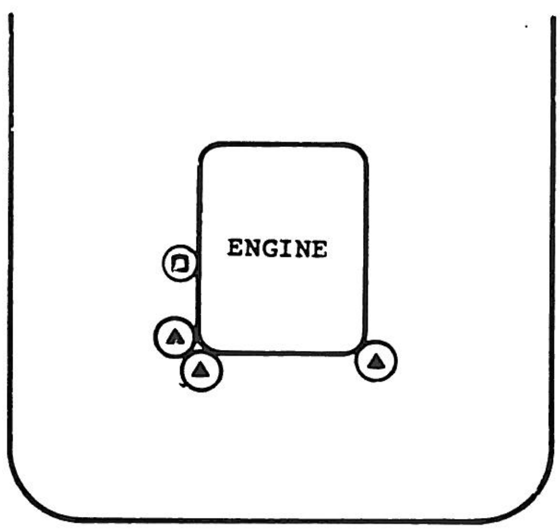
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 67. Battery and Horn Locations - Light Trucks.



CARBURETOR



FUEL PUMP

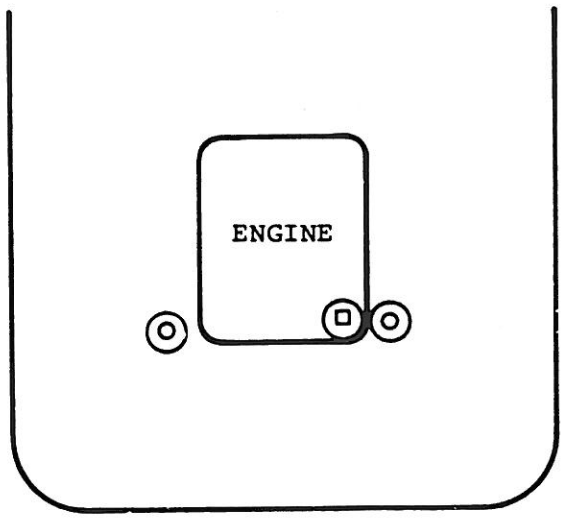
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

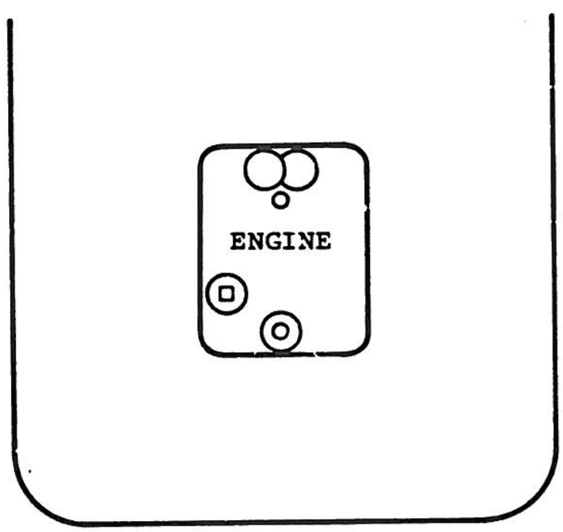
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 68. Carburetor and Fuel Pump Locations - Light Trucks.



ALTERNATOR/GENERATOR



DISTRIBUTOR

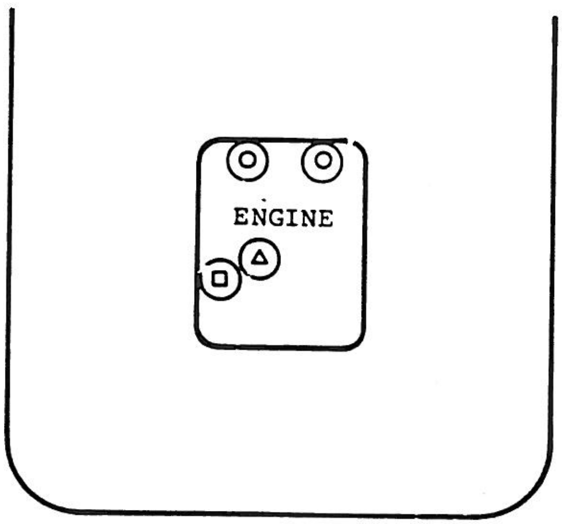
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

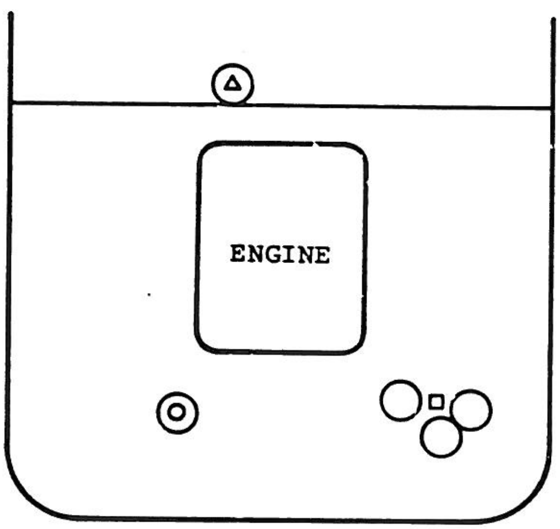
LOCATION (Height relative to engine)

- △ Above top
- O Top
- □ Middle
- ▲ Bottom

Figure 69. Alternator/Generator and Distributor Locations - Light Trucks.



COIL



VOLTAGE REGULATOR

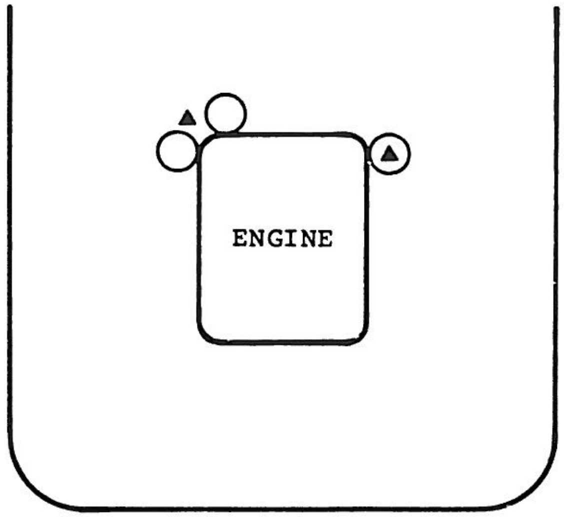
COMPONENT
IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

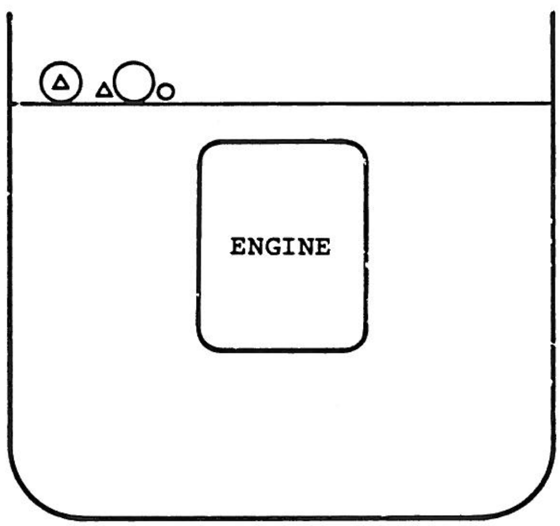
LOCATION (Height relative to engine)

- △ Above top
- O Top
- □ Middle
- ▲ Bottom

Figure 70. Coil and Voltage Regulator Locations - Light Trucks.



STARTER



HEATER BLOWER

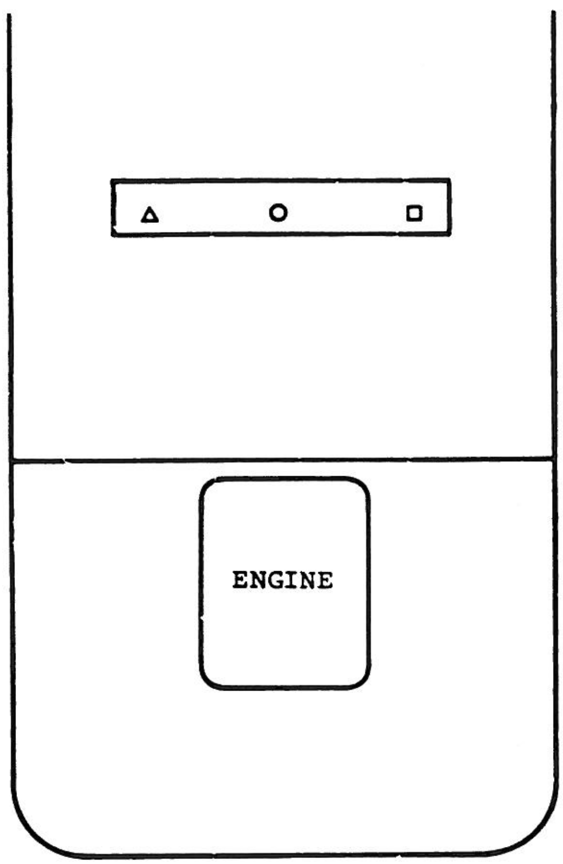
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 71. Starter and Heater Blower Locations - Light Trucks.



COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

△ Above top

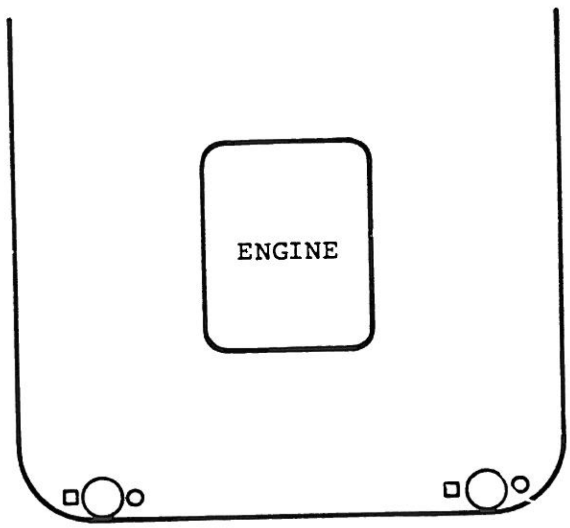
○ Top

□ Middle

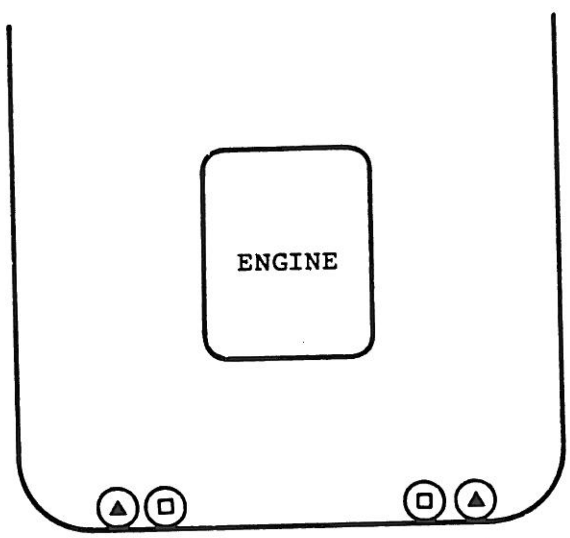
▲ Bottom

FUEL TANK

Figure 72. Fuel Tank Location - Light Trucks.



LIGHTS



PARKING AND DIRECTION LIGHTS

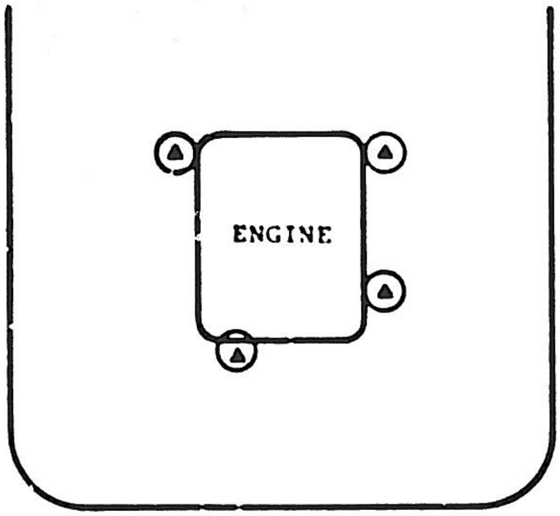
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

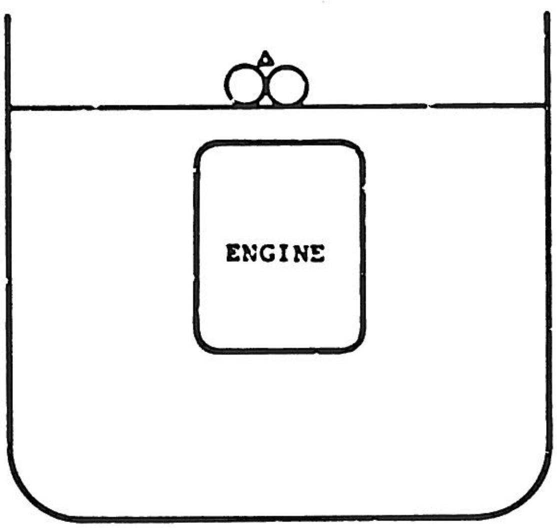
LOCATION (Height relative to engine)

- △ Above top
- ○ Top
- □ Middle
- ▲ Bottom

Figure 73. Front Light Locations - Light Trucks.



OIL FILTER



WINDSHIELD WIPER MOTOR

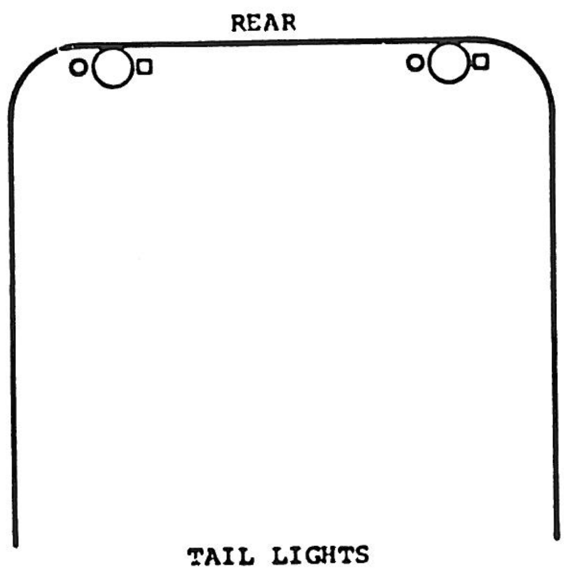
COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- ▲ Above top
- ○ Top
- ▢ Middle
- ▲ Bottom

Figure 74. Oil Filter and Windshield Wiper Motor Locations - Light Trucks.



