FUEL TANK PROTECTION

FINAL REPORT

PREPARED FOR

U.S. DEPARTMENT of TRANSPORTATION
NATIONAL HIGHWAY SAFETY BUREAU

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FAIRCHILD HILLER
REPUBLIC AVIATION DIVISION
FARMINGDALE, LONG ISLAND, NEW YORK

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Final Report

FUEL TANK PROTECTION

An Investigation of Fuel, Exhaust and Electrical Systems as Related to Post Crash Fire Safety

Contract No. FH-11-6919

Prepared for:

U. S. Department of Transportation
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CONTENTS

CONTENTS (Cont'd)

- The rear axle region, in front engined passenger vehicles, is usually crowded with the fuel tank, exhaust piping, and fuel line
- A problem arises in heavy trucks due to the large amount of fuel carried in vulnerable externally mounted, exposed tanks, the high temperature of the exhaust systems, and the proximity of the fuel and exhaust systems
- The compact arrangement of motorcycles and the almost total lack of engine exhaust shielding makes them subject to fuel/exhaust/electrical systems related fires
- An ideal fuel tank would have some of the characteristics of both plastic and metal
    - Very high distortional capability and high strength
    - Not corroded by environment or contents
    - Flexibility and integrity of functional connections
    - Non-sparking when ruptured by an object or abraded
- The fuel tank should be located so that it is separated from the engine
- Generally a fuel tank surrounded by a sturdy structure is safer than an unguarded tank
- Support and retention of the fuel tank may employ some of the following
    - Straps or clamps
    - Threaded hardware, straight, hooked or U bolts
    - Secondary structural tie members, longitudinal or transverse

  These items should have sufficient strength so that they do not fail abruptly under crash conditions.

TABLE 1-1. FUEL TANK PROTECTION STUDY DATA SURVEY

U.S. Manufactured Automobiles (13)-1966, 1967, 1968

American Motors
Buick
Cadillac
Chevrolet
Chrysler
Dodge
Ford
Imperial
Lincoln
Mercury
Oldsmobile
Plymouth
Pontiac

Imported Automobiles (12)-1967, 1968

Datsun
English Ford
Fiat
Mercedes-Benz
MG
Opel
Renault
Rolls-Royce
Toyota
Triumph
Volkswagen
Volvo

U.S. Manufactured Trucks (9)-1967, 1968

Chevrolet
Dodge
Ford
G. M. C.
International
Jeep-Universal
Jeep-Truck
Mack
White

U.S. Manufactured Busses (2)-1967, 1968

Flxible
G. M. C.

Motorcycles (8)-1967, 1968

BMW
BSA
Harley Davidson
Honda
Lambretta
Suzuki
Triumph
Yamaha

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

TABLES

SECTION I

INTRODUCTION, CONCLUSIONS, AND RECOMMENDATIONS

A. INTRODUCTION

The statistical percentage of fire occurrences in accidents involving automobiles is a very small proportion of the total destructiveness resulting from all types of car collisions. Published data, References 1-1 and 1-2, indicate that fire occurs in less than one-half of one percent of passenger vehicles involved in injury producing collisions. Nevertheless, fire in automobiles constitutes a hazard that is responsible for more deaths than the lives lost in all types of commercial aircraft accidents annually.

In the desire to reduce the risk of injuries and fatalities due to motor vehicle crash fires, the U.S. Department of Transportation, Federal Highway Administration, awarded Contract FH-11-6919, titled "Fuel Tank Protection Study," to the Republic Aviation Division of Fairchild Hiller Corporation. The general requirements of the contract were to collect and analyze the mechanical features of the fuel systems of 1966 through 1968 models of domestic passenger cars and 1967 through 1968 models of those foreign passenger cars having 10,000 or more vehicles per model year in operation in the USA. The identical and/or equivalent information was to be accumulated for trucks and motorcycles for 1967 and 1968 model years where 10,000 or more vehicles per model year are in operation, and for integral busses for 1967 and 1968 model years where 500 or more vehicles per model year are in operation. In addition, features of the electrical systems and the engine exhaust systems of the above vehicles were to be collected and analyzed. The collection would include illustrated examples of the fuel system, the electrical system and the exhaust system.

For the study, the salient features of each of these systems are identified for ready reference for use in the analysis of post crash fire safety as related to the design features involved. The documentation produced considers and provides for an updating of the data for each succeeding year. This is followed by additional analyses of the possible interactions of the fuel system with the electrical and/or the exhaust systems.

Available data from the performance of this study is expected to provide a basis for the recommendation of minimum performance standards for the fuel, electrical, and exhaust systems. The fuel system recommendations are to be applicable to federal standards such as Motor Vehicle Safety Standard No. 301 covering fuel tanks, fuel tank filler pipes, and fuel tank connections. The performance standards recommended are considered reasonable, practical, and appropriate for near-term implementation. These performance standards are priority rated based on considerations of crash fire hazard reduction at an acceptable cost benefit level to the consumer. Table 1-1 lists the specific manufacturers of the vehicles for which data was collected.

Engineering and service manuals provided the foundation of the necessary material. In addition, extensive reference was made to data obtained from automotive trade associations and trade publications. Finally, examples of the representative motor vehicles were obtained for individual inspection of their physical characteristics. Significant findings from these examinations, added to the conclusions drawn from the reference material, form the basis for the criteria for post crash fire safety standards.

The opinions, findings and conclusions expressed in this publication are those of the authors and are not necessarily those of the National Highway Safety Bureau.

B. CONCLUSIONS

The following are some of the conclusions reached after studying the fuel/ exhaust/electrical systems as they relate to post crash fires.

- The principle cause of post crash fire is generation of vapor by unconfined fuel

- The fuel system itself may be directly disrupted (e.g., vehicle underride impacting fuel tank), with resultant free flammable vapor

CONTENTS (Cont'd)

ILLUSTRATIONS

- The fuel tank vent presents the following problems to fuel tank leakage in post crash fires
    - Fuel spillage through vent during rollover
    - Impact-caused fuel surge out of vent
    - Breakage of vent connection by impact
- In passenger vehicles, the filler pipe assembly usually terminates at the exterior of the vehicle and the tail pipe may be under and close to the filler cap
- In passenger cars, the fuel line to fuel pump is usually metal but flexible hose connections with clamps are used at tank pickup and fuel pump. Flexible hose connections may be broken by crash impact
- The fuel line is clip-supported to frame members. Crash-caused frame failure may break the fuel lines
- The exhaust system front piping is usually well separated from the fuel system components, but the rear pipes and sound absorbers may run in proximity to the fuel line and terminate close to the tank
- Fuel spillage during impact may be accompanied by electrical sparking from any of the three unprotected, heavy current battery circuits or any of the other protected electrical circuits
- The location and/or design of some fuel system components are conducive to hot manifold ignition of fuel upon impact
- The fuel tank should be so designed and located to minimize hazards to the occupant compartment upon impact
- Automatic transmission fluid surging through filler pipe under crash decelerations may cause an engine compartment fire if filler is located in proximity to exhaust manifold

C. ELEMENTS FOR CONSIDERATION IN FORMULATING POST CRASH FIRE SAFETY STANDARDS

The development of performance criteria and the elimination of hazardous features in the fuel/exhaust/electrical system is suggested with consideration for the effort, time, and costs needed to implement the recommendations.

Environmental, hydrostatic pressure, and dynamic loading tests would be effective in evaluating the fuel/exhaust/electrical system construction.

These tests and the following vehicle modifications would contribute to the safety and reliability of the fuel/exhaust/electrical systems.

- Warning placards mounted in areas where vehicle modification should not be performed
- Grommets installed in holes where fuel line or electrical wires pass through structural members or body metal
- Fuel shut-off valve incorporated into the fuel pickup unit
- Position of fuel tank accessory connections away from exhaust system components
- Strengthening of fuel line and retention devices
- Improvement in electrical wire groupings and incorporation of retention devices
- Adjusting the length of the fuel line and electrical wires so that they circumvent hazardous areas
- Incorporating a rear firewall to protect the passenger compartment
- Standardized bumper heights to prevent underride by striking vehicle

D. RECOMMENDATIONS FOR FUTURE PROGRAMS

As design improvements increase the integrity of the passenger compartment, the occupant will be provided with additional safety during impact and the capability to egress after impact, thus resulting in less fatalities. Post crash fire would therefore become the prime detriment to safe occupant removal from a vehicle.

For this reason, fire statistics should be continuously collected and analyzed, and new model vehicles should be surveyed and evaluated for crash fire safety characteristics.

A test program should be developed to determine the actual performance of existing vehicles, components, and subsystems and for evaluating new and proposed improvements.

E. REFERENCES

1-1 "New York State Safety Car Program - Prevention of Crash Fire Injury in Automobiles," Fairchild Hiller, Republic Aviation Division Report No. 3040-9, 2 June 1967.

1-2 "Investigation of Motor Vehicle Performance Standards for Fuel Tank Protection," Fairchild Hiller, Republic Aviation Division Report No. PD 070R-5002, 29 September 1967.

SECTION II

STATEMENT OF POST CRASH FIRE HAZARDS

A. FUEL SYSTEM

1. Introduction

The average quantity of fuel contained in the tank of a typical U.S. passenger vehicle has been assumed to be eight gallons. At approximately 116,000 BTU/gallon gasoline,* eight gallons of fuel have a potential energy of approximately 928,000 BTU or 720 million foot pounds. Automotive fires involving the fuel system may readily cause damage to life and property.

2. Fuel System Components

The fuel system is considered to comprise all parts from the filler cap through the tank, fuel line, fuel pump, and carburetor to the carburetor mounting pad on the engine and such auxiliary details as vent lines and fuel return lines.

3. Fire Hazards

The appreciable quantity of low viscosity, flammable, and volatile liquid fuel of high specific potential energy presents the prime hazard. Any of the components of the fuel system may suffer loss of fluid retention capability from various crash effects as follows:

1) Direct Impact Loading - Shock or impact loading rupturing structure of fuel tank, filler pipe or connection, fuel line or connection, pump housing or carburetor body.

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* 20,000 BTU/lb heating value - medium grade, 0.70 specific gravity gasoline:-

$$20{,}000 \times 0.70 \times \frac{231}{1728} \times 62.4 \approx 116{,}783 \text{ BTU/gallon gasoline}$$

2) Indirect Impact Loading - Shock or impact loading, breaking supports, fastenings, or anchorage of fuel system component(s), and secondary impact of component(s) against another part of the vehicle.

3) Gross Deformations - Distortion or displacement of vehicle structural or mechanical parts.

4) Rollover - Overturn with spillage from fuel tank vent or carburetor vent.

5) Secondary Collision Effects - Exposed portions of fuel system impacted by accessories, transported articles, or broken, detached vehicle parts acting as random missiles.

4. Cause of Combustion

Spillage of fuel or the presence of fuel vapor may result in fire. Liquid fuel contacting hot components or exposed to sparking of electrical or mechanical origins may result in combustion. Many undefinable variables enter into the triggering of fire.

B. EXHAUST SYSTEM

1. Exhaust System Components

The exhaust system is considered to comprise the parts from exhaust manifold(s) connection(s) through to the tailpipe exits.

"V" type or opposed bank engines may use either single (with a crossover connection) or dual exhaust systems. The basic components of any exhaust system consist of the front pipe, muffler, and tail pipe. Intermediate pipes or resonators may be standard or optional additional components. Brackets, clamps, and other hangers, rigid or elastic, are used to attach the exhaust system to the vehicle underbody.

2. Fire Hazards

a. Non-Crash Conditions

Delayed ignition in the engine, or "after burning" as it is sometimes termed, can produce active combustion in the exhaust system. If the combustion is rapid, the pressure and temperature rise may be explosive in effect with possible disruption of exhaust system components or connections. The probability of fire from this non-crash malfunction is low. However, the combination of spilled fuel, plus flame from a crash damaged exhaust system, may cause a fire.

b. Crash Conditions

The underside of an automotive vehicle is free from combustible construction materials. Displacement, disassembly, or fragmentation of hot exhaust system components in a crash could start a fire only if heated exhaust debris could penetrate vehicle spaces which contained combustibles. The probability of such an occurrence is low. There is no statistical evidence relating to the presence of vehicle undercoating as a factor contributing to crash fires.

C. ELECTRICAL SYSTEM

1. Storage Battery

The storage battery of an automotive vehicle, having the greatest energy in the electrical system, possesses the system's highest capacity to cause fires if displaced. shorted, or otherwise disturbed by crash damage. Vehicle battery ratings vary from 10 to 200 ampere hours at 20 hour standard (motorcycle to heavy passenger vehicles or trucks) and 6, 12, or 24 volts (Reference 2-1). A short circuit for a short time interval can result in a high amperage battery discharge. High current discharge will produce excessive gas evolution in the battery. The hydrogen-oxygen mixture is explosive, and sparking or arcing near the battery may easily produce an explosion - which in turn may provide the ignition for a more sustained fire. If the short circuited battery should be in proximity to combustibles, other than fuel, subsequent to an accident, the intensity of the heat caused by excessive current may start a fire.

2. Wiring

The complexity of the wiring in passenger or cargo vehicles, with little protection against intrusive or structural deformation damage to conductors or components, constitutes a continuous hazard for electrical failure; however, most of the circuits are protected by fuses, fusible links, or circuit breakers. The unprotected circuits, unfortunately, are the heavily loaded ones; battery to ignition, battery to starting motor, alternator (or generator) to battery.

3. Electrical System Rating

The electrical system of automotive vehicles, unless the vehicle is for special use (explosives carriers, etc.) may be considered as inherently inferior to approved aircraft, marine, industrial, commercial, or residential systems; however, fires of electrical origin will usually not occur without severe crash damage which causes breakage, separation, or severe insulation abrasion. The electrical system relies, to a great degree, on the vehicle structure for physical support.

D. INTERACTION OF SYSTEMS CONTRIBUTING TO POST CRASH FIRE HAZARDS

1. Inherent Fire Hazard of Fuel

The liquid fuels used in automotive vehicles constitute the prime fire hazard. The principal source of post crash fire is the generation of flammable vapor by unconfined fuel.

2. Structural Deformation Effects

The fuel system itself may be directly disrupted by crash effects, with resultant free flammable vapor. But structural distortion or severance of a structural component may result in failure of the fuel system by transmittal of impact loads through items in the structure which normally secure and support the fuel system components. If the structure cannot absorb crash energy without disruption or severance of fuel system components, the structure has definitely increased post crash fire hazard.

3. Hazardous Design Features

The general arrangement and details of the various systems comprising automotive vehicles can increase the hazards that ensue after crash. Examples of design problems are the exposed location of the fuel tank and its immediate accessories, flimsy mounting hardware, and proximity of fuel system components to sharp profiled structural or mechanical parts.'

4. Fuel and Exhaust System Interaction

The possible post crash spatial relations of the exhaust system components relative to fuel system components are factors in fire hazard. An easily crushable muffler or resonator may serve as a cushion when a displaced fuel tank strikes it, or a connection flange may act as a piercing tool to rupture the tank at crash. The exhaust system becomes heated during vehicle operation. The possibility exists that a fire may be started by fuel spilling on hot components of an exhaust system, subsequent to a crash, or that a fire may be kindled by hot exhaust components contacting combustible vehicle items or cargo; but the probability is low. Combustible materials, in the presence of air, if heated sufficiently, will ignite even without spark or flame. The temperature at which ignition occurs is termed the autogenous ignition temperature. For gasoline, this temperature is approximately 500°F; for diesel fuels, it is approximately 600°F.

5. Fuel and Electrical System Interaction

Malfunction of the electrical system, combined with fuel spillage, under crash conditions may result in a fire. The soundness of the electrical system also depends on the structural stability of the vehicle, as well as on its own electrical adequacy.

In some vehicles electrical wiring is in proximity or in contact with a fuel line. Abrasion may cause weakening of the electrical insulation or fuel line during normal operation, and crash effects may result in insulation breakdown accompanied by fuel leakage.

The interrelation of fuel system/electrical system/structure is always a factor.

E. REFERENCE

2-1 "Storage Batteries," Society of Automotive Engineers Standard No. J537d, December 1966.

SECTION III

EVALUATION OF SPECIFIC DESIGN FEATURES FOR POST CRASH FIRE PROTECTION

A. FUEL SYSTEM

1. Problem Areas

a. Fuel Tank and Accessories

The fuel tank, as a prime source of fire, presents an array of problems relative to post crash fires. Fire prevention is affected by the following items:

- Capacity
- Material type, thickness, and coating
- Construction method
- Location
- Support and retention
- Filler arrangement and location
- Vent arrangement
- Fuel pickup and metering unit
- Structural protection

Usual fuel tank capacities for different types of vehicles are approximately as follows:

Motorcycles	2 to 5 gallons
Passenger vehicles	15 to 25 gallons
Trucks - main tank	40 to 70 gallons
Trucks - reserve tank	15 to 25 gallons
Trucks - small types	15 to 25 gallons
Motor Busses - city or school*	20 to 30 gallons
Motor Busses - intercity*	75 to 175 gallons

*"Nomenclature - Truck, Bus, Trailer" Society of Automotive Engineers Standard No. J687b, August 1967.

The varying fuel tank capacities for the different vehicle types are determined by the principal service demands of these types. Although it is obvious, it must be stated that the more fuel carried by an accident involved vehicle, the greater the fire hazard.

An ideal material for fuel tanks as presently manufactured would have the following characteristics:

- Very high distortional capability and high strength
- Not corroded by environment or contents
- Not easily flammable
- Non-sparking when impacted by an object or abraded
- Electrically non-conductive

High strength metals have low ductility. Reinforced plastics are weaker than steel or aluminum alloys. The ideal cannot be attained, but the use of functional, safe material or combination of materials is within reach.

With the exceptions of the fiberglass reinforced plastic used in the Corvette optional 36 gallon fuel tank and in some special tanks for motorcycles, passenger vehicle fuel tanks are made of soft steel sheet, usually 0.024 inch thick (24 gauge), terne coated. This steel, after forming and assembly, has the following approximate mechanical properties:

Yield point - 30,000 lb/sq in.
Ultimate - 40,000 lb/sq in.
Elongation - 30% in 2 inch length

Soft steel sheet is capable of withstanding large permanent deformation before rupturing. High impact loading, if distributed over a reasonable area, will not easily destroy the tank's integrity. This is a plus for fire prevention; however, if the impact is confined to a small area, the thin sheet may be penetrated.

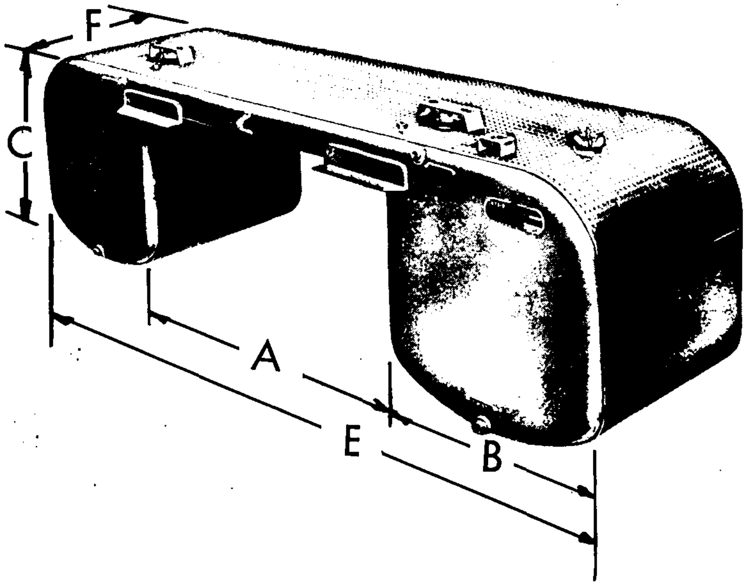
Small trucks use fuel tanks of the same or slightly thicker terne sheet as used in passenger vehicles. The larger capacity fuel tanks used in heavy trucks or tractors are usually made of formed steel sheet up to 0.135 inch thick (10 gauge). The most common thicknesses are 0.075 (14 gauge) or 0.105 inch (12 gauge). Since the tanks may act as steps, checkered or diamond patterned steel plate is sometimes used for primary construction or as external reinforcement. Various protective coatings may be used internally and externally. Aluminum sheet, alloy 5082 and similar alloys up to 0.125 inch thickness are also used instead of steel.