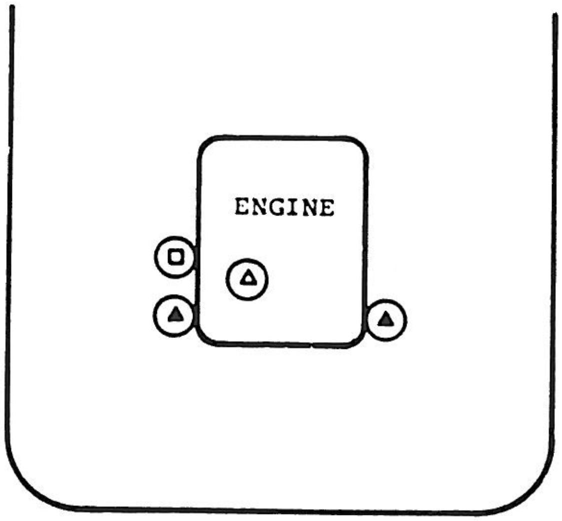
COMPONENT
IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

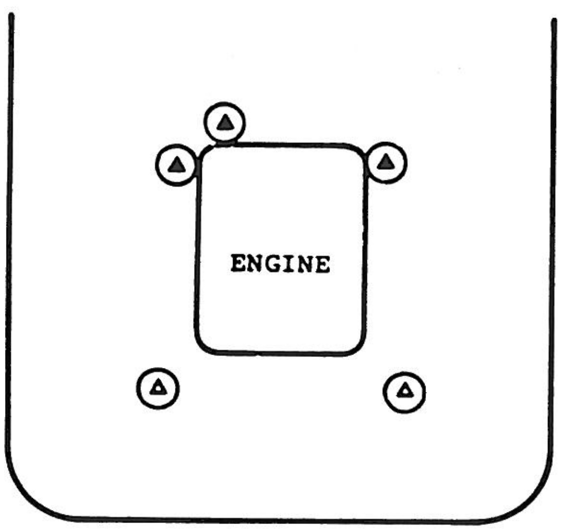
LOCATION (Height relative to engine)

- △ Above top
- O Top
- ▢ Middle
- ▲ Bottom

Figure 75. Tail Light Locations - Light Trucks.



FUEL FILTER



STARTER SOLENOID

COMPONENT IDENTIFICATION

1. Battery
2. Horn
3. Carburetor
4. Fuel Pump
5. Alternator/ Generator
6. Distributor
7. Coil
8. Voltage Regulator
9. Starter
10. Heater Blower
11. Fuel Tank
12. Lights
13. Parking and Direction Lights
14. Oil Filter
15. Windshield Wiper Motor
16. Tail Lights
17. Fuel Filter
18. Starter Solenoid

LOCATION (Height relative to engine)

- △ Above top
- O Top
- □ Middle
- ▲ Bottom

Figure 76. Fuel Filter and Starter Solenoid Locations - Light Trucks.

behind the passenger compartment. Many owners install additional auxiliary tanks, usually of 18-gallon capacity, outside the frame rail behind the passenger compartment. With optional and auxiliary tanks and the standard tank inside the passenger compartment, some light trucks may carry up to 80 gallons of fuel.

The location of the fuel tank inside or just behind the passenger compartment protects the tank from damage in the event of front or rear-end impacts. A side impact on the filler neck side of the truck might result in tank damage. This possibility is not considered too serious since the filler neck is located fairly high up on the truck structure. The auxiliary tanks may be extremely vulnerable to side impacts.

Although the fuel tank is protected from direct impacts by its location inside the passenger compartment, the tank could be punctured during a crash by loose objects stored behind the seat or by failed seat structure, especially if the tank wall has been weakened due to long-term chafing by the seat back or other objects. The subsequent release of fuel directly into the passenger compartment would have catastrophic results in the event of fuel ignition.

With exception of the fuel tank location, the primary and secondary hazards in light trucks are the same as those in front engine passenger cars. In general, though, light truck components are carried higher since the body silhouette is higher. Engine compartments in light trucks are roomier than in passenger cars and more sheet metal displacement must take place before components are endangered.

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7. ACCIDENT TYPE INFLUENCE ON COMPONENT DAMAGE

7.1 GENERAL

The amount of electrical system damage experienced in any given accident is primarily dependent upon three major factors: (1) the type of vehicle and/or obstacles involved, (2) the type of accident, and (3) the impact velocity. The type of vehicles and/or obstacles involved and the accident type will determine which components will be exposed to damage while the impact velocity will influence the degree of damage. For example, a front engine passenger car impacting a solid barrier at 30 mph can be expected to sustain severe damage to the electrical system. A similar car impacting the side of another front engine passenger car in an intersection collision at 15 mph will probably sustain only minor damage to the electrical system, provided neither vehicle rolls over. In the frontal barrier impact, the probability of fire occurring in the impacting car is moderate. In the car-to-car side impact, the probability of fire occurring in the impacting car is low.

For the purpose of this study accidents have been classified in four types:

- Front Impact
- Rear Impact
- Side Impact
- Roll-over

The percentage distribution for front impacts, rear impacts, and roll-overs is shown in Figure 1 for accidents which involved at least one injury. No data were available on the distribution of side impacts, however, they are included here since they present a hazard to certain portions of the automotive electrical system.

In the following discussion each accident type is analyzed with relation to component damage potential.

7.2 FRONT IMPACT ACCIDENTS

The front impact accident represents 69 percent of the injury-producing accidents. The fire incidence is high in this type of accident - 42 percent of the fire accidents occur as a result of frontal impact.

Maximum component exposure to damage occurs when a front engine vehicle is involved in a front impact, either with another vehicle or an obstruction. This is because the front engine vehicle (passenger car, station wagon, or light truck) carries the majority of its electrical components in the engine compartment. Also, the most hazardous of these electrical components, such as batteries, voltage regulators, starter solenoids, etc., are located peripherally on the front and side of the engine compartment. For this reason even moderate impact damage may be expected to produce damage to one or more hazardous electrical components sufficient to produce sparking.

In addition, the front engine vehicle carries many of its fuel system components in the engine compartment. Damaged fuel system components can release fuel which may be ignited by a spark from the damaged electrical system. Such fuel system components are fuel filters of the canister type, fuel pumps, flexible fuel lines (from the fuel tank to the pump or from the fuel pump to the carburetor), and the carburetor itself. Front engine vehicle fuel system components most likely to be damaged in a front impact are the fuel pump, the canister-type fuel filter mounted on the pump, and the flexible hoses immediately adjacent to the pump.

Front impact of front engine vehicles with other vehicles or large obstructions usually results in moderate to severe damage to many components since the impact damage is spread over a wide area of the vehicle. Impacts with small obstructions, such as poles, may produce severe localized damage because of the small area of impact involved. Figures 77 and 78 show typical damage caused by frontal impacts with large obstructions and with small obstructions. Notice in Figure 77 that the vehicle has the battery, voltage regulator, and starter solenoid all located in close proximity to each other. Although the damage illustrated would probably not have produced sparking, a small amount of additional damage could have caused shorting of the voltage regulator terminals or the exposed starter solenoid terminals. In the wreckage shown in Figure 78 the battery is totally destroyed. This vehicle also had the battery, voltage regulator, and starter solenoid located in close proximity to each other. Assessment of damage to the latter two components was impossible due to the fact that they were completely hidden by the destroyed battery and deformed sheet metal. It is possible that this impact could have produced severe sparking. The amount of intrusion into the engine compartment could also have been sufficient to cause damage to the fuel pump or fuel filter mounted on the lower front corner of the engine block. Such fuel system damage, combined with the spark potential available

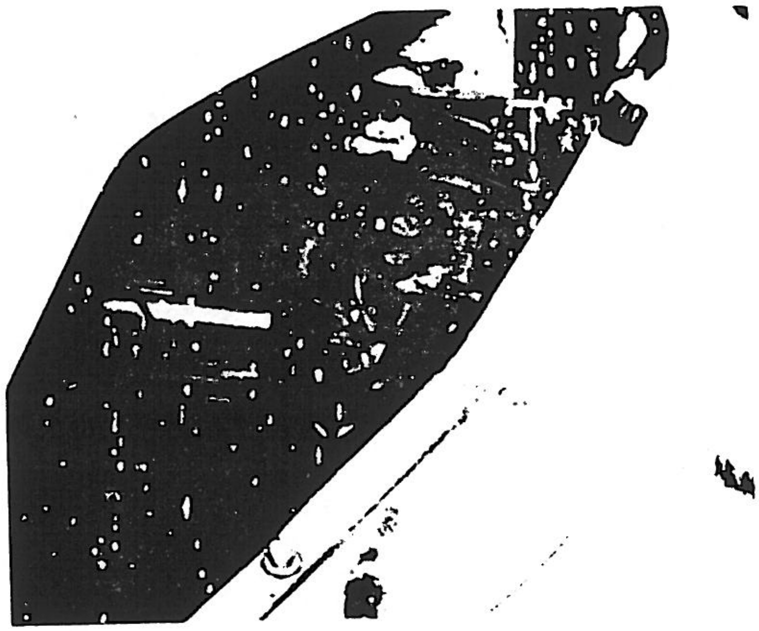

Figure 77. Typical Damage Due to Front Impact With a Large Obstruction.

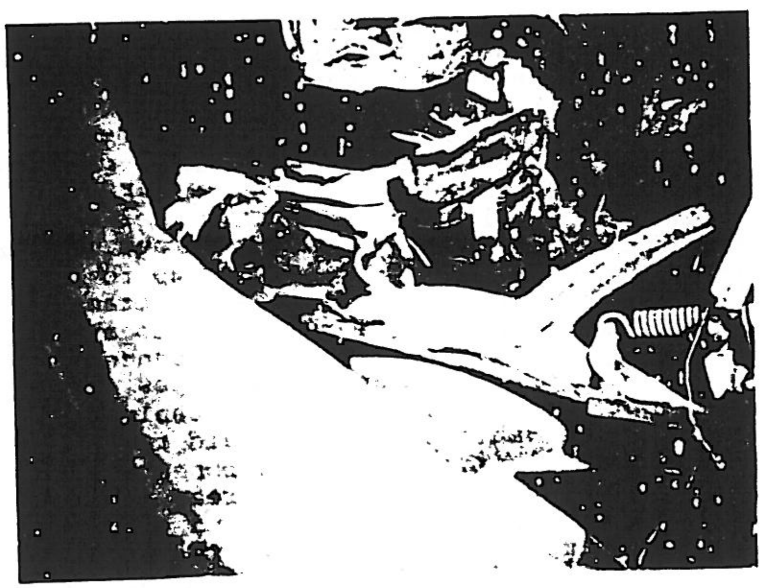

Figure 78. Typical Damage Due to Front Impact With a Pole.

due to the damaged electrical system components, could easily have resulted in a fire.

Rear-mounted tanks may be dislodged in front impacts due to failure of the mountings. This can result in massive fuel spillage due to filler neck separation.

Front impacts involving rear engine passenger cars and/or light vans will produce varying degrees of damage to the electrical system, dependent upon the location of system components. Damage to headlights can be expected since they are always located on the front of the vehicle. Some rear engine passenger cars and some vans have hazardous electrical system components located well forward in the vehicle. These components may include batteries, voltage regulators, heater blower motors, windshield wiper motors, and horns.

Because of their relatively light construction, rear engine passenger cars can be expected to suffer electrical system damage in even the most moderate front impacts unless the hazardous components are located well to the rear of the vehicle. Figure 79 shows typical damage incurred by a rear engine passenger car in an impact with a large obstruction. This particular vehicle was involved in a front impact with a barrier at an impact velocity of 30 mph. Any electrical system components located ahead of the firewall could be expected to suffer severe damage, resulting in sparking.

Fuel system damage in front impacts of rear engine passenger cars is highly probable in vehicles which carry the fuel tank in the front luggage compartment. These tanks are usually located quite near the exterior of the car with minimal protection being afforded by the spare tire located immediately in front of the fuel tank. Thus, fuel tank damage can be expected even in a moderate front impact. Since tank damage could result in the release of up to 10 gallons of fuel, electrical sparking could result in a catastrophic fire. However, it should be noted that, according to available data, there is no material difference in the incidences of fire in rear engine vehicles [illegible] front engine vehicles when both are subjected to frontal impacts. This is probably due to the fact that rear engine vehicles with forward fuel tanks have the most hazardous electrical system components located well to the rear. Rear engine vehicles with rear fuel tanks provide better protection from tank damage and the most hazardous electrical system components are located farther forward. Thus, while spilled fuel and electrical sparks may both be present in rear engine car accidents, they are not normally in close proximity to each other.

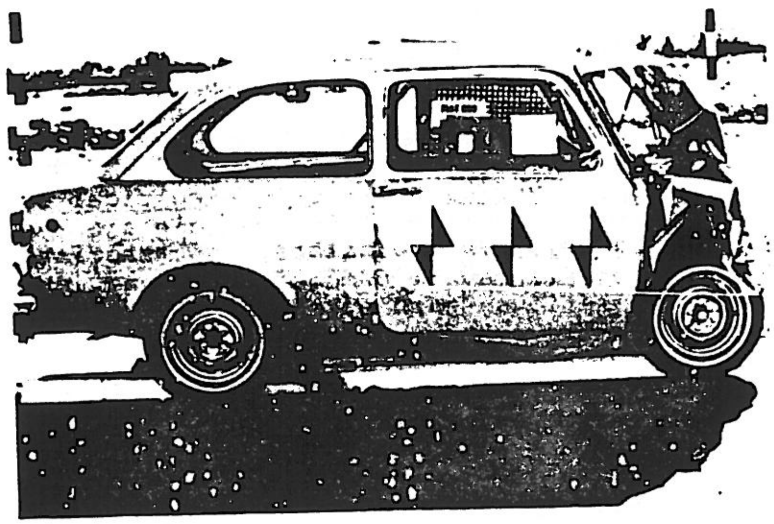

Figure 79. Damage to Rear Engine Passenger Car Due to Frontal Impact.