Bus fuel tanks are modifications of truck tanks. Capacity is according to service requirements and the weight of metal used is compatible with capacity; 0.105 inch thickness steel is the most frequently used. The materials used are selected for their strength and corrosion resistance (Table 3-1).

Small fuel tanks are made of two pieces of sheet metal, stamped to form flanged pans with stiffening beads or corrugations. Continuous seam welding is used for assembly. The major problem is to make the tank fluid tight. Another problem, as related to crashworthiness, is to make the tank sufficiently stiff for service stability, but to maintain fluid retention capability during crushing. Small bend radii, extreme drawing depth, and other forms of stress raisers add to the weakness of thin metal tanks.

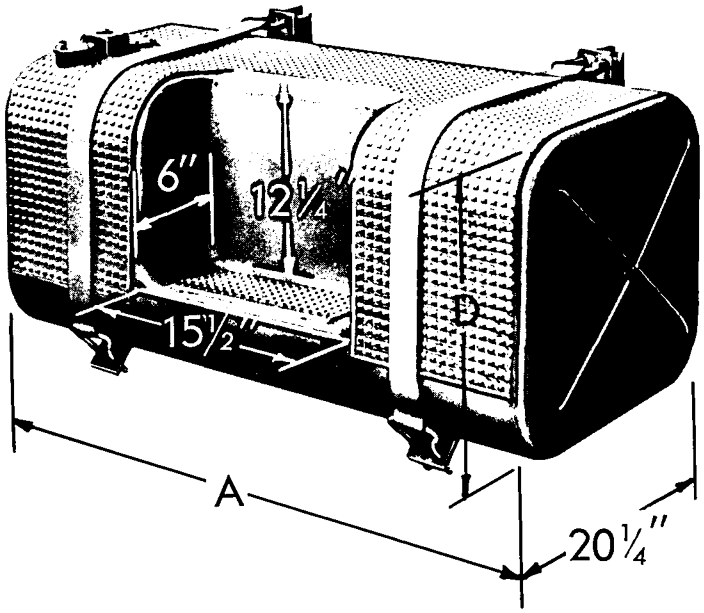
The larger fuel tanks used in heavy trucks and busses are usually cylindrical or rectangular in shape. Continuous seam welding is used for fabrication.

Typical truck fuel tanks, as manufactured by Snyder Tank Corporation, Buffalo, N.Y.,are shown in Figures 3-1 through 3-5.



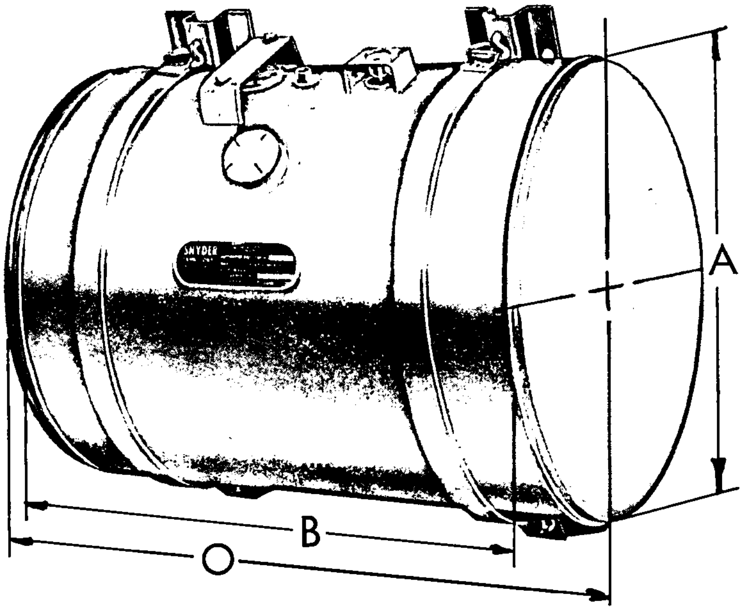
Model No.	Total Cap. ICC Gal.	DIMENSIONS				
		A	B	C	E	F
90A	90	37¾	20½	24	78¾	22
90B	90	45½	20½	24	86½	22
106A	106	37¾	20½	24	78¾	26
106B	106	45½	20½	24	86½	26
125A	125	37½	24⅝	25¾	86¾	24
125B	125	45¼	24⅝	25¾	94½	24
135A	135	37½	24⅝	25¾	86¾	26
135B	135	45¼	24⅝	25¾	94½	26
145A	145	37½	24⅝	25¾	86¾	28
145B	145	45¼	24⅝	25¾	94½	28

Figure 3-1. Steel Saddle Tanks



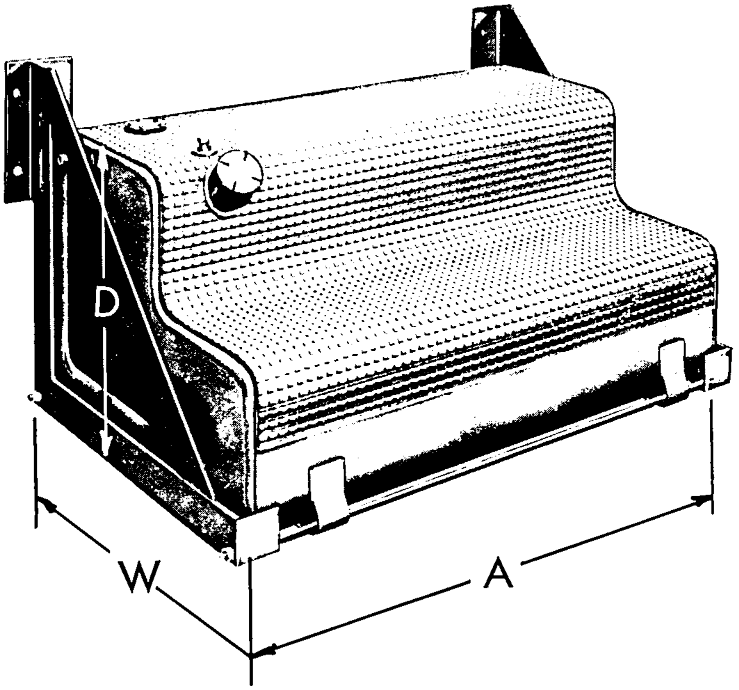
Steel Model No.	Aluminum Model No.	Cap. ICC Gal.	DIMENSIONS A	DIMENSIONS D	Steel or Alum. Tank Bracket Ref.
CS-1740	ACS-1740	40	36	17	RTB-18
CS-1750	ACS-1750	50	43	17	RTB-18
CS-1760	ACS-1760	60	50	17	RTB-18
CS-1770	ACS-1770	70	57	17	RTB-18
CS-1840	ACS-1840	40	33	18	RTB-19
CS-1850	ACS-1850	50	40	18	RTB-19
CS-1860	ACS-1860	60	47	18	RTB-19
CS-1870	ACS-1870	70	55	18	RTB-19
CS-1880	ACS-1880	80	61	18	RTB-19

Figure 3-2. Center Step Tanks - Steel and Aluminum



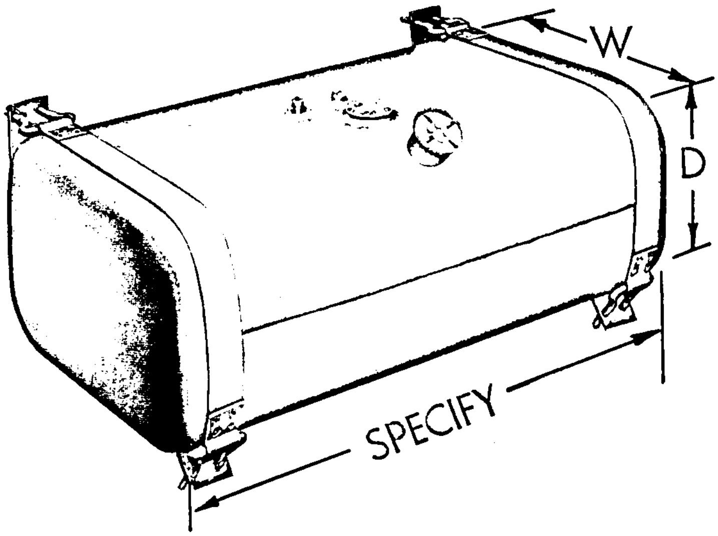
Model No.		Cap. ICC Gal.	DIMENSIONS			Steel Bracket Ref.	Alum. Bracket Ref.
Steel	Alum.		A	B	O		
UR-1828	——	30	18	28	33	CTB-18	——
UR-1836	——	40	18	36	41	CTB-18	——
UR-2028	AUR-2028	40	20	28	33¼	CTB-20	ALCTB-20
UR-2036	AUR-2036	50	20	36	41¼	CTB-20	ALCTB-20
UR-2230	AUR-2230	50	22	30	36¼	CTB-22	ALCTB-22
UR-2236	AUR-2236	60	22	36	42¼	CTB-22	ALCTB-22
UR-2426	AUR-2426	50	24	26	33	CTB-24	ALCTB-24
UR-2430	AUR-2430	60	24	30	37	CTB-24	ALCTB-24
UR-2436	AUR-2436	70	24	36	43	CTB-24	ALCTB-24
UR-2452	AUR-2452	100	24	52	59	CTB-24	ALCTB-24

Figure 3-3. Universal Cylinder Tanks - Steel and Aluminum



Model No.	Total Cap. ICC Gal.	DIMENSIONS			Bracket Reference
		A	D	W	
FS-3	40	29	18	24	FSB-3
FS-5	50	37	18	24	FSB-5
FS-7	60	44	18	24	FSB-7
FS-9	70	51	18	24	FSB-9
FS-10	30	33	12¼	24¼	FSB-10
FS-12	40	43	12¼	24¼	FSB-12
FS-17	40	34¼	15	24	FSB-17
FS-19	50	42¾	15	24	FSB-19
FS-21	30	41½	12¼	20¼	FSB-21
FS-22	35	48½	12¼	20¼	FSB-22

Figure 3-4. Steel Fuel Step Tanks



Head Model No.	ICC Gal. Per 1" Length	Head Dimen. D	W	Bracket Reference
1016U	.676	$10\frac{1}{4}$	$16\frac{3}{8}$	RTB-1464-1
1018U	.741	$10\frac{1}{8}$	$18\frac{1}{8}$	RTB-1464-2
1019U	.775	$10\frac{1}{16}$	$19\frac{1}{16}$	RTB-1464-3
1117U	.814	$11\frac{1}{2}$	$17\frac{1}{2}$	RTB-1464-14
1214U	.731	$12\frac{1}{2}$	$14\frac{1}{2}$	RTB-1464-13
1320U	1.014	$12\frac{15}{16}$	$20\frac{1}{8}$	RTB-14
1315U	.792	$13\frac{1}{16}$	15	RTB-1464-4
1323U	1.227	$13\frac{1}{2}$	$23\frac{1}{8}$	RTB-15
1328U	1.435	$12\frac{5}{8}$	$27\frac{7}{8}$	RTB-1464-10
1425U	1.518	$13\frac{15}{16}$	$24\frac{15}{16}$	RTB-1464-9
1525U	1.457	$15\frac{1}{8}$	$24\frac{7}{8}$	RTB-24
1621U	1.354	$15\frac{15}{16}$	$20\frac{7}{8}$	RTB-1464-5
1623U	1.516	16	$23\frac{1}{4}$	RTB-1464-6
1624U	1.559	$15\frac{7}{8}$	$24\frac{3}{4}$	RTB-1464-7
1627U	1.758	16	$27\frac{1}{4}$	RTB-1464-12
1720U	1.331	$16\frac{13}{16}$	$20\frac{1}{16}$	RTB-18
1724U	1.586	16	$23\frac{3}{4}$	RTB-17
1820U	1.418	$17\frac{13}{16}$	$20\frac{1}{8}$	RTB-19
1826U	1.922	$18\frac{1}{2}$	26	RTB-20
1919U	1.512	$19\frac{7}{8}$	$28\frac{5}{8}$	RTB-21
1929U	2.210	$18\frac{7}{8}$	$28\frac{5}{8}$	RTB-1464-11
2123U	2.019	$21\frac{1}{4}$	$23\frac{3}{4}$	RTB-22
2424U	2.263	$23\frac{3}{4}$	$23\frac{3}{4}$	RTB-23

Figure 3-5. Universal Rectangular Tanks - Steel and Aluminum

TABLE 3-1. SCHOOL BUS TANK DATA (REFERENCE 3-1)

Application	Approx. Capacity (gal)	Material	Approx. Weight (lb)	Approx. Cost ($)	Corrosion Resistance	Safety Type Tank
Used currently	30	20-18 gauge terne plate	35	20.00	fair	no
Used sometimes	30 to 60	14-12 gauge hot rolled steel	30 to 60	24.00 to 29.00	poor	yes
Used seldom	30 to 60	12-10 gauge aluminum	35 to 100	40.00 to 52.00	good	yes

It is preferable to locate the fuel tank so that it is physically separated from the engine. Passenger vehicles and busses usually have the fuel tank outside of the occupant's compartment. Motorcycle fuel tanks are placed above the engine, and like all other items, are close to the passengers, so that there is extreme fire hazard, mitigated only by the lack of vehicle enclosure. Trucks frequently carry fuel tanks in the cab. These cab mounted tanks are sometimes the main tanks, as in medium trucks, and the reserve tanks in large trucks. Most small trucks have the fuel tank inside the frame at the rear.

Large truck and truck tractor main fuel tanks, shown in Figures 3-1 through 3-5, are located at the sides of the vehicle near the cab, or behind the cab.

The fuel tank in passenger vehicles is usually positioned so that the passenger compartment separates the tank from the engine. The fuel tank is in the rear trunk compartment for front engined vehicles and in the front compartment for almost all rear engined vehicles. Several makes of station wagons mount the fuel tank outside the left side frame members. They are externally shielded only by the body metal of the left rear wheel housing and the quarter panel. Such fuel tanks have little protection and are highly susceptible to damage in rear side impacts.

Placing the fuel tank inside the passenger vehicle frame does not, in some instances, result in protection against crash, since sharp mechanical or structural components in proximity to the tank may, with little relative displacement, crush or penetrate the tank. In general, a fuel tank surrounded by sturdy structure is usually safer than an unguarded tank.

The fuel tank in busses is usually located under the passenger compartment. Most coaches of current manufacture use rear mounted engines and the fuel tank is positioned ahead of the engine compartment and suspended from the vehicle underbody. The shielded location of the fuel tank affords protection against most crashes. However, the presence of many persons in the vehicle and the tank location under the passenger compartment increases the danger of possible injuries and fatalities from fire.

Support and retention of the fuel tank may employ some or all of the following:

- Straps or clamps
- Threaded hardware, straight, hooked, or U bolts
- Secondary structural tie members, longitudinal or transverse

These items should have sufficient strength so that they do not fail abruptly under crash conditions. Again, energy absorption capability under dynamic loading must answer the problems of crash impact. Failure of supports can cause tank rupture by impact or severance of filler pipe and fuel line connections.

The filler assembly starts the problems of post crash fire. The integrity of the filler pipe and its connection to the fuel tank subsequent to crash is dependent on many variable circumstances of accident phenomena as well as the design. The filler cap is near the external body metal or completely exposed. The short flexible hose connections used on many passenger vehicles are susceptible to severance if the filler pipe is displaced. Whatever the location of the filler cap may be, it is generally on or near the exterior of most vehicles and its crash resistance to direct impact is very low. Some vehicles with the fuel tank safely inside a vehicle compartment may have the filler assembly vulnerable to exterior or interior impact damage.

The venting of the fuel tank is essential for fuel flow. The vent presents fuel leakage problems relative to post crash fires that are as follows:

- Rollover and fuel spillage through vent
- Impact-caused fuel surge out of vent
- Breakage of vent connection by impact

Any of the above may generate fuel vapor sufficient in quantity and concentration to support combustion ignited by such sources as sparks from abraded metal, electric short circuits, or hot metal.

Fuel pickups and metering units are subject to damage because of their exposed location. Since the fuel gauge is electrically operated, the wiring which is close to the fuel line at the pickup adds an electrical hazard to the fuel system. The fuel line (and the return line provided in some vehicles) usually has a clamp-secured flexible hose at each end connected to the double wall, metal tubing fuel pipe. Crash damage resulting in displacement may separate the connection, allowing heavy fuel spillage. Fire may then follow from the sources previously mentioned.

The vehicle structure, by its configuration and strength, may prevent or reduce direct impact effects on the fuel tank. Externally mounted large fuel tanks, such as those used on large trucks, are freely exposed to direct impact. According to the September 1969 issue of Traffic Safety magazine, published by the National Safety Council, fuel tanks crushed in collision is the second largest cause of all truck fires.

Some vehicles have the fuel tank inside a luggage compartment with ample crush space; yet severe damage and fire may result from crashes because the vehicle structure is fragile, and massive structural deformation permits tank disruption.

A large conventional front-engined, rear-positioned fuel tank passenger vehicle, designed with heavy framing and broad, sturdy bumpers, may suffer severe tank damage in some cases of rear end collision. Sudden braking can cause "nose dive" with front end dropping and rear end rising. Two vehicles colliding at this attitude may have the front of the second vehicle diving under the rear of the first and directly striking the rear and underside of its now exposed and vulnerable fuel tank. In this case, the weight distribution/suspension characteristics have worked to nullify the good design features of the structural arrangement.

b. Fuel and Return Lines

The fuel line and, where a vehicle is so equipped, return line, present fewer problems than the fuel tank relative to post crash fire. Breakage of the line or separation at connections will result in fuel spillage and possible danger of fire.

Passenger vehicles depend on the vacuum created by the fuel pump or injector assembly for transfer of fuel through the fuel line. Fuel line breakage or separation will usually allow only limited fuel spillage in the case of passenger vehicles if there is no siphoning. The motorcycle fuel line gravity feeds fuel from tank to carburetor and a line break will result in rapid spillage flow. A hot engine may then start a fire.

> "No fuel system on a motor vehicle shall be so constructed as to permit gravity or syphon feed direct to the carburetor or injector."
>
> (Reference 3-2)

This safety regulation is applicable to motor carriers; busses, trucks and truck tractors as designed, manufactured and used in normal operation. It does not apply to passenger vehicles or motorcycles.

The fuel line in passenger vehicles, trucks and busses is tied to structural members by various types of clips. The comparatively short spans of the line act to prevent breakage under impact and so reduce chances of fire. Proximity to exhaust system components may increase fire hazard at crash.

The truly critical portion of the fuel line is at the flexible hose connecting the line to the fuel pump or injector in the engine compartment. Ambient temperature there may be about 160°F. Temperature may decrease the resilience of the hose and impact may then cause failure.

c. Fuel Pump

The fuel pump on most USA manufactured passenger vehicles is rocker arm driven by crankshaft cam actuation. A few USA and foreign manufactured vehicle fuel pumps are electric powered submerged types.