Fuel tanks in front engine light vans are usually located at the rear of the vehicle and are not vulnerable to damage in a front impact, although the tank might be dislodged due to mounting failure. Fuel components which might be damaged in a front impact are the fuel pump, fuel filter, fuel lines within the engine compartment, and the carburetor. These components are located behind a considerable amount of structure so that large deformations must take place before the components are endangered.

In front engine light vans several electrical system components are located well forward in the vehicle, subject to damage in front impacts. However, fuel system components are located inside the engine compartment and, even if damage should occur, sparking and fuel sources are separated.

7.3 REAR IMPACTS

Although rear impacts constitute only 5 percent of the total injury-producing accidents, the incidence of fire in this type accident is disproportionately high. Approximately 15 percent of all injury-producing accidents involving fire occur as a result of rear impacts. With the exception of rear engine passenger cars, rear impacts do not endanger hazardous electrical system components in the impacted vehicle. However, front engine passenger cars, front engine station wagons, and light vans all carry the fuel tank at the rear of the vehicle in an exposed location. If this type vehicle should be impacted by another front engine vehicle, where the hazardous electrical components are in the front, a source of fuel and a potential source of ignition would be in close proximity to each other.

In front engine vehicles the only electrical system components located near the rear of the vehicle are the tail lights, brake lights, turn indicators, and associated wiring. While these components may be damaged in a rear impact, they do not present a serious spark potential unless the impact should occur when the systems are energized. Figure 80 shows a typical tail light wiring harness layout for a front engine passenger car. Notice that the wiring (A) is routed just inside the exterior sheet metal and passes in close proximity to the filler neck of the fuel tank. Note also that the bulb sockets (B) are of the push-in variety which are held in place by a spring clip and can be shaken or pushed out as a result of only minor damage to the tail light assembly. Other configurations of front engine vehicles use the same general type of wiring but with slightly different routings.

Figure 81 shows typical damage caused by a rear impact to a front engine passenger car. Notice the downward displacement of the fuel tank causing it to be exposed to damage. Further observe that the fuel filler neck (A) has been pulled completely free of the tank. This would allow massive spillage of fuel to occur. Exposed tail light wiring (B) can be seen in the center of the picture just to the right of the license plate frame. This wiring, if damaged while the circuit was activated, could produce a spark which might ignite the fuel spilled as a result of the filler neck damage.

Rear engine passenger cars carry many of the hazardous electrical system components in the rear where they are particularly vulnerable to damage during a rear impact. Such components include voltage regulators, alternators, generators, tail light bulbs, ignition coils, distributors, and the associated wiring. In addition, several of the more hazardous fuel system components are also located in the rear of the vehicle. These include the fuel pump with associated fuel lines and the carburetor. Because of the light construction of the smaller rear engine vehicles, damage to these components may result from a relatively minor rear impact. The small amount of space available in the engine compartment places the electrical

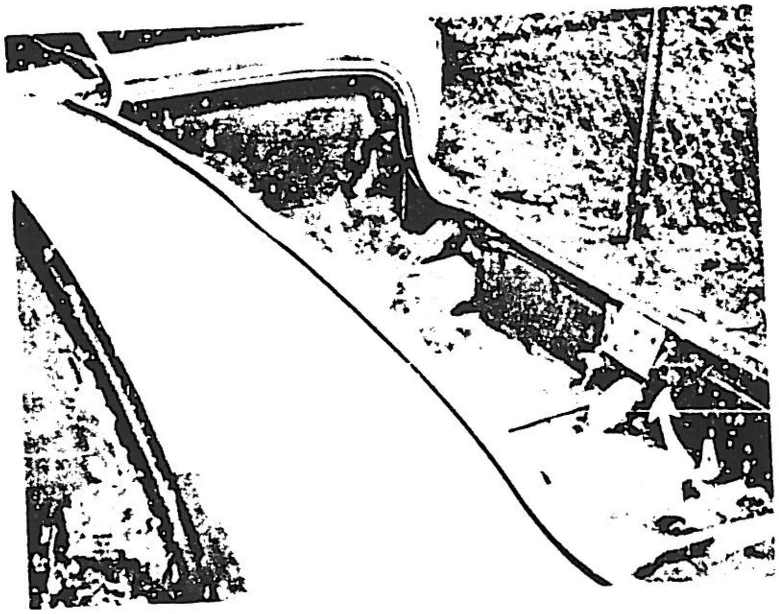

Figure 80. Typical Tail-Light Wiring - Front Engine Passenger Car.

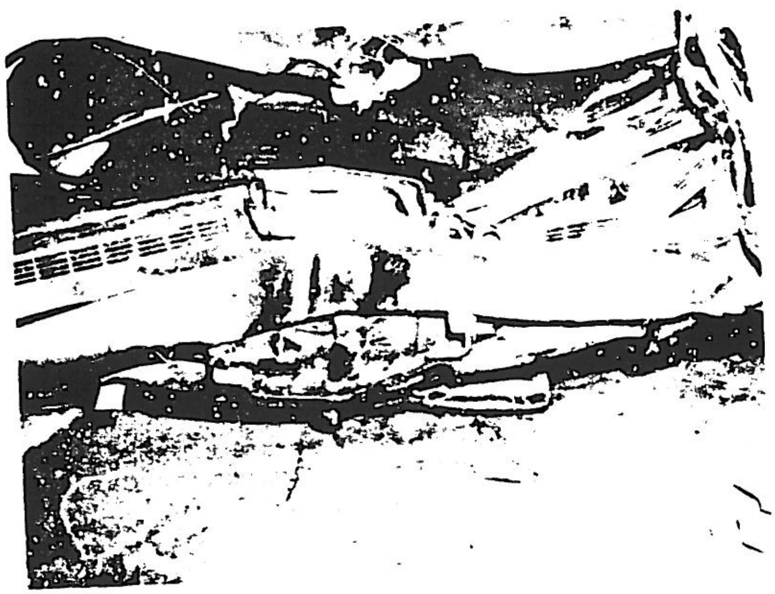

Figure 81. Typical Damage to a Front Engine Passenger Car Due to a Rear Impact.

system and fuel system components in close proximity to each other so that the fuel from damaged fuel system components may be very close to potential sparks from damaged electrical system components. Figure 82 shows damage to the engine compartment of a rear engine passenger car that resulted from a relatively minor impact. Notice that the distributor cap (A) has failed, exposing the ignition terminals, and the air cleaner and carburetor (B) have been displaced forward. The fuel pump (C), located immediately to the right of the distributor and just below the carburetor, has not been damaged in this particular impact. However, this exposed location would make it vulnerable in a more severe impact. The damage to this vehicle was limited to that visible in Figure 82 plus minor damage to the engine compartment door.

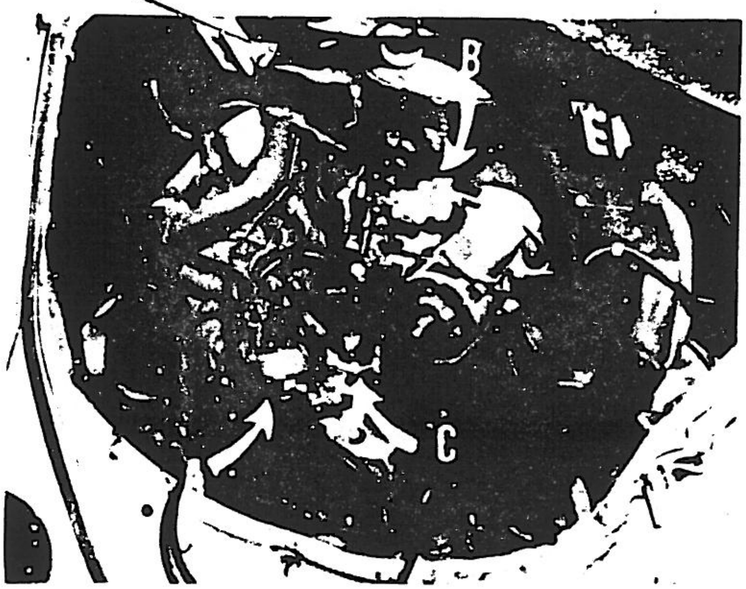

Figure 82. Engine Compartment Damage to Rear Engine Passenger Car Due to Minor Rear Impact.

7.4 SIDE IMPACTS

Reliable statistics are not available concerning the frequency of occurrence of side impacts or the frequency of fire in side-impact accidents. Side impacts are discussed here, however, because certain electrical system and fuel system components are vulnerable to damage in this type of accident.

Front engine vehicles, such as front engine passenger cars, station wagons, and light vans, have electrical wiring and fuel lines routed along the outer edge of the vehicle body. Although the wiring and the fuel lines are usually well protected by the routing inside the frame rail, it is possible that sufficient displacement can occur to damage these components. Should both fuel lines and the light wiring be damaged in the same impact, fuel and ignition sparks might be present at the same time and the same location. Figures 83 and 84 show damage to front engine passenger cars that occured in typical side-impact accidents. In Figure 83 note the fuel line (A) exposed just ahead of the rear wheel and just below the bottom of the rear door. Although this line was not damaged, it is in an exposed position and could have easily been damaged in the impact. Figure 84 shows electrical system wiring (A) exposed by displacement of body metal. Note that the exposed wiring is in close proximity to sharp, jagged metal edges.

The electrical system components in rear engine passenger cars that are vulnerable to side-impact damage consist primarily of the wiring to the headlights, tail lights, and accessories. This wiring is often routed just inside the door sill near the exterior of the car where displacing sheet metal can damage it during a side impact.

The fuel line from the tank to the pump for rear engine cars with front-mounted fuel tanks is not particularly vulnerable to damage in a side impact. Protection exists in its routing down the center of the vehicle inside the tunnel containing the transmission shift linkage. For rear engine cars with rear-mounted fuel tanks the line is also not particularly vulnerable. The tank itself may be vulnerable if sufficient body displacement occurs to impinge upon the tank.

7.5 ROLL-OVER ACCIDENTS

From a fire hazard standpoint, the roll-over accident is the most severe of the four types of accidents being discussed. Although they comprise only 23 percent of the total injury-producing accidents, roll-over accidents produce 41

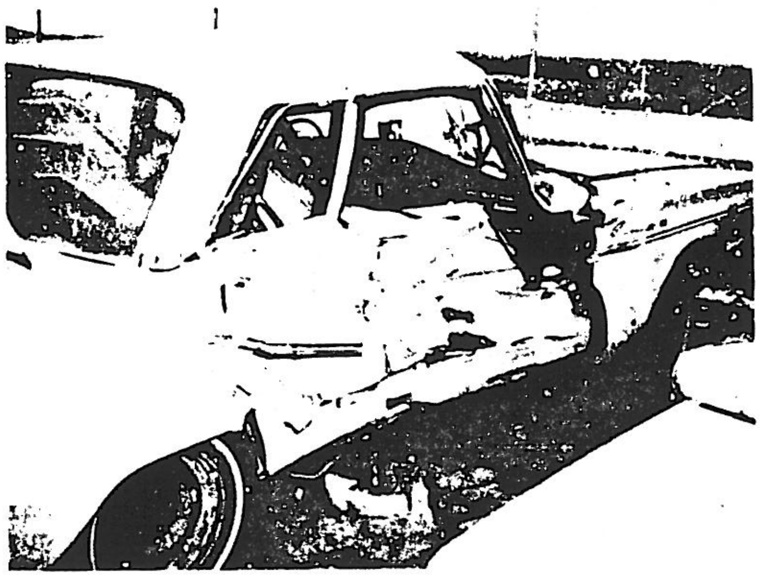

Figure 83. Damage to Front Engine Passenger Car Due to Side Impact.

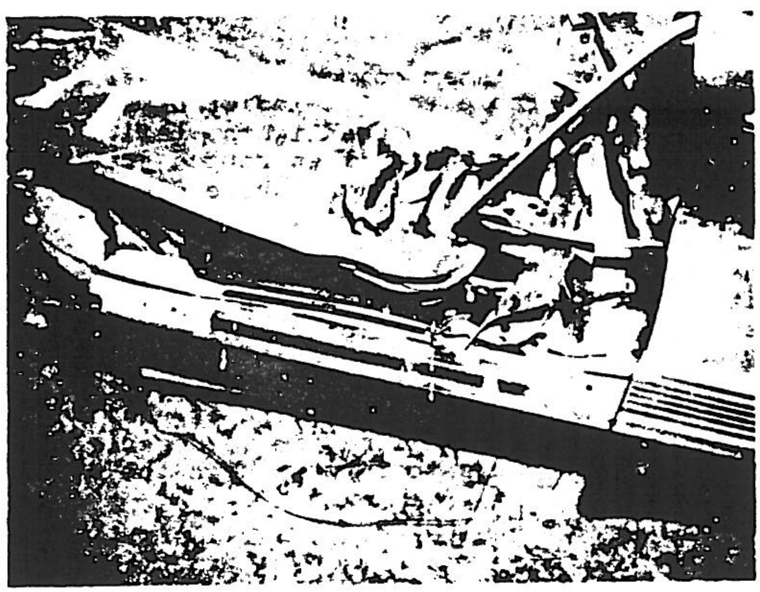

Figure 84. Damage to Front Engine Passenger Car Due to Side Impact.

percent of the fire accidents. In addition, 80 percent of these fire accidents cause extreme damage to vehicles and result in fatal burns to over 9 percent of all occupants.

The high incidence of fire in roll-over accidents is probably due to spillage of fuel from components which were not intended to function in an inverted position. The spillage might come from the inverted carburetors or from the fuel tank through the vent line. In addition, oil may be spilled from oil-bath type air cleaners or from the crankcase if the filler cap should be displaced. Damage to fuel and/or electrical system components may also result if heavy components, such as the battery, break loose from their mountings and impact other components in the engine compartment.

Roll-over accidents may result when vehicle operators lose control of their vehicles due to excessive speed and/or slick roadways and the vehicles simply overturn without impacting solid obstructions. Roll-over accidents may also occur as a result of a glancing impact with a vehicle or another obstruction, or by being impacted by another vehicle from the side or rear. In the case where the vehicle simply overturns and no obstruction is involved, major structural displacement does not usually occur. Where the roll-over follows a previous impact, the type and amount of structural deformation will depend to some extent upon the type and location of the impact preceding the roll-over.

Front engine passenger cars, station wagons, and light trucks that sustain roll-over without prior impact may suffer damage to electrical system components located near the exterior of the vehicle. Although large structural deformation does not usually occur in this type accident, many of the hazardous components, such as batteries, voltage regulators, and starter solenoids, are located immediately adjacent to the exterior of the vehicle where even a small amount of deformation may subject them to damage. Figure 85 shows a battery in a front engine vehicle that was damaged due to a small amount of structural deformation during a single car roll-over with no prior impact. Note that the metal of the fender has impinged the battery terminal (A). Since this particular battery terminal is the ground terminal, this impingement would not have produced a spark. However, had the other terminal suffered similar damage or the battery had been reversed in its mounting, a spark would undoubtedly have occurred. Notice also the proximity of the fender sheet metal to the exposed terminals on the starter solenoid located just to the rear of the battery.

Figure 85. Battery Damage in a Front Engine Vehicle Due to Roll-Over.

Damage to electrical components during roll-over may also occur as a result of displacement of large components in the engine compartment. As an example, Figure 86 shows a battery which was displaced in a roll-over type accident. This particular accident involved roll-over preceded by a side impact. The battery was originally located, as shown by Arrow A, on the opposite side of the engine compartment between the radiator and the splash guard. It is not known whether the battery was displaced due to the impact or whether the impact served merely to fail the mounting system, and displacement occurred during the subsequent roll-over. Regardless of when displacement occurred, the fact remains that an object of this mass (approximately 50 lbs.) moving at random inside the engine compartment has the potential of inflicting severe damage on electrical system and fuel system components.

In accidents involving front engine vehicles which roll over after an impact, the damage inflicted upon the fuel system and electrical system will depend upon the type of causal impact although the roll-over may intensify damage initially caused by the impact. In addition, the subsequent roll-over

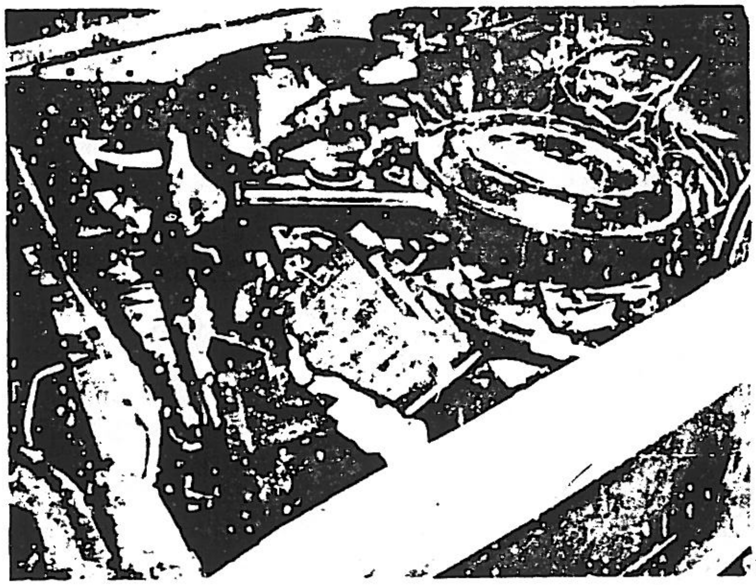

Figure 86. Battery Dislocation in a Front Engine Passenger Car Due to Impact Followed by Roll-Over.

introduces a greater probability of fuel spillage due to inversion of the tank and carburetor. Fuel spillage from the tank can be particularly disastrous since there is a high probability that spilled fuel will enter the passenger compartment. Should this happen and ignition occur, a catastrophic fire could result inside the passenger compartment.

Front engine vans involved in roll-overs without prior impact will probably suffer only minor damage to electrical system components. This is because the box-like construction of the light vans will not suffer major structural deformation during a simple roll-over. Further, since most vans are of slab-sided construction with a height in excess of their width, a complete roll-over is not likely. However, this construction results in a high center of gravity and a high roll center, making the van comparatively easy to overturn. Because of the relationship of the height to the width most vans overturn by simply laying over on one side and sliding. Since this type accident usually does not result in pronounced structural deformation, the electrical components within the van interior are not likely to be severely damaged.

The fuel system in front engine vans is also fairly well protected in the roll-over type accident without prior impact. Although a spillage hazard exists from the rear-mounted fuel tank, the balance of the fuel system components are protected by the frame rails and by the structure surrounding the engine compartment. Spillage from the fuel tank through the vent line or through a damaged tank or filler neck could conceivably enter the passenger compartment. A fire originating in the engine compartment would create an especially hazardous situation since the engine compartment is located within the confines of the passenger compartment. The engine compartment cover usually consists of a hinged fiberglass lid, secured at the front by one or two latches. If this lid remains in place throughout the accident, a fire originating in the engine compartment would probably be confined thereto for a sufficient period of time to allow occupant evacuation. However, should the latches be loosened during the accident and the engine compartment lid be opened, a fire originating in the engine compartment would present an immediate hazard to the occupants.

Light vans involved in a roll-over preceded by an impact would experience electrical system component damage dependent upon the type of pre-roll-over impact. As with the front engine passenger car, the roll-over following impact may simply serve to intensify damage caused by the impact and to cause fuel spillage from the fuel tank and/or carburetor when these components are placed in unusual attitudes.

Rear engine passenger vehicles subjected to roll-over accidents without prior impact may be expected to suffer electrical system and fuel system damage. Due to the small size and light construction of these vehicles, components are often located in close proximity to exterior sheet metal and each other. Thus, even a small amount of deformation may endanger hazardous electrical system components, such as batteries, voltage regulators, and alternator/generators, as well as headlights and associated wiring. Because of their small size and rounded exterior configuration, the rear engine passenger car is extremely likely to be completely inverted one or more times in a roll-over accident. Damage to electrical system components may be wide spread due to repeated impacts. Fuel spillage from the fuel tank and carburetor is also more likely since these components may be inverted one or more times during the crash sequence.

Rear engine passenger cars exposed to roll-over accidents following an impact will suffer electrical system damage determined by the location and severity of the pre-roll-over impact. Because of their small size and light construction, considerable displacement of body metal may occur during a comparatively minor impact. This displacement can endanger both electrical system components and fuel system components.

Fuel spillage from front-mounted fuel tanks in rear engine passenger cars can be extremely hazardous due to the tanks' proximity to the passenger compartment. Spillage is extremely likely in roll-overs preceded by front or front-quarter impacts. Rear-mounted fuel tanks in rear engine passenger cars, although located in close proximity to the passenger compartment, are fairly well protected and would seem to be less vulnerable to damage due to impact, although the danger of spillage through the vent line or displaced filler cap during a subsequent roll-over still exists.

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8. REDUCTION OF ELECTRICAL SYSTEM IGNITION HAZARD

8.1 GENERAL

To reduce the electrical system ignition hazard, electrical arcs or sparking from damaged components and/or wires must be eliminated. There are three basic methods by which this may be accomplished. These are: (1) inerting of the electrical system before spark-producing damage can occur, (2) relocating electrical system components and wiring away from areas of possible crash impact, and (3) shielding electrical system components and wiring from crash damage.

These methods are not mutually exclusive and some combination of them will probably offer the most effective and economical means of reducing the electrical system ignition hazard. Each of these methods is discussed in detail herein.

8.2 INERTING

Any of the electrical system circuits can be inerted by placing a device in the circuit which would sense the crash impact and open the circuit. Placing such a device in the wire from the hot lead of the battery to the starter solenoid would remove the battery from the ignition switch circuit, thus inactivating this circuit. Another device would be needed in the circuitry between the starter solenoid and the generator to inert the rest of the electrical circuits in the event the engine is not stopped by the impact. This method will not, however, inert the battery. The battery will remain a prime ignition source if displaced metal comes in contact with the battery hot lead. This method will, however, eliminate the possibility of sparking from broken or disconnected wiring or from damaged electrical system components.

The basic components of an inerting system consist of: (1) a crash sensing device or switch which is activated by the crash impact, (2) an inerting device or switch which actually renders the electrical system inactive, and (3) transmitting circuitry between the crash sensing device and inerting device if these two are remote from each other.

There are three general types of crash sensing devices now available. These are contact switches, deformation switches, and inertia switches. Each of these devices sense a different aspect of the crash environment. The sensory input is then transmitted, either electrically or mechanically, to the inerting device.

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8.2.1 Contact Switches. Several different types of contact switches are available, all actuated by contact with foreign objects. One such device consists of three separate electrical wires embedded in a silicone rubber-neoprene sandwich. When this strip is compressed by contacting an object, the wires are forced together, completing an electrical circuit. Another type is a mechanical lever switch which is tripped upon contact with an object. A third type is a frangible switch which is actuated by being broken upon impact.

Although these switches are readily applicable in detecting aircraft crashes where impact forces are fairly high and impact directions are fairly predictable, there are several drawbacks to the use of these devices for crash sensing on automobiles. An automobile would have to be surrounded by these switches in order to detect an impact from all possible directions. In addition, there are many minor collisions, such as bumping an adjacent car while parking or bumping up against a high curbing or post, where it would not be desirable for the switch to actuate.

8.2.2 Deformation Switches. These switches sense displacement between two adjacent objects. In one such device a predetermined change in the distance between the objects activates a plunger or piston-type mechanism to trip a microswitch. Switches of this type could be used to detect excessive movement between the sheet metal body and the frame of the automobile.

Again, while these switches are applicable to aircraft crashes, their application to automobile crashes is questionable since their uni-directional characteristics would require a large number of switches to detect impacts from all possible directions.

8.2.3 Inertia Switches. An inertia switch senses a change in the acceleration of the vehicle in which it is mounted. The acceleration change is transmitted to a movable mass, usually a lever arm or ball. The movement of the mass opens or closes an electrical circuit which triggers the actual inerting device. Inertia switches should be rigidly mounted to the body structure to sense the acceleration changes of the vehicle as a whole.

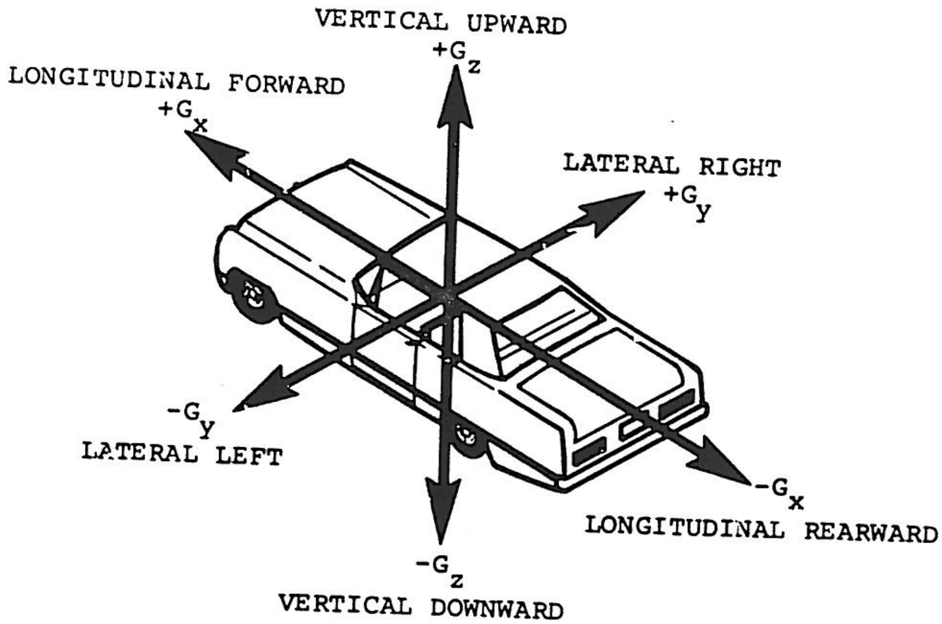
An inertia switch should be simple yet completely reliable, sensing every crash situation but not functioning under operational conditions. Inadvertent functioning of an inertia switch during operational conditions would not normally be hazardous, however there are specific situations where actuation could be highly dangerous, such as inadvertently turning off the headlights while driving at night. Thus, the operational criteria of inertia switches must be examined in detail.

An effective crash sensing device must sense acceleration changes in every possible impact direction. These directions can be resolved into their components along the three mutually perpendicular axes shown in Figure 87. In the majority of automobile accidents only longitudinal or lateral accelerations and decelerations are involved. A rear impact will lead to a longitudinal acceleration of the struck vehicle along the X-axis ($+G_X$) while a front impact will lead to a longitudinal deceleration along the same axis ($-G_X$). Side impacts may produce accelerations in either direction along the Y axis ($+G_Y$, $-G_Y$) depending upon the side of the vehicle impacted. Decelerations along the vertical Z axis ($+G_Z$) would be limited to a deceleration arising from impacting the ground after a free fall, as might happen if a vehicle ran off an elevated roadway. Any downward acceleration ($-G_Z$) would be limited to free fall with the possible exception of roll-over accidents. The direction of acceleration during a roll-over would be the resultant of random directions and would be difficult to predict with any degree of accuracy.

Ideally, an inertia switch should function during an impact from any direction. However, inertia switches that are uni-directional sensors may be effective if more than one is used, and provided the switches are aligned with mutually perpendicular axes. Thus, uni-directional inertia switches lined up along the longitudinal and lateral axes would sense practically all automobile crash impacts, since any vertical accelerations would also be combined with a longitudinal or lateral acceleration during the moment of impact.

G forces will also exist during normal operation of the automobile. Accelerations will be experienced along the longitudinal axis during starting and stopping, along the lateral axis during cornering, and along the vertical axis during operation on rough roads. Since the magnitude of these accelerations will be less during operational conditions than during crash conditions, it is important that the inertia switch react at a predetermined G level which will differentiate between normal and crash conditions.

Field tests (Reference 8) suggest the following levels for operational accelerations: (1) jounce - 6G vertical, (2) braking - 2.5G longitudinal and 2G vertical, and (3) curbing - 2.5G on the sprung weight. Information available (Reference 9) on vehicle shock spectra, which includes the time



DIRECTION OF ACCELERATIVE FORCES

Longitudinal Axis	- Acceleration, Braking, Front and Rear Impacts
Lateral Axis	- Cornering, Side Impacts
Vertical Axis	- Bumps, Potholes, Free Fall

Figure 87. Accelerative Forces on an Automobile.

duration of the pulses, is given in Figure 88. Based on these data, an inertia switch should not activate below 3G in the longitudinal or lateral direction. The vertical acceleration level must be considerably higher than 3G.