In general, fuel pump bodies are made of zinc alloy die castings of medium strength with low shock resistance. The fuel pump is usually located at the side of the engine block toward the front of the compartment. Crash fire hazard from fuel pump failure is low.

Fuel injection pumps are alloy steel, high pressure, precision accessories. Their material and design features make them highly shock resistant and their contribution to crash fire hazard is extremely low.

d. Fuel Delivery Line to Carburetor and Fuel Lines to Injector Nozzles

Most vehicles use a direct steel tube, fuel delivery line from pump discharge to carburetor inlet. A few fuel systems have a fuel filter between the fuel pump and carburetor with clamp-secured flexible hose connectors. The pump discharge pressure is low, ranging from 3 to 5 psig. The line runs closely around and over the engine block in a comparatively hot area. The usual line location creates a fire hazard in case of leakage or line failure. Crashes that cause severance of this line will send fuel spraying onto the engine block with a high probability of fire.

The fuel distribution lines that run from injection pump to injector nozzles may be low or high pressure lines. On injection type gasoline engines the pressure is approximately 10 psig. Diesel engines use distillate or other less volatile fuels which are delivered to the injector nozzles at approximately 2300 psig in most diesel engine types. General Motors diesel engines combine the fuel injection pumping with the individual injection nozzles, so that there is no high pressure fuel piping in this system. The high pressure piping will, if broken, furnish fuel to start a fire.

It must be emphasized that the final fuel delivery lines are relatively immune to crash damage, and unless broken, their potential for contributing to crash fires is low.

e. Carburetor

The carburetor is one of the most complex components of an automotive vehicle. By malfunction it may flood or leak, spilling fuel over a hot engine; or it may be disrupted by backfire with loss of integrity. But in crash situations its location shields it from most impacts, so that its probability of starting fires is low. However, in rollover, the vents and openings may permit fuel spillage from normally safe functional passages.

f. Conclusion

It must be noted that as long as liquid fuel is in the liquid state, ignition is difficult. When fuel vapor and air mixtures are formed, the flammability is high.

Federal Motor Safety Standard No. 301 limits fuel spillage at and after test impact. Quoting the pertinent paragraph from this standard

> "S4. Demonstration procedures. A front end longitudinal barrier collision test shall be conducted at a speed of at least 30 miles per hour in accordance with Society of Automotive Engineers Recommended Practice J850, "Barrier Collision Test," February 1963."

This test is considered unrealistic, since it is a frontal impact test and bears little relation to the effects of vehicle-to-vehicle rear end collision at superhighway operating speeds.

2. Examples of Current Practice

The previous descriptions have covered fuel system arrangements from the viewpoint of post crash fire hazard problems. As part of this study, various vehicles were examined. Brief descriptions and photographs showing desirable and undesirable fuel system features of some of the vehicles follow:

a. 1967 American Motors Rambler

The metal fuel supply and return lines are protected by rubber sleeving as they pass between the transverse transmission support member and the floor pan (Figure 3-6).

The fuel supply line incorporates a flexible hose at the end of its run to the fuel pump. Figure 3-7 shows the undesirable characteristic of a flexible hose passing between the distributor and the engine block. However, in the same illustration, the metal line which carries the fuel pump discharge to the carburetor inlet is well-formed to run to the top of the cylinder head, then forward before it turns and goes around the coolest part of the engine to terminate at the carburetor.

b. 1967 Buick Riviera

This vehicle has flexible hose fuel lines running through a punched hole in a structural member. Grommets, to act as cushions, would prevent cutting of these fuel lines in a crash or abrasive deterioration during normal operation. Figure 3-8 shows the fuel supply and return lines as viewed from below, looking toward the rear of the vehicle.

c. 1966 Cadillac Coupe de Ville

Figure 3-9 is an illustration of the filler pipe as it passes through the rear frame rail, using a flexible hose connector. Rear impact, causing transverse deformation of the rear rail, could break the connection. These illustrations also show the two longitudinal straps that adequately support the fuel tank.

Figure 3-10 shows the cushioning sleeves that protect the fuel line as it is routed forward of the rear axle.

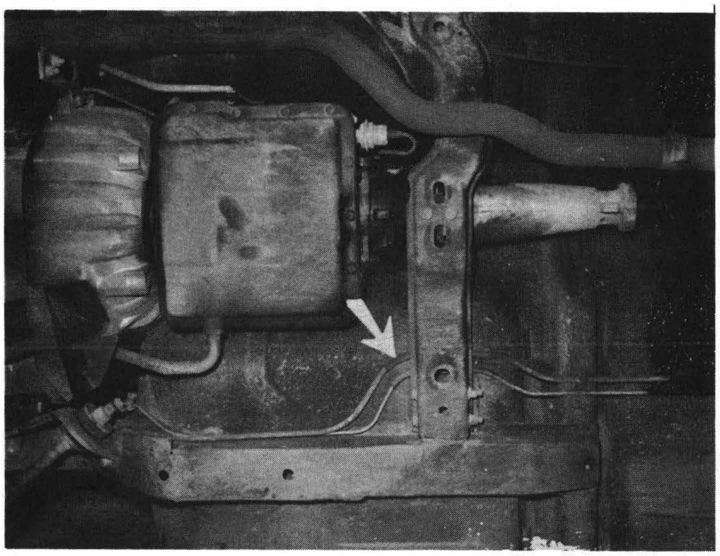


Figure 3-6. 1967 Rambler Fuel Line Routing at Transmission

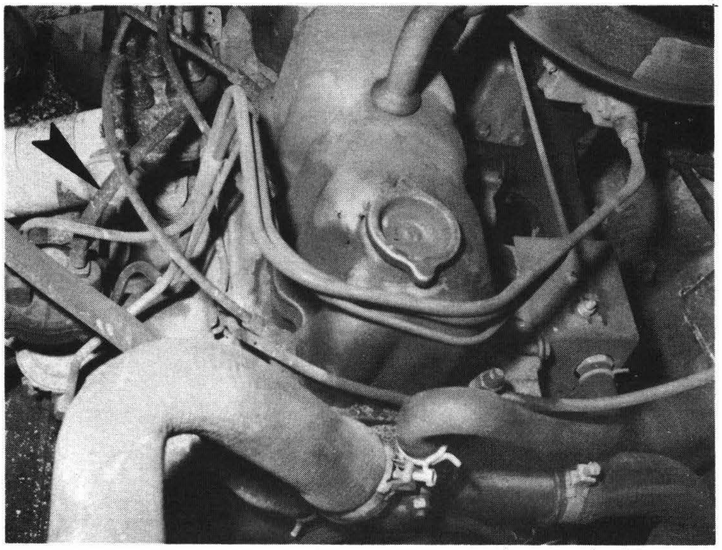


Figure 3-7. 1967 Rambler Fuel Line Routing at Engine

Figure 3-8. 1967 Buick Riviera Fuel Line Passing Through Structural Member

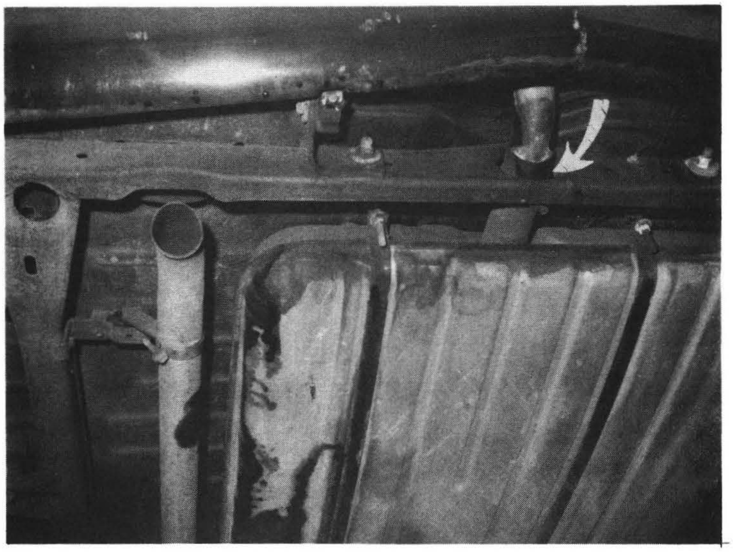


Figure 3-9. 1966 Cadillac Coupe de Ville Filler Pipe Passing Through Structural Member

Figure 3-11 shows two undesirable features. The flexible hose of the fuel line passes between the oil pan and the A-frame. Displacement could pinch the hose. Also, the metal fuel supply and return lines are routed around a flange of the exhaust piping.

d. 1968 Chevrolet Impala SS

Figure 3-12 shows the desirable feature of ample space between the front of the fuel tank and the stabilizer bar attachment. Undesirable construction details are also indicated. The fuel line passes between the floor pan and a cross brace member, with the possibility of crushing the fuel line if crash displacement occurs. The illustration also shows the vent line which runs upward and then down to form an inverted "V" near the right rear wheel housing. This type of vent (used by General Motors, Chrysler and Ford) may permit fuel spillage during rollover.

e. 1968 Chrysler New Yorker

Figure 3-13 shows the fuel tank location at the extreme rear of the vehicle. The flanged edge of the rear crossrail (indicated by the arrow) is very close to the tank and rear impact could easily drive the flange against the tank with possibility of rupture.

Figure 3-14 shows the fuel line passing between the floor pan and exhaust pipe. The line is about 3 inches above the top of the gooseneck of the front pipe. Minor rerouting of the fuel line would have provided more clearance.

Figure 3-15 shows the metal fuel line emerging from the bottom of the right side frame rail through a punched hole. A grommet would help to prevent fuel line abrasion.

Figure 3-16 shows a fuel filter connection sleeve touching an alternator support member. Abrasive deterioration during normal operation and failure from crash impact may result.