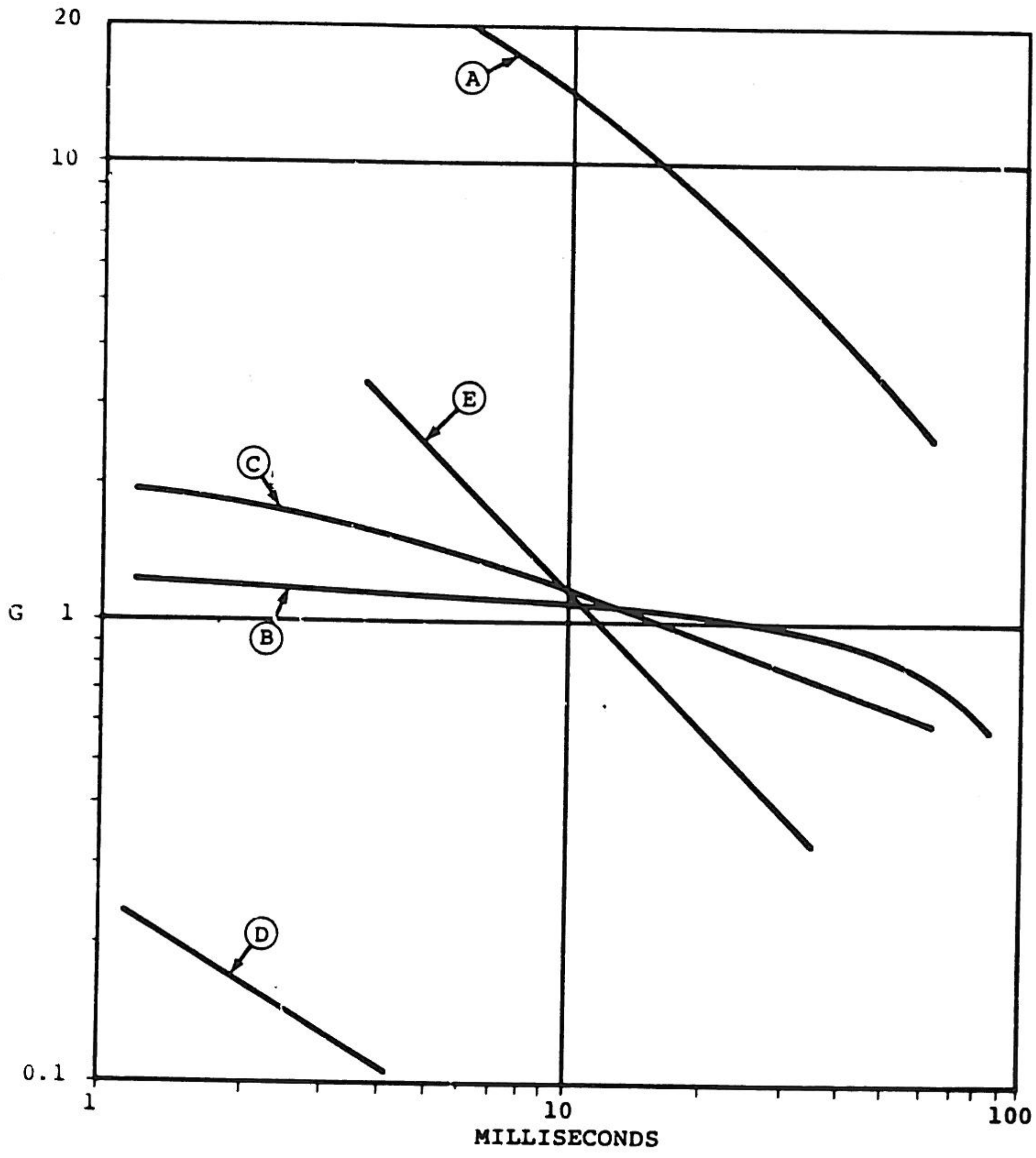
Crash impact acceleration levels are available from controlled automobile crash tests. Figures 89, 90, and 91 give typical acceleration responses for head-on, rear-end, and side-impact collision tests (Reference 10). Barrier impact acceleration responses (Reference 11) are shown in Figure 92. These data indicate that for an inertia switch to function reliably in side and rear impacts at 30 mph or less, the G level required to actuate the switch should be no more than 4-5G. A higher setting for lower speed impacts could preclude actuation. At higher speeds or in front impacts, a higher setting could allow excessive deformation to occur before actuation.

Another factor to be considered in the operation of an inertia switch is the time duration of the crash pulse. A transitory shock, such as from slamming a car door or bumping into a post, will not have the time duration that a crash pulse exhibits. If an inertia switch is so designed that the specified minimum G level must be exceeded for a certain time duration, a safety factor against inadvertent actuation will be provided. An excessively long time duration, however, may not allow the switch to actuate before damage to the electrical system occurs.

Based on the data in Figures 88 through 92 and on high-speed photographic data from automotive crash tests conducted by Dynamic Science and others, it would appear that the time duration should not be less than 10 msec to avoid inadvertent operation nor more than 25 msec to insure operation before excessive vehicle damage occurs. These values should be verified by full-scale testing before specific design criteria are set.

Little data is available concerning acceleration levels to be expected in a roll-over accident which is not preceded by an impact. It is conceivable that the accelerations in a simple roll-over might be of insufficient magnitude and/or duration to activate an inertia switch. The capability of attitude sensing should also be incorporated into the inerting system to allow for this possibility.

At least four inertia switches are currently available on the commercial market which incorporate the time delay method. Three of these devices have been developed specifically for



A - Upward Acceleration Limit, Due to Potholes, etc.
B - Downward Acceleration Limit (Free Fall)
C - Transverse Acceleration Limit, Skidding Sideways or Bumps
D - Vibration Region
E - Fore and Aft Acceleration Components

Figure 88. Condensed Data of Vehicle Shock Spectra (from Reference 9).

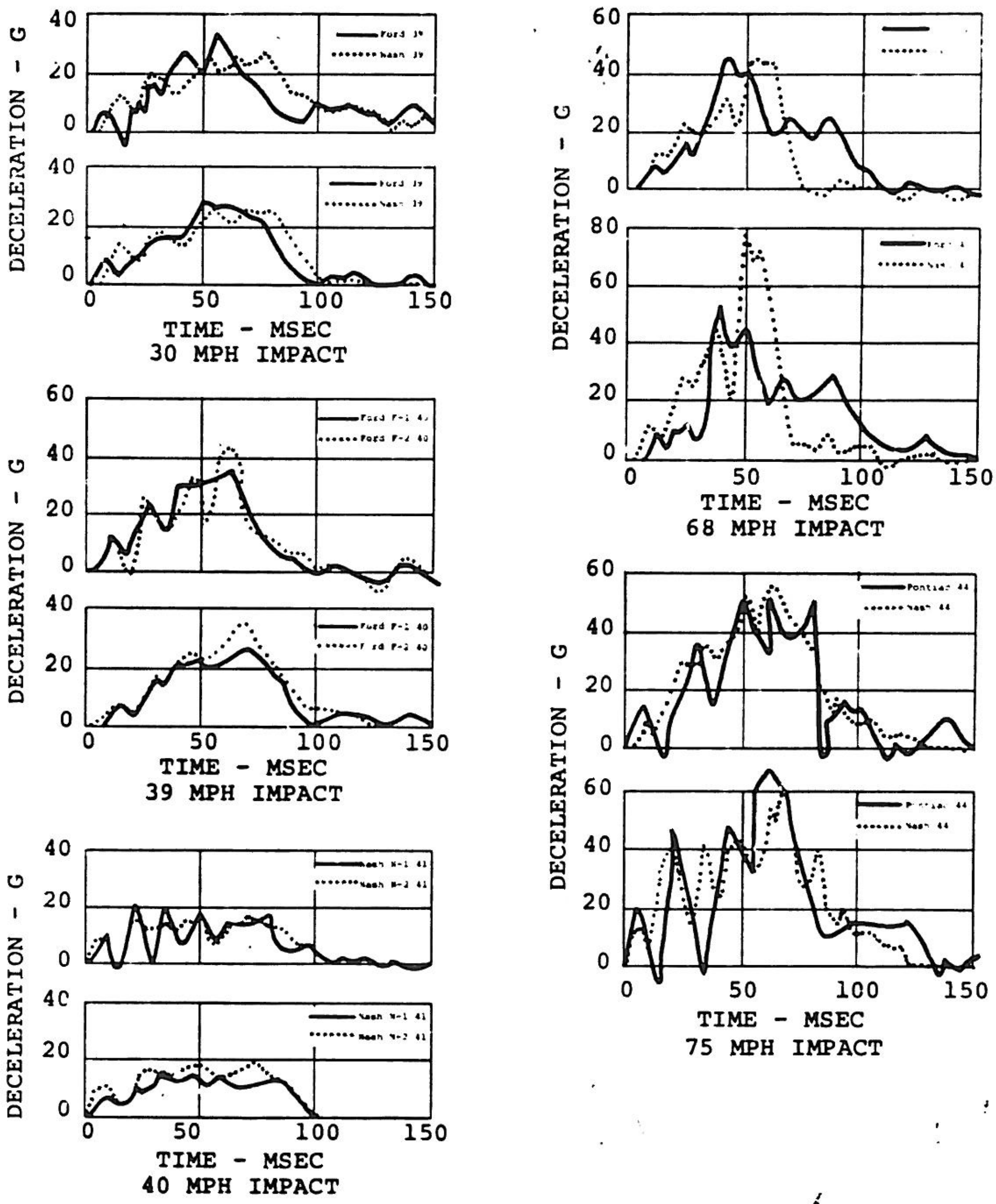


Figure 89. Deceleration Responses of Vehicles Subject to Head-On Collision Experiments (from Reference 10).

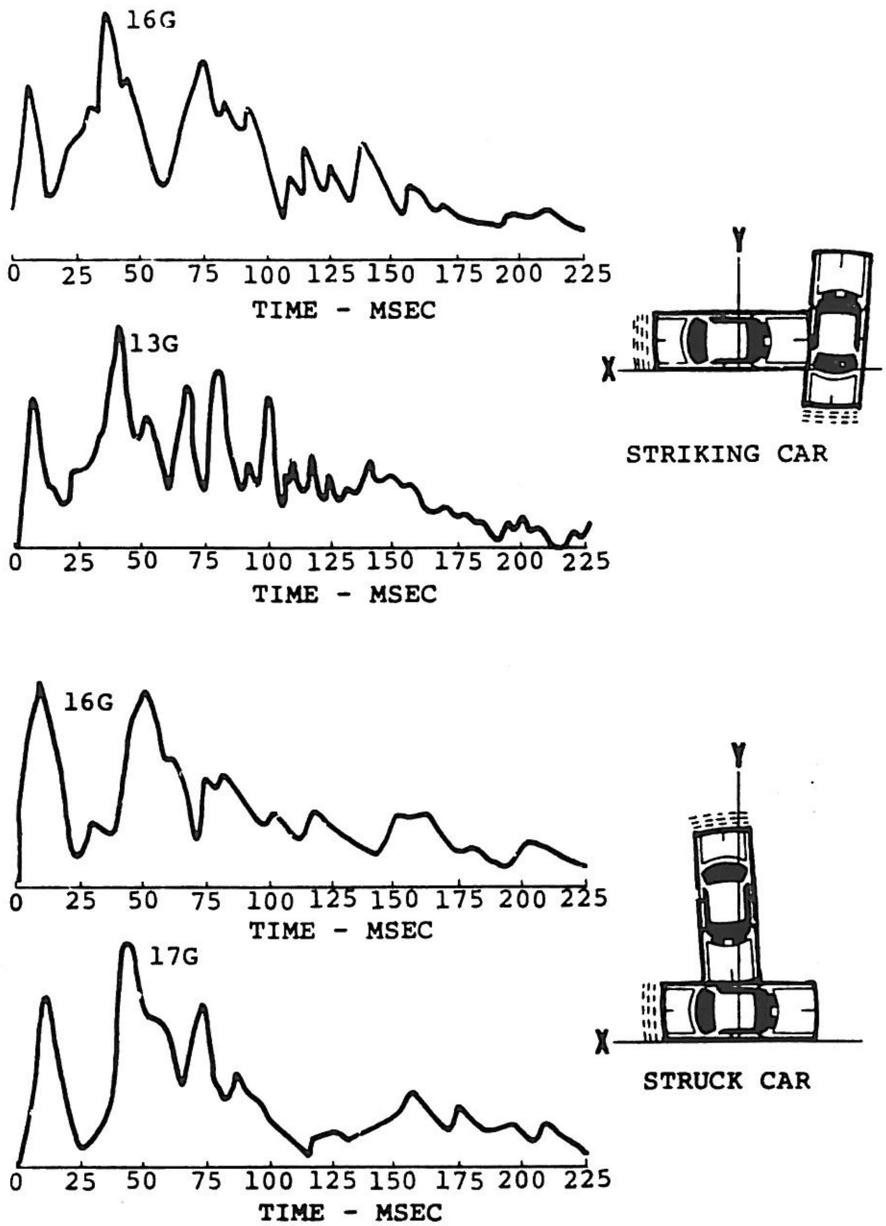


Figure 90. Deceleration Responses of Vehicles Subject to 30 mph Side-On Collision Experiments (from Reference 10).