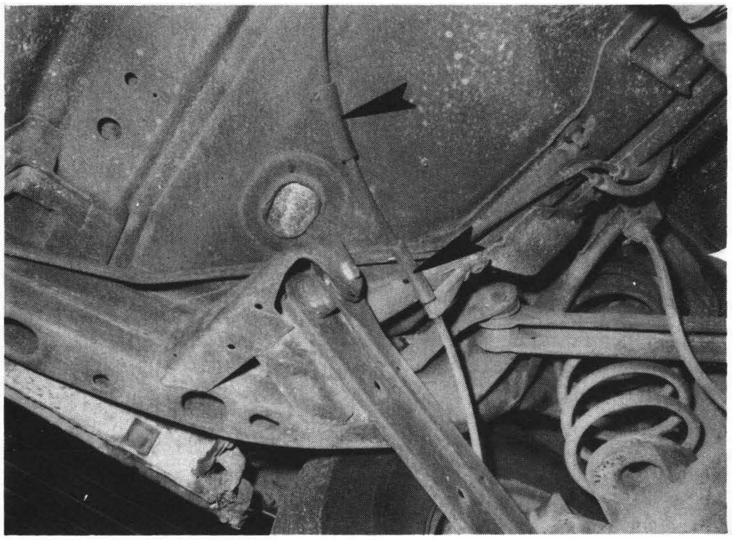


Figure 3-10. 1966 Cadillac Coupe de Ville Fuel Line Cushioning Sleeves

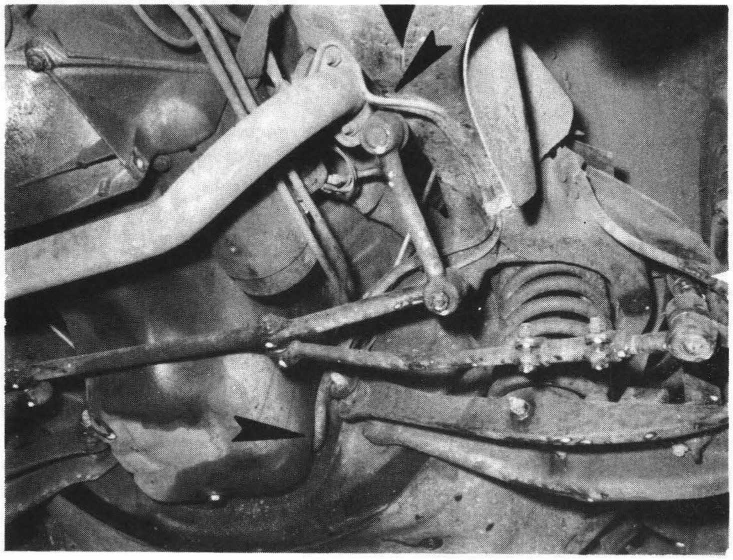


Figure 3-11. 1966 Cadillac Coupe de Ville Fuel Line Routing

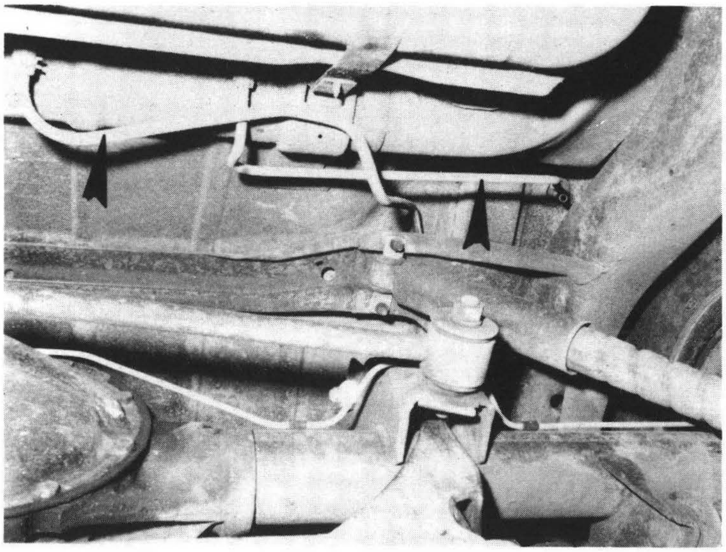


Figure 3-12. 1968 Chevrolet Impala Fuel Line and Vent

Figure 3-13. 1968 Chrysler New Yorker Rear Crossrail Proximity to Fuel Tank

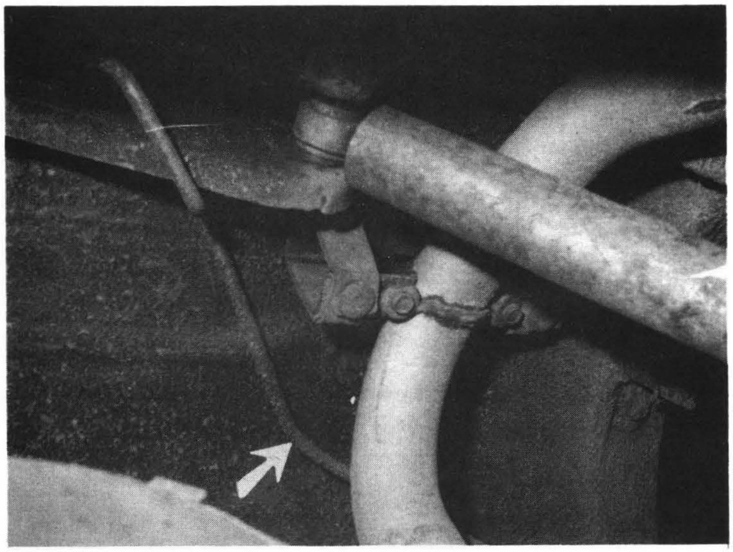


Figure 3-14. 1968 Chrysler New Yorker Fuel Line Routing around Exhaust Pipe

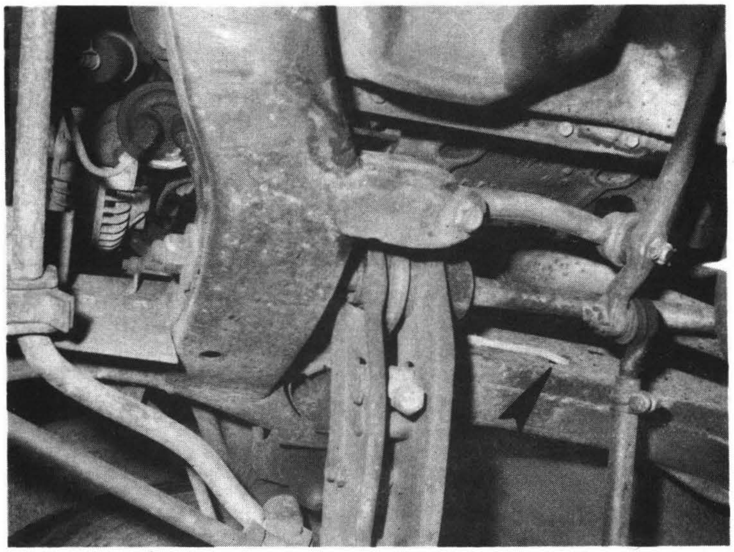


Figure 3-15. 1968 Chrysler New Yorker Fuel Line Passing Through Structural Member

f. 1966 Dodge Coronet 500

Figure 3-17 shows good routing of the fuel line to clear the exhaust pipe gooseneck. Figure 3-18 shows the same fuel line passing through a punched hole in a frame cross member.

g. 1967 Dodge Coronet 500

Figures 3-19 and 3-20 show two undesirable fuel system features. The filler pipe and vent line run through a punched flanged hole in the floor pan (Figure 3-19). The spare wheel well,which is formed in the floor pan,is immediately behind the fuel tank (Figure 3-20). Since there is a small space between the wheel well and the rear crossrail, rear impact could drive the depressed wheel well into the fuel tank.

h. 1968 Dodge Coronet 440

Figure 3-21 shows the fuel tank at the extreme rear of the vehicle. The small space between the rear crossrail flange and the rigidly anchored filler pipe could cause a failure of the fuel tank assembly if rear impact occurred.

i. 1967 Dodge Dart

A compact, because its space is limited, may incorporate features that detract from post crash fire safety. For instance, the tank is retained by a single transverse strap which may be considered a marginal means of support.

Figure 3-22 shows the fuel line bent around a floor pan attachment bracket. Distortion in this area could rupture the line.

Figures 3-23 and 3-24 show how the fuel tank partially encloses the spare wheel well at the rear portion of the floor pan. Impacts, whether from side or rear, that are sufficient to deform the floor pan, could cause damage to the fuel tank since the crush spaces are small.

Figure 3-25 shows the proximity of the left rear shock absorber to the fuel tank.