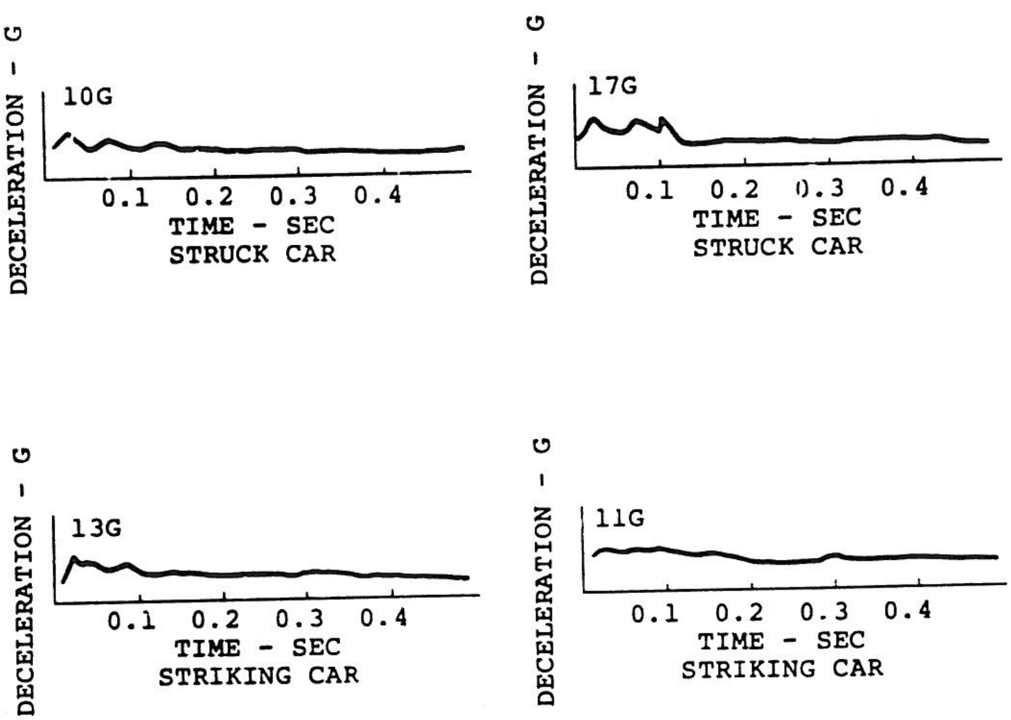


Figure 91. Deceleration Responses of Vehicles Subject To 30 mph Rear-End Collision Experiments (from Reference 10).

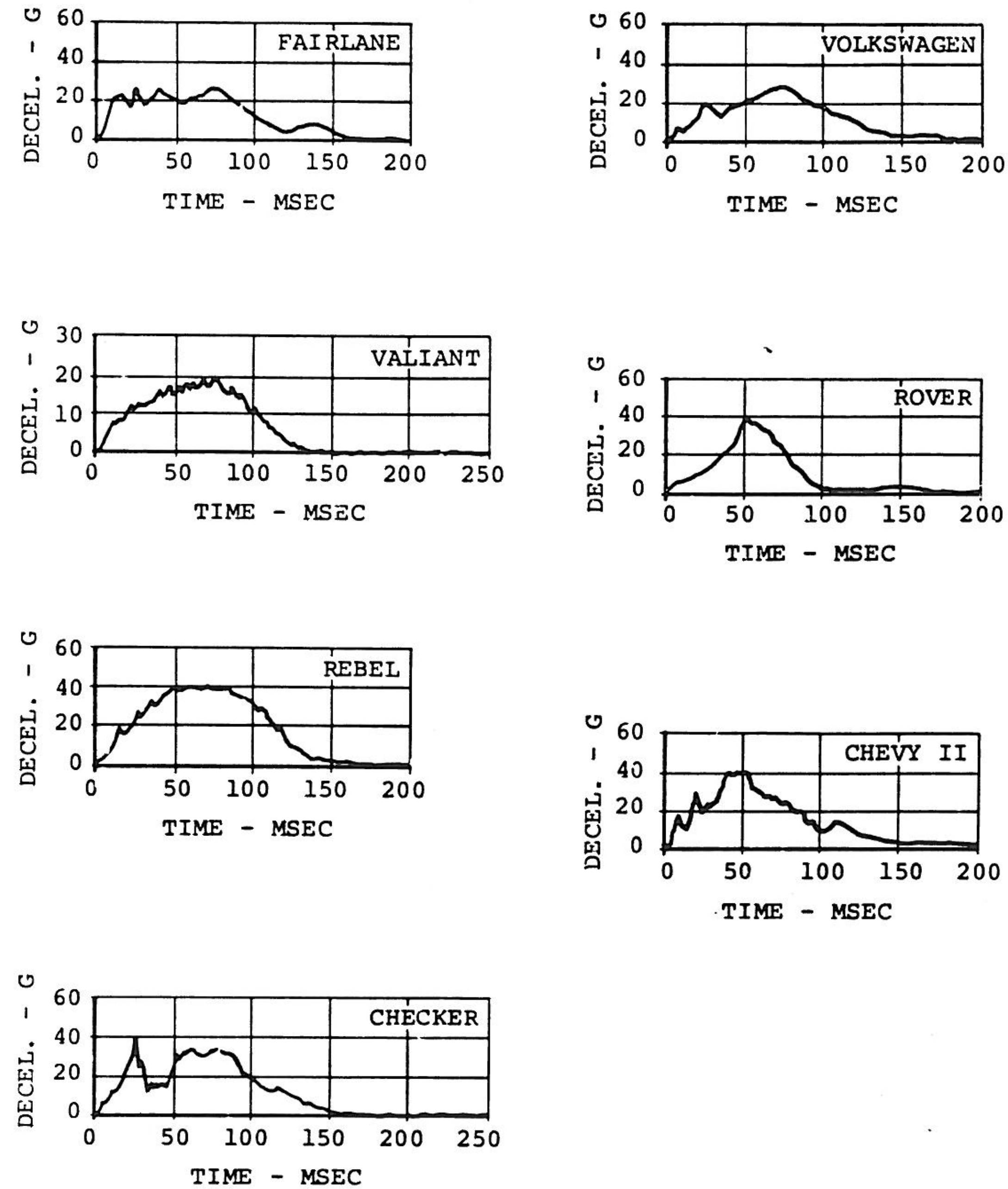


Figure 92. Deceleration Responses of Vehicles Subject to 30 mph Barrier Impact Experiments (from Reference 11).

the automotive market. The fourth should be readily adaptable to automotive applications.

The devices are referred to numerically in the following discussion.

8.2.3.1 Inerting Device No. 1. This device is intended for use in an electrical power circuit and uses a steel ball magnetically retained in a conical seating to sense accelerations, see Figure 93. When the ball is subjected to an inertial load sufficient to overcome the magnetic pull, the ball breaks free, rises up the slope of the cone, and strikes a plastic plunger. This plunger carries a metallic contact ring and is held in place by current-carrying spring clips. Since the plunger is much lighter than the ball, the impact of the ball will move the plunger upward, raising the contact ring and opening the circuit. The spring clips then latch into a detent on the plunger, holding it in the open position.

In this device, the actuating force and the time delay are controlled by the interaction of the magnetic force holding the ball in place, the force in the spring clips, and the mass relationship between ball and plunger. The switch, as manufactured, is readily actuated by a 6G load sustained for 32 msec.

Because of the conical seating arrangement, this inertia switch should respond to any impact in a horizontal plane. However, operation of the device in a roll-over accident is questionable.

High currents passing through the switch produce an excessive temperature rise in the plastic body material. A 145 ampere current routed through the switch for a short period produced a slight warming of the switch and a small amount of local melting where the contact springs had touched the switch body. This limitation of the switch precludes its use in any of the high energy circuits where the spark potential is greatest.

A limited amount of controlled testing has been done with this switch (Reference 9). Eleven switches with sensitivities ranging from 2 to 10G were fitted into a car which was then impacted head-on into a barrier at a speed of 30 mph. All switches triggered satisfactorily during the impact, which produced peak decelerations of 45G along the longitudinal axis of the car. The switches were undamaged by the impact. There was no inadvertent actuation during normal driving prior to the barrier test. However, further tests should be conducted on these switches under extreme operational conditions to

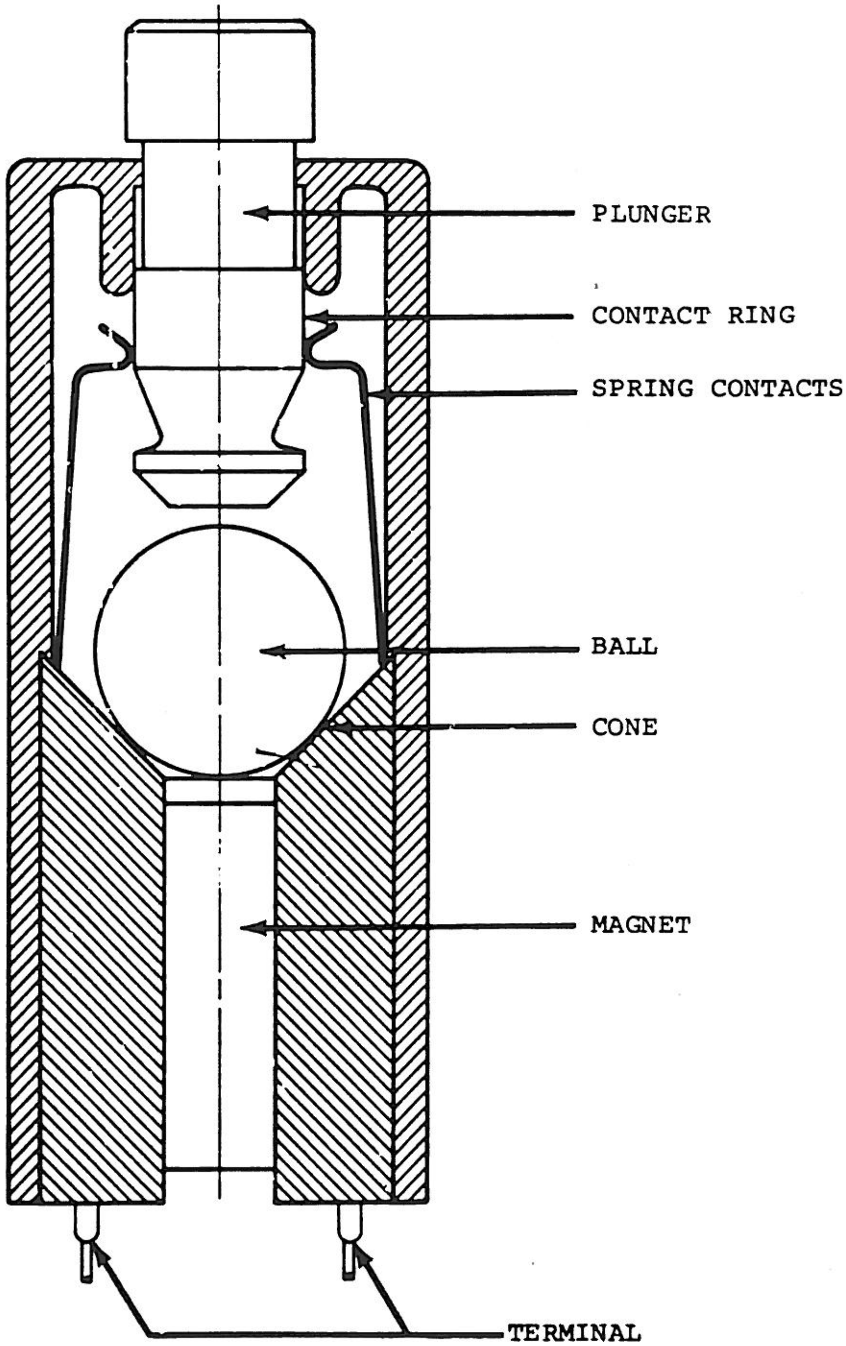


Figure 93. Inerting Device No. 1

insure that inadvertent actuation does not occur prior to crash impact. Additional testing should also be performed to determine if the switch will actuate during rear impacts, side impacts, and roll-over crashes.

8.2.3.2 Inerting Device No. 2. This device, like Device No. 1, consists of a steel ball resting in a conical seat, see Figure 94. The ball is held in position by the force of gravity. During a higher-than-normal acceleration change, the steel ball travels up the surface of the cone, striking a spring loaded metal plate. The plate is forced against a metal housing, enabling current to flow to a solenoid contained in the device. The activation of the solenoid causes a lever arm arrangement to move, breaking the battery ground and, at the same time, grounding the distributor side of the ignition coil.

The characteristics of the switch afford protection against inadvertent operation in impacts where no damage occurs since it is essential that there be at least some slight motion after impact for this device to function. In the event of an abrupt stop of the vehicle, such as might occur by running into the bumper of an adjacent car in a parking manuever, the ball travels up the inclined surface and rebounds so quickly to its original position that insufficient time is afforded for energizing the solenoid.

This switch will function during all longitudinal and lateral accelerations. The combination of G force and time can be varied in the design of the switch by changing the angle of the conical seat. With a setting of approximately 4.5G, the time to activate the device is approximately 30 milliseconds.

An attitude switch is also incorporated into the device. The switch consists of a second steel ball in a separate compartment. The ball, which is held in position by the force of gravity, is free to move as the device tilts. If the angle of tilt exceeds 90 degrees, the ball moves far enough to bridge a gap between the metal housing and a metal plate. This completes an electrical circuit which trips the solenoid. Thus, the device will also work during a roll-over accident.

Verbal communication with the manufacturer indicates that controlled testing of the device has been done. The device has been mounted in several vehicles and performed satisfactorily during normal driving conditions and has also functioned in several accidental crashes. However, the lack of controlled testing precludes any knowledge of the actual operating limitations and capabilities of this device.

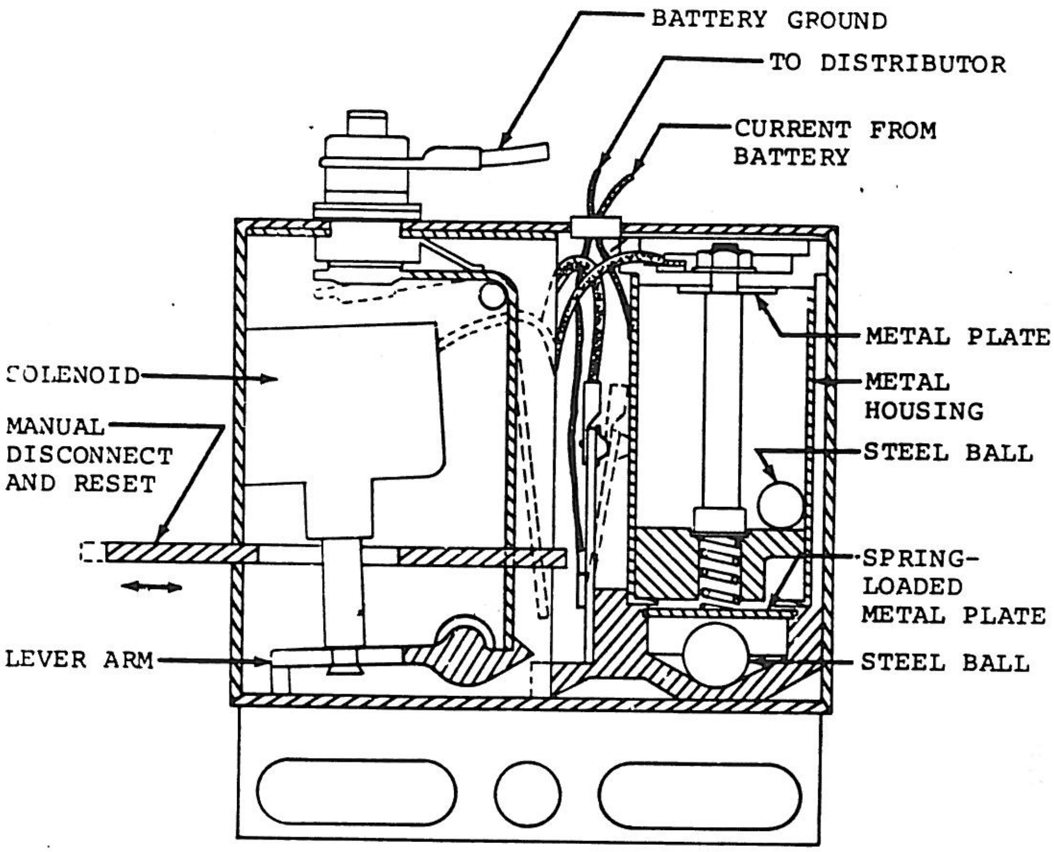


Figure 94. Inerting Device No. 2.

8.2.3.3 Inerting Device No. 3. The third crash sensing switch consists of a new electro-mechanical, low friction device, see Figure 95. There are three main elements to this device; two parallel guide surfaces, a thin band, and two rollers. The band is formed into a loose S shape and the rollers are inserted into the loops of the S. Tension is then applied to the band to lock the rollers against the guide surfaces. As the configuration moves, the rollers roll without slipping on the band while the band simply peels away from one guide surface, flattening out on the other. When this device is used as an inertia switch, the roller cluster is held at a preset position by an adjustable stop which determines the G level at which the switch is to actuate. When the switch is accelerated in one direction the roller cluster experiences a force in the opposite direction. If this force exceeds the limits of the adjustable stop, the cluster travels to the end of the device, closing electrical contacts and completing a circuit. The cluster is then locked in place with a latching tongue. Predetermined G loads and time pulse durations can be designed into the switch by varying the band design.

This is a very simple device and therefore should have a high degree of reliability although no controlled testing in an automotive application has been performed. In addition, the device can be made extremely small. The switch is unidirectional and two switches, one mounted along the longitudinal axis of the car and the other mounted along the lateral axis, would have to be used.

This is a crash sensing device only and a separate inerting device, connected by appropriate circuitry, would be required. The inerting device could be a relay or circuit breaker to interrupt the electrical circuits. If one relay were placed between the battery and the starter solenoid and another between the battery and generator, all current through the electrical system would be blocked even if the engine continued to operate. As in the case of the other devices, the battery would still be a prime ignition source because of the possible shorting across the battery terminals due to sheet metal displacement during crash impact. The transmitting circuitry between the inertia switch and the inerting device would have to be routed carefully and protected from damage so it would function during the crash impact.

8.2.3.4 Inerting Device No. 4. Inerting Device No. 4 (Figure 96) is an inertia impact sensor that is being developed in connection with the airbag restraint system. The requirements for this sensor are very similar to those outlined above and could be used to deactivate electrical

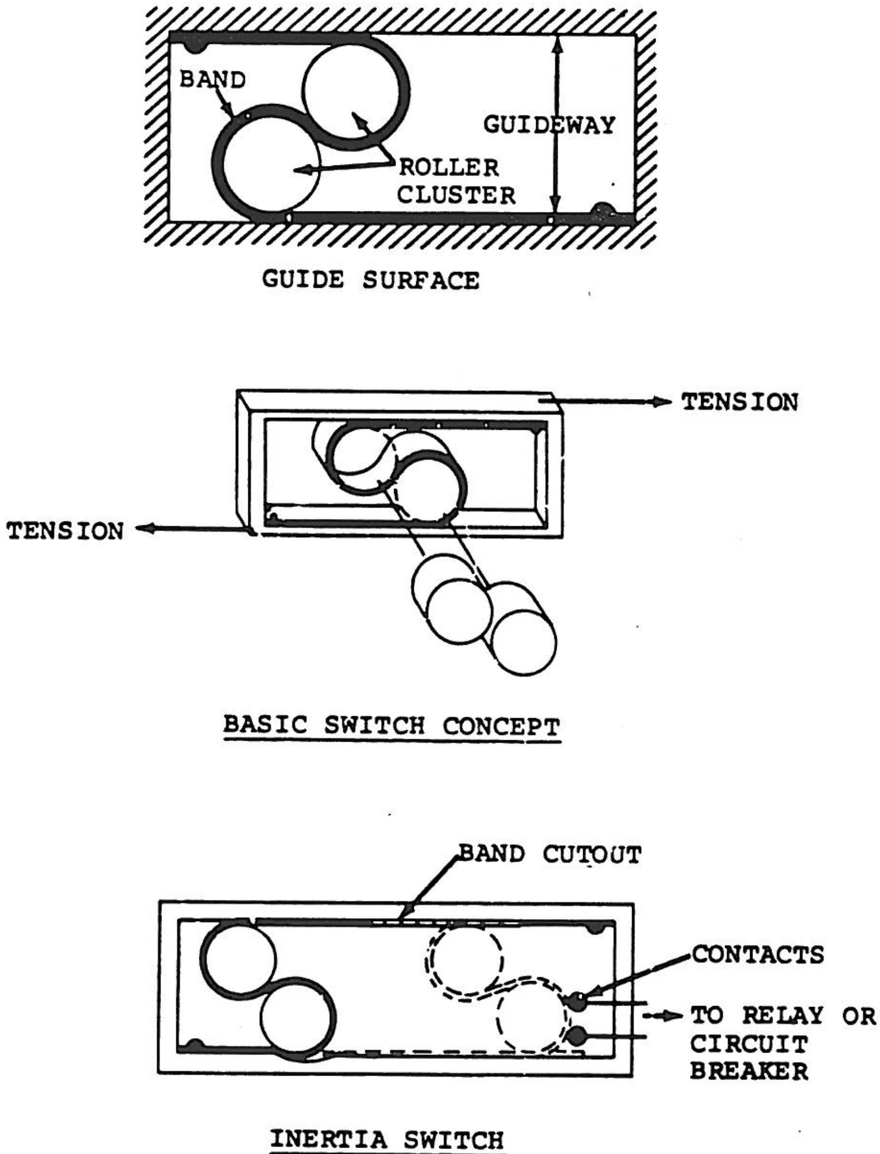


Figure 95. Inerting Device No. 2

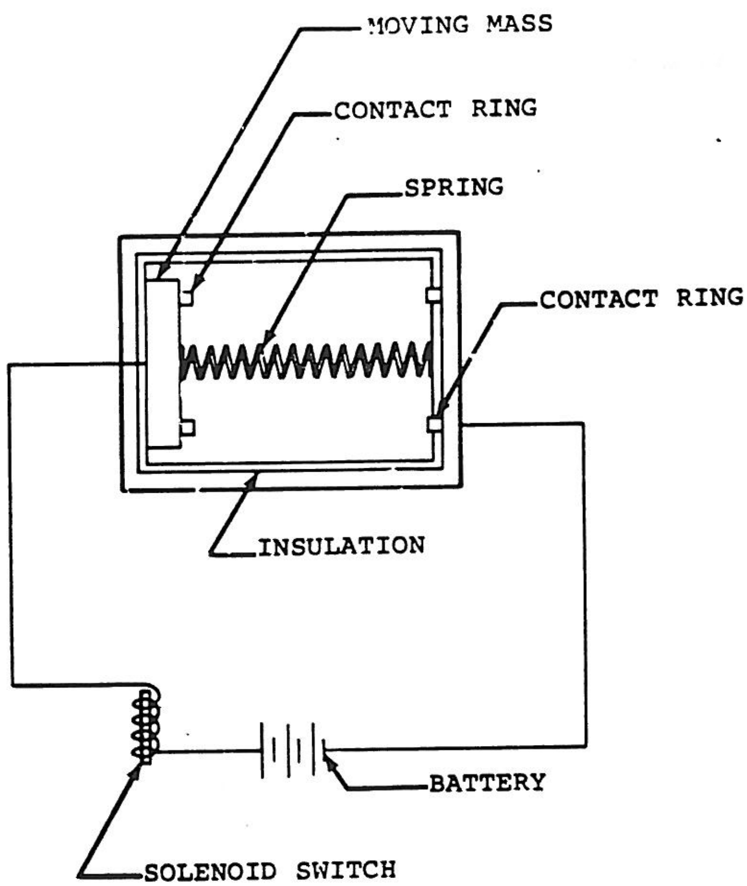


Figure 96. Inerting Device No. 4.

systems. It must operate in the event of a crash but not in the case of less severe decelerations.

It consists of a switch whose contacts are separated by a spring. One of the contacts is a small movable weight which operates against the spring which represents a 4G pre-load. Impact must be of sufficient level, 4G, and duration, about 20 msec, to move the weight contact into the fixed contact, closing an electrical circuit. As used in the restraint system, this causes activation of a detonator which opens a gas source to fill the bag.

In the application of this device for inerting electrical systems, a solenoid could be activated in place of the detonator, similar to Inerting Device No. 2 described in paragraph 8.2.3.2.

8.3 RELOCATION

Relocating electrical system components and wiring away from the exterior of the car toward the center of the structure would protect these components from crash damage except in the most severe impacts. This should not be too difficult for wiring and small components, such as the voltage regulator and starter solenoid. Relocating the battery from its vulnerable position in the front of the engine compartment to another location would be difficult, however. As shown in Figures 8 and 9, the engine compartments of front engine passenger cars are limited in available space. In most of these cars considerable rearranging of the engine compartment components would have to be done in order to move the battery back toward the firewall. The safest location for the battery is under the rear seat, as in some rear engine passenger cars. However, this may be undesirable from a maintenance standpoint.

Other components which would present relocation problems are the alternator/generator, headlights, tail lights, and parking lights. The alternator/generator is belt-driven off the crankshaft of the engine and must be near the front of the engine compartment in front engine vehicles or the rear of the engine compartment in rear engine vehicles. This device is sufficiently sturdy, however, and, with properly designed and shielded terminals, it would not constitute a spark hazard.

Headlights, tail lights, and parking lights must be located on the exterior of the vehicle to perform their function. However, if the wiring and connectors are well designed and properly located, and the system is properly inerted during the crash sequence, only the hot filaments will remain as an ignition potential.

8.4 SHIELDING

Another means of reducing the ignition hazard from the electrical system is through the use of appropriate shielding methods and materials to protect the electrical system components from crash impact damage. This is especially important in the case of the battery where, although the battery circuits might be opened, a potential for sparking still exists if broken wires or sheet metal contact the battery terminals. One method of protecting the battery is to shield the terminal connections with an appropriate insulating material. However, there is still a possibility that these shielded connections could be pulled loose during a crash, exposing the battery terminals. Therefore, the battery should be completely enclosed in a protective box. This box could be satisfactorily made of a material such as low density polyethylene which is non-conducting and impact resistant. The cover should fit well down over the bottom of the box to prevent its being pulled loose during a crash. In addition, the battery should be firmly attached to the automobile frame and a clamping strap run from this attachment over the top of the box. A bayonet-type connection should be used between connecting circuitry and the battery terminal cable, with a shielded female end on the circuit wire and the male end on the battery cable well recessed within the protective box. A conceptual view of such an arrangement is shown in Figure 97. Although no provision for servicing is shown, the lid of the box could be made removable by providing slots below the cable to permit raising the lid without disconnecting the wiring.

All wiring should be encased in a protective shield to increase its resistance to cutting. This might be done by the use of heavy polyethelene conduit or by molding the wires in insulation to form a cable.

All terminals in the electrical system should be shielded and should be of the bayonet type. In all cases the terminal should be designed so that if separation should occur, any exposed pins in the connector will be shielded. In addition, the connector should be designed so that the force required for separation is no more than 50 percent of the force required to fail the weakest wire in the connector. This will insure that the connector will separate before failure of an energized wire can occur. The connector body should be molded from a flexible material to prevent shattering of the connector due to impact.

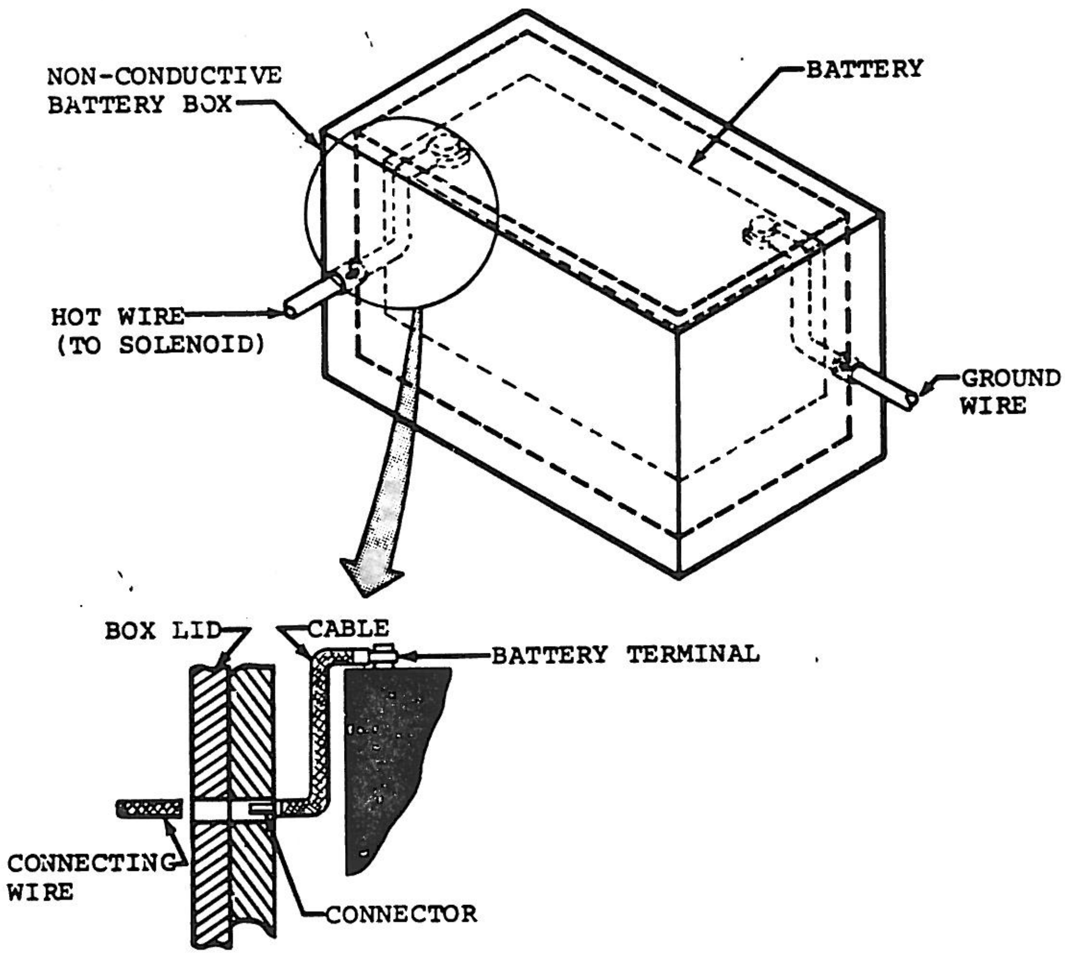


Figure 97. Protective Battery Box.