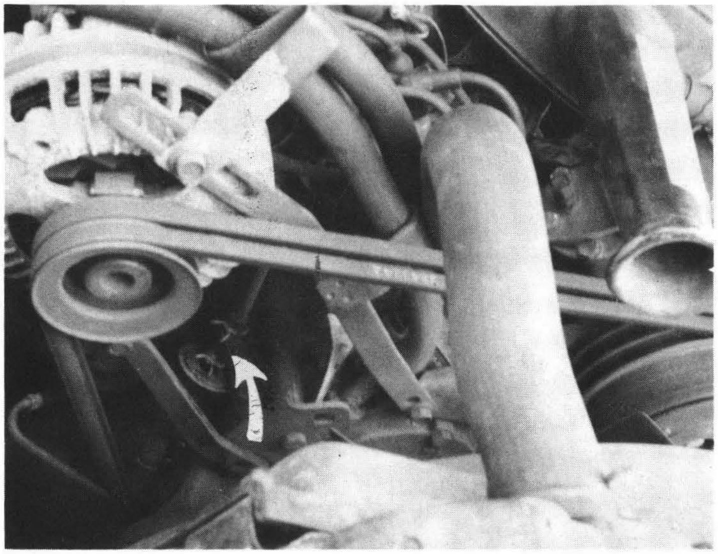


Figure 3-16. 1968 Chrysler New Yorker Fuel Filter

Figure 3-17. 1966 Dodge Coronet 500 Fuel Line Routing around Exhaust Pipe

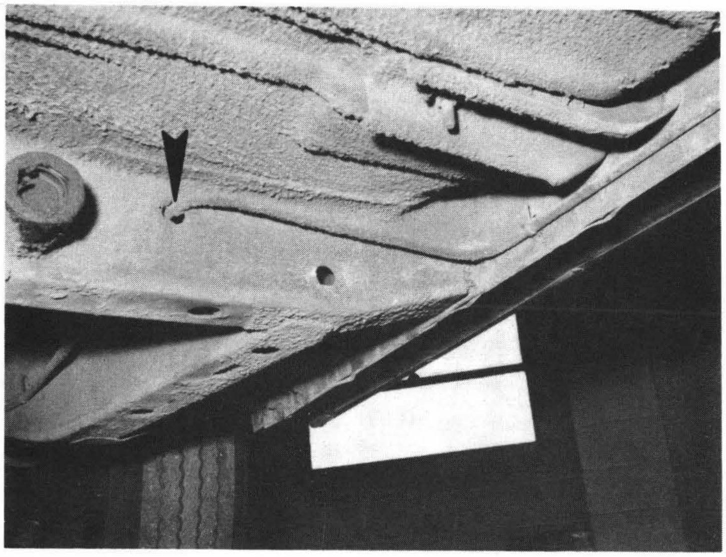


Figure 3-18. 1966 Dodge Coronet 500 Fuel Line Passing through Structural Member

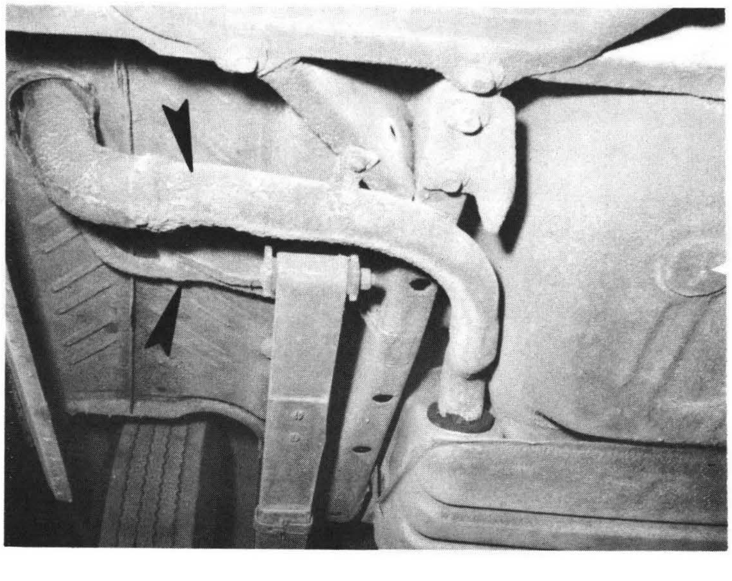


Figure 3-19. 1967 Dodge Coronet 500 Filler Pipe and Vent Line

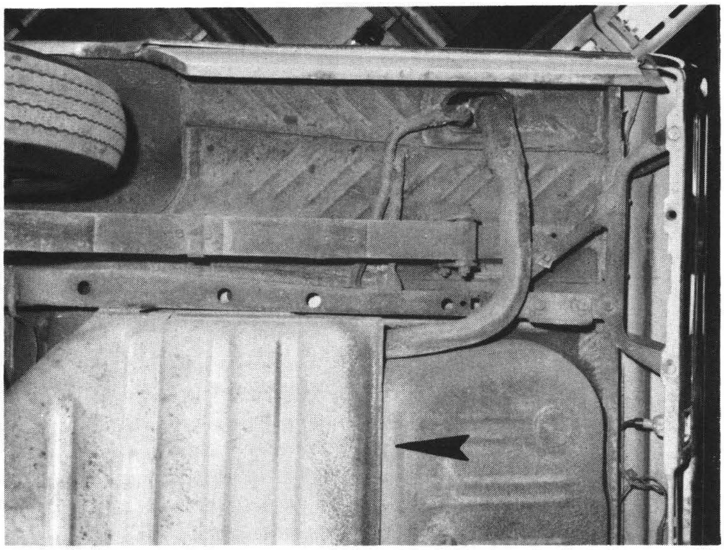


Figure 3-20. 1967 Dodge Coronet 500 Fuel Tank Location

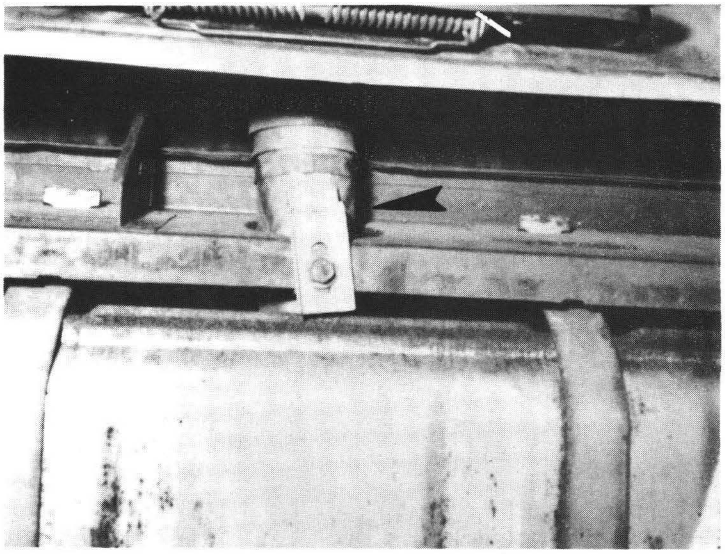


Figure 3-21. 1968 Dodge Coronet 440 Filler Pipe Arrangement

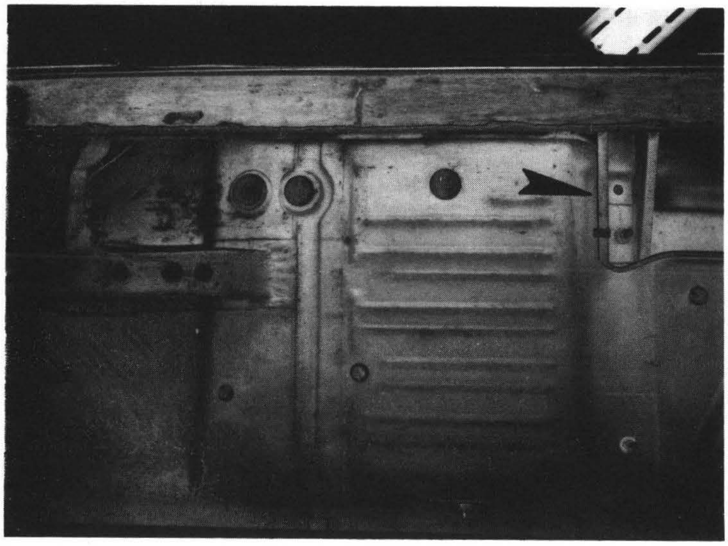


Figure 3-22. 1967 Dodge Dart Fuel Line Routing

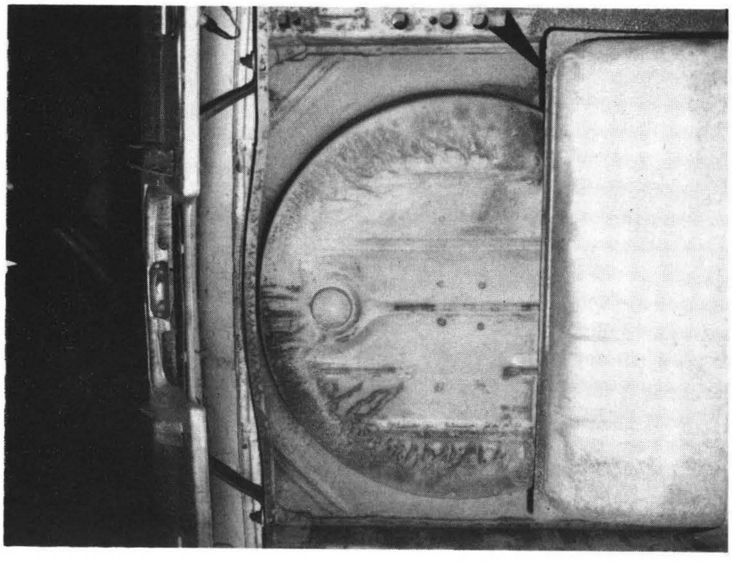


Figure 3-23. 1967 Dodge Dart Fuel Tank Location

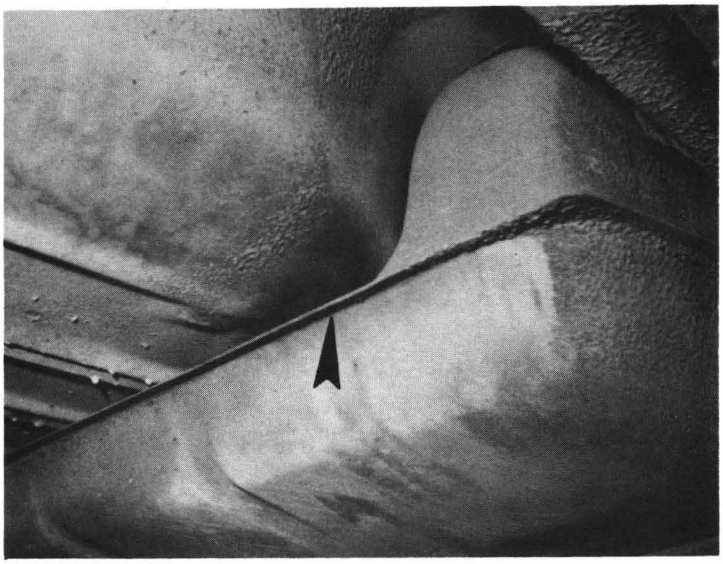


Figure 3-24. 1967 Dodge Dart Fuel Tank Formation

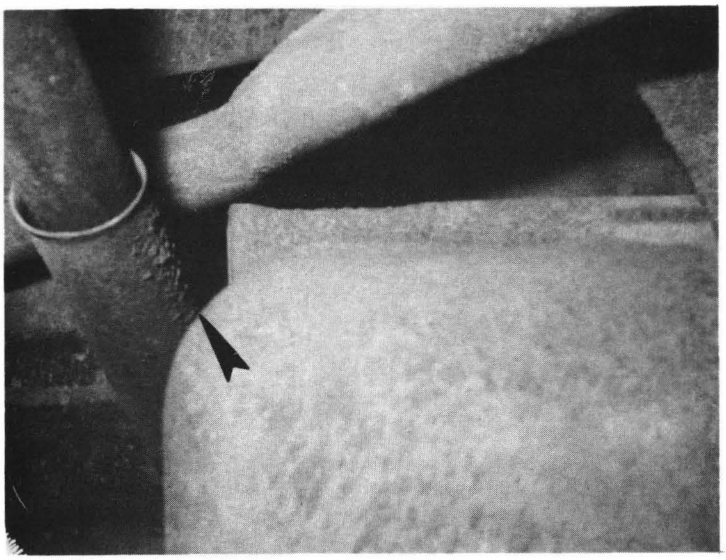


Figure 3-25. 1967 Dodge Dart Fuel Tank Proximity to Shock Absorber

Figure 3-26 illustrates another instance of a fuel line running through unprotected holes in sheet metal.