Wiring which cannot be relocated away from areas of potential structural displacement should be made at least 20 percent longer than necessary. This extra length will allow the wire to displace rather than fail.

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9. SUGGESTED SAFE DESIGN GUIDE FOR AUTOMOTIVE ELECTRICAL SYSTEMS

9.1 GENERAL

In Section 8 of this report potential methods of reducing electrical system ignition hazards were discussed. In this section specific design criteria will be recommended to implement those methods.

The recommended design criteria presented here is in the form of a suggested electrical system design guide. Each section of the design guide is later discussed to point out the influencing factors and to discuss those areas where further study is needed.

9.2 PROPOSED MOTOR VEHICLE ELECTRICAL SYSTEMS DESIGN GUIDE _____.

S1 Purpose and Scope

The purpose of this design guide is to recommend design requirements for automotive electrical systems in order to reduce the crash fire ignition potential. The guide should be used for all passenger motor vehicles having a curb weight between 1,000 and 6,000 pounds.

S2 Definitions

Electrical Components - Devices in the automotive electrical system which produce, store, or utilize electrical energy in their normal operation.

Flammable Fluid Lines - Lines which contain fuel, oil, or hydraulic fluid.

Roll Angle - The angle between the vehicle lateral axis and a horizontal reference plane.

Terminal - The interface between electrical wiring and the component served.

S3 Design Criteria

S3.1 General. Electrical system wiring and components should conform to applicable SAE standards and recommended practices, latest revision.

S3.2 Component Location. All electrical system components should be located as near the center of the vehicle as

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possible. No part of any electrical system component should be less than 24 inches horizontally or 6 inches vertically from the exterior of the vehicle.

Exceptions to this provision may be necessary if the component cannot perform its intended function when located as described above, or the comparative sizes of the vehicle and the component in question will not permit mounting as specified above. In these cases, it is mandatory that all other applicable sections of this guide be complied with to achieve a crashworthy system.

S3.3 Shielding. Electrical components, except external lights, should be enclosed in a housing of non-conductive material. Each individual component should be provided with a separate housing which is capable of containing the component and insulating it from its surroundings even though the component itself is damaged. Provisions for ventilating the container should not compromise the ability of the container to protect the component.

All electrical wiring should be protected from damage by encasement in a flexible, non-conductive material. This encasement should increase the wire resistance to pinching to at least three times the value required by SAE J878. Where more than one wire is encased, minimum pinch resistance should be based on the smallest wire involved.

S3.4 Terminals and Connectors. All terminals and connectors used in the electrical system should be of the bayonet type and should be designed so that the energized portion of the connector or terminal is not exposed when the terminal or connector is separated. The non-conductive portion of these terminals and connectors should be constructed of flexible materials. Loads required to disconnect the terminal or connector should be no more than one-half the failure load of the weakest wire in the terminal or connector.

S3.5 Routing of Electrical Wiring. All electrical wiring should be routed as near the center of the vehicle as possible and should conform to the provisions of SAE J556, latest revision.

Wiring serving components located near the exterior of the vehicle should be routed so as to take maximum advantage of protection afforded by the vehicle structure. Such wiring should be 20 percent longer than the length between terminals. This additional length should be located in the area of maximum expected vehicular deformation.

Clips used in securing all wiring to structure should be of a non-metallic frangible type which will fail or pull free to release the wire when excessive load is applied. The load required to fail these clips should be less than one-half the load required to fail the wiring.

Electrical wiring should not be routed adjacent to flammable fluid lines.

S3.6 Fusing. Fusing or other overload protection should not produce an exposed spark upon actuation. Fusing and circuit breakers should comply with the provisions of the most recent revision of SAE J553 and J554.

S3.7 Inerting Devices. The electrical system should be provided with a device mounted to the vehicle structure which, when activated by a crash impact, will disconnect the battery from the electrical system and inert the ignition system. This device should be capable of activating due to a crash pulse acceleration of not less than 3G nor more than 5G acting in a horizontal plane and a minimum time duration of 25 milliseconds. The device should also actuate when the roll angle of the vehicle exceeds 90 degrees.

The inerting device could easily be triggered by the same inertia switch used to trigger the airbag restraint system, since the airbag inertia switches are designed to operate within approximately the same crash pulse limits as recommended for the inerting devices.

The inerting device should not be subject to inadvertent operation under normal operating conditions. However, should inadvertent operation occur, power to the headlight circuit should not be interrupted. The device should provide a readily accessible means of restoring normal electrical system operation following actuation. The restoration device should be located in the passenger compartment to prevent trapping of occupants due to inability to operate power windows.

All components and wiring associated with this device should conform to all other applicable provisions of this standard.

The device should not create an exposed spark upon actuation.

9.3 DISCUSSION OF PROPOSED MOTOR VEHICLE DESIGN GUIDE

This section follows the format established in 9.2 and presents an analysis of the criteria set forth therein. Effort has been made to discuss specific items in the design guide with regard to their current state-of-the-art.

S1 Purpose and Scope

This section describes the purpose of the design guide and specifies the vehicles to which the guide should apply. Since this design guide is intended to apply to the vehicles examined in the study, the range of curb weights was set to include passenger cars, light vans, and pickup trucks, while excluding heavier commercial vehicles. These heavier commercial vehicles present different problems with regard to fire ignition and should be studied separately.

S2 Definitions

This section serves to define those terms used in the standard which might otherwise not be clear.

S3 Design Criteria

S3.1 General. This section states that electrical systems on these vehicles should meet the requirements of the applicable SAE Standards and Recommended Practices.

S3.2 Component Location. This section sets forth minimum requirements for component location with respect to the exterior of the vehicle. While it is highly desirable that electrical components be located as near the center of the vehicle as possible, it is realized that in some cases these minimum location requirements cannot be met due to the size of the component, the size of the vehicle, or a combination of these two factors. It is also realized that certain components (e.g., external lights) cannot readily serve their intended purpose when located within the minimum requirements described. Therefore, exceptions to this section of the design guide may be necessary. It was felt that the wording of this section would result in a maximum number of electrical system components being located as far as possible from the exterior of the vehicle.

S3.3 Component Shielding. In this section the criteria for component protection are set forth.

The requirement that a housing be capable of containing the component even though the component itself is damaged may seem at first to be rather restrictive. However, it is believed that this requirement is within the current state-of-the-art of protective materials. External lights are excepted from the provisions of this section since these components cannot readily perform their function when encased in a housing.

Encasing electrical wiring in a flexible non-conductive material will serve a two-fold purpose. First, the wiring will be afforded protection from damage during an accident and, second, such encasement will result in increased operational reliability of the electrical system by providing additional protection against insulation deterioration caused by exposure to the normal operational environment.

S3.4 Terminals. Terminals and connectors designed in accordance with this section should eliminate sparking occurring as a result of an energized wire being pulled free of its terminal. In addition, sparking due to shattering of the terminal under impact is eliminated by requiring that the terminal housing itself be of a flexible material. The requirement that separation loads required to disconnect the terminal or connector be no more than one-half the failure load of the weakest wire is very important. If excessive loads are required to separate the terminal, then an energized wire might fail, thus creating a spark.

The load factor used in this section was derived as a result of research performed on aircraft wiring and fuel system connections. Utilization of this factor results in a separation load that is sufficiently high to preclude inadvertent separation of the connector and yet low enough to insure that the connector will separate before the wire fails under dynamic loading.

S3.5 Routing of Electrical Wiring. The purpose of this section is to insure that electrical wiring be located as far as possible from the exterior of the vehicle. It is realized that in all cases this will not be possible since all components requiring wiring cannot be located near the interior of the vehicle. Provision for such exceptions is made by providing additional length for wiring located near the exterior of the vehicle. This additional wiring, when secured by frangible clips, will allow for considerable structural displacement before subjecting the wiring to excessive loads.

The provision discouraging the routing of electrical wiring adjacent to flammable fluid lines is intended to prevent the current practice of routing fuel lines and electrical wiring in close proximity to each other. If the fluid lines and wiring are damaged, fuel and ignition sources would both be present in a small area. Ideally, the wiring would be routed as far as possible from the fluid lines so that the same impact would be less likely to damage both.

S3.6 Fusing. All motor vehicle electrical systems are presently provided with some type of overload protection in all except the high current circuits involving the battery, voltage regulator, starter motor and alternator/generator. This overload protection may take the form of circuit breakers, conventional fuses, or a fusible link. These overload protection devices are designed solely to protect the wiring and the component that it serves from damage due to circuit overloading. These devices should, therefore, be treated as any other electrical component and should be shielded accordingly. In addition, their actuation should not produce a spark which could cause ignition of volatile fumes.

S3.7 Inerting Devices. The provision for an inerting device which will activate during a crash impact or rollover to insure that the electrical system is de-energized is based on limited test data. Additional research and testing is required to accurately determine the acceleration environment required for actuation of these devices during a crash sequence, and insure against inadvertent actuation when exposed to normal vehicle operating conditions.

10. SUGGESTED PERFORMANCE CRITERIA FOR AUTOMOTIVE ELECTRICAL SYSTEMS

10.1 GENERAL

In Section 9 of this report a design guide was presented for crashworthy automotive electrical systems. In this section performance standards are recommended for such crashworthy electrical systems. These performance standards are presented in the form of a suggested motor vehicle safety standard.

To reduce testing costs and secure maximum data from each test it is recommended that the tests specified in this standard be conducted in conjunction with other compliance testing such as compliance testing for FMVSS 204, 301, 212 and others as they become available.

10.2 PROPOSED MOTOR VEHICLE SAFETY STANDARD NO._______ (Automotive Electrical System Integrity)

S1 Purpose and Scope

The purpose of this standard is to specify performance requirements for automotive electrical systems subjected to crash impact tests in order to reduce the crash fire ignition potential. The standard will apply to all passenger motor vehicles having a curb weight between 1000 and 6000 pounds.

S2 Definitions

Electrical Components - Devices in the automotive electrical system which produce, store, or utilize electrical energy in their normal operation.

Roll Angle - The angle between the vehicle lateral axis and a horizontal reference plane.

S3 Requirements

Automotive electrical systems must demonstrate the capability to retain their integrity during the following full-scale impact tests:

a. Frontal barrier impact at 30 mph

b. Rear impact with moving barrier at 30 mph

c. Side impact with moving barrier at 20 mph

d. Roll-over at 30 mph

In addition, the installed impact sensing device must demonstrate actuation in each of the above tests and be capable of restoring power to the electrical system following the test.

S4 Test Methods

A. Frontal Barrier Impact. The frontal barrier impact shall be conducted generally in accordance with the Society of Automotive Engineers Recommended Practice SAE J850.

B. Rear Barrier Impact Test. The rear barrier impact test shall be conducted generally in accordance with the Society of Automotive Engineers Recommended Practice SAE J972. The weight of the moving barrier employed in this test shall be adjusted to be within ±50 pounds of the weight of the car being tested.

C. Side Barrier Impact Test. The side barrier impact test shall be conducted generally in accordance with SAE Recommended Practice SAE J972 with the following exception. The flat frontal plate on the moving barrier will be replaced with a simulated pole of 18 inches diameter. This pole shall be a minimum length of 36 inches and mounted vertically such that the lower end is no more than 6 inches above ground level. The weight of the barrier shall be adjusted to within ±50 pounds of the car being tested.

D. Roll-Over Test. The roll-over test shall be conducted by mounting the vehicle to be tested on a sled. The vehicle shall be oriented at right angles to the direction of sled travel at a roll angle of 15 degrees in the direction of sled travel. The sled with the vehicle mounted on it will then be accelerated to the required impact velocity by towing or other suitable means. The sled will then be stopped by means of a padded barrier to allow the vehicle to be ejected from the sled and roll over.

S5 Pretest Preparation

The vehicle to be tested shall be inspected to insure that all electrical systems and components are installed and operational. Wiring and components located in the area of anticipated vehicle damage will be inspected to insure that no pretest damage exists.

The installed impact sensing device will be inspected to insure that it is properly wired and operational. The reset mechanism will be tested to insure that it is capable of restoring power to the system following actuation. The battery will be inspected and tested to determine the level of charge. The battery will be brought to full charge condition prior to test.

S6 Posttest Inspection

Immediately following the test a thorough inspection of all wiring and components located in the area of vehicle damage will be conducted. The results of this inspection will determine compliance or non-compliance of the electrical system with the provisions of this standard. The disclosure of any one of the following conditions during this inspection shall be considered grounds for a determination of non-compliance.

a. Damage to any electrical component and/or wiring which results in the exposure of electrical conductors. Separation of terminals or connectors will be allowed provided that such separation does not expose the energized portions of the connector or terminal to possible short circuiting. Damage to externally mounted light bulbs shall not be grounds for non-compliance.

b. Failure of the impact sensing device to inert the electrical system within 15 milliseconds of impact.

c. Failure of the impact sensing device to restore the electrical system through actuation of the manual reset mechanism following the test.