Figure 3-27 shows the fuel line at the carburetor. The "S" shaped metal tubing from filter to carburetor provides adequate support and impact flexibility.

j. 1968 Dodge Dart

Figure 3-28 shows the long filler pipe, completely exposed and subject to impact by articles carried in the luggage compartment.

k. 1966 Dodge Polara

Figure 3-29 shows the fuel tank positioning and support. The two longitudinal straps appear adequate, but the rear of the tank is so close to the rear crossrail that rear impact vulnerability is high.

Since the tank is placed off center longitudinally to clear the exhaust system resonator and tail pipe, the left rear shock absorber is very close to the front left corner of the tank (Figure 3-30). The left side rail is close to the tank, but since its web is adjacent to the tank, this frame member serves as protection from left side impacts.

Figure 3-31 is a view looking forward into the luggage compartment. The vent line can be seen rising through the floor and then returning downward to discharge to the atmosphere.

Figure 3-32 shows the fuel line crossing above the exhaust system intermediate pipe gooseneck with ample clearance.

l. 1966 Ford Mustang

This model, as well as other Ford manufactured passenger vehicles, uses the top of the fuel tank as the floor of the luggage compartment. Heavy, sharp articles, if present at a crash, might penetrate the tank top. Figures 3-33 and 3-34 show the luggage compartment of a 1966 Mustang with the cover mat partially and completely removed. Notice that the tank is at the extreme rear of the vehicle with little crush space to absorb rear impact.

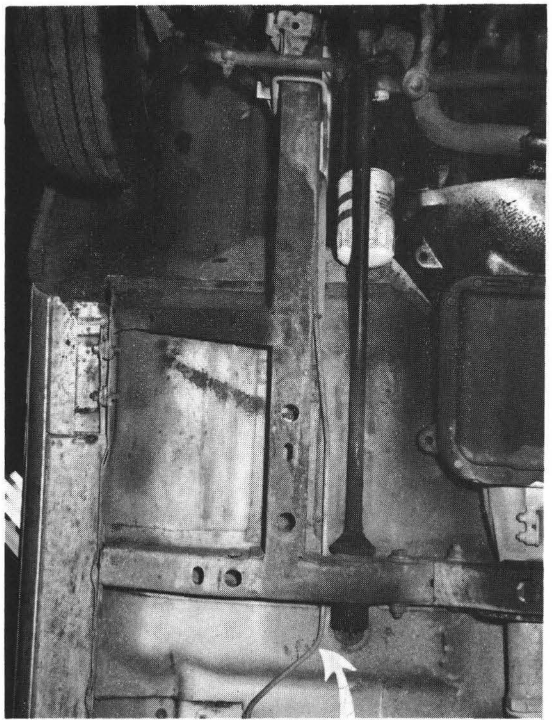


Figure 3-26. 1967 Dodge Dart Fuel Line Routing

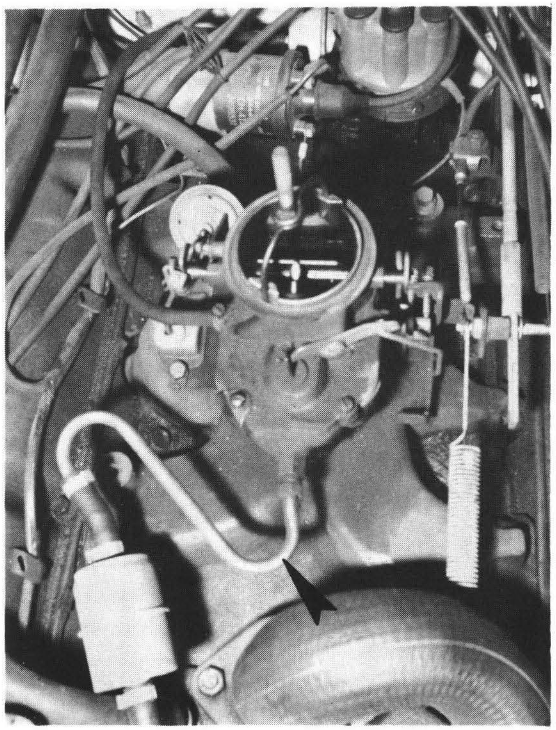


Figure 3-27. 1967 Dodge Dart Fuel Line at Engine

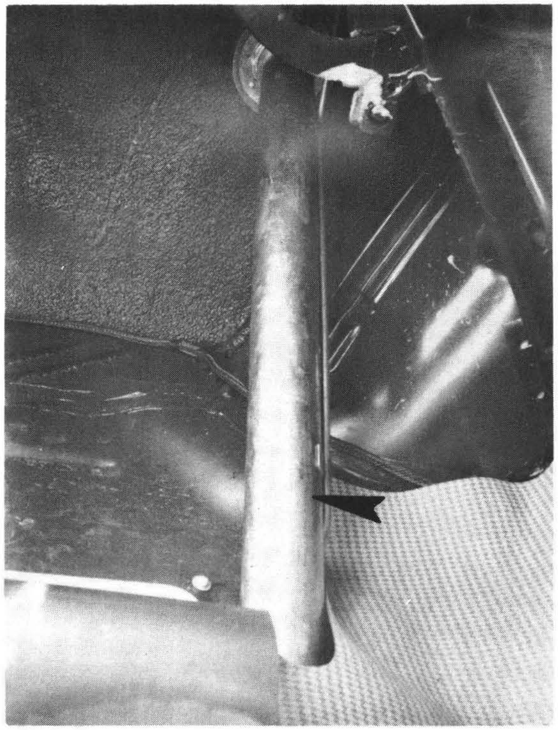


Figure 3-28. 1968 Dodge Dart Filler Pipe

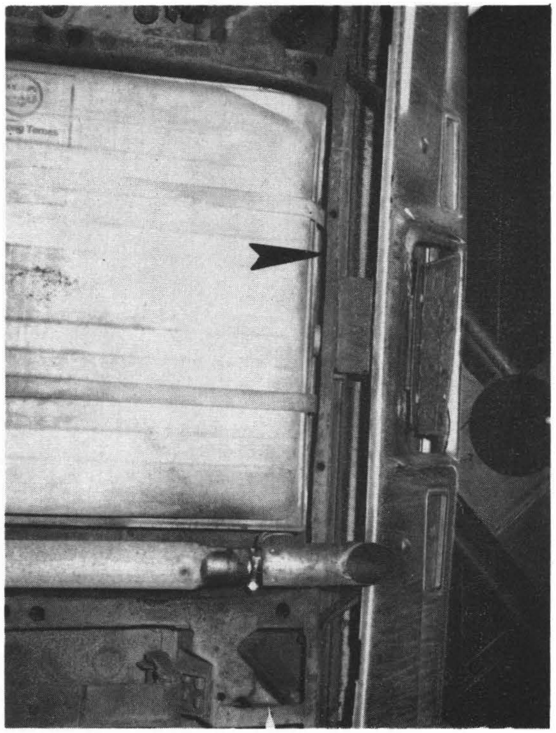


Figure 3-29. 1966 Dodge Polara Fuel Tank Proximity to Rear Crossrail

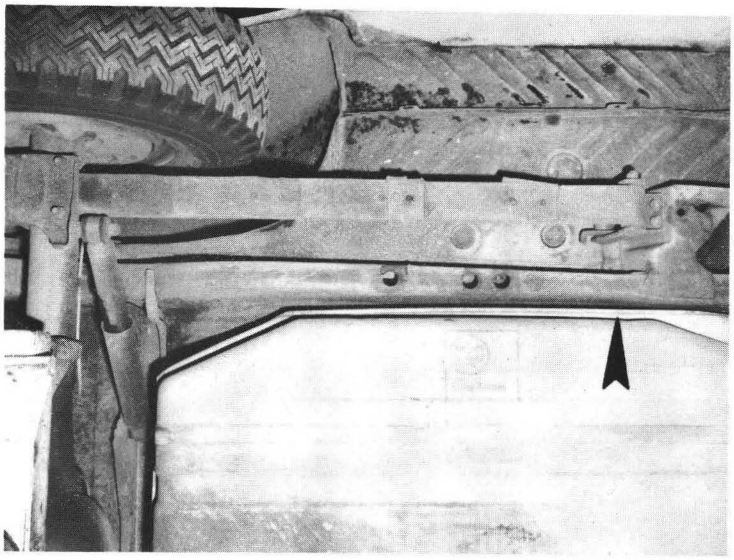


Figure 3-30. 1966 Dodge Polara Tank Proximity to Side Rail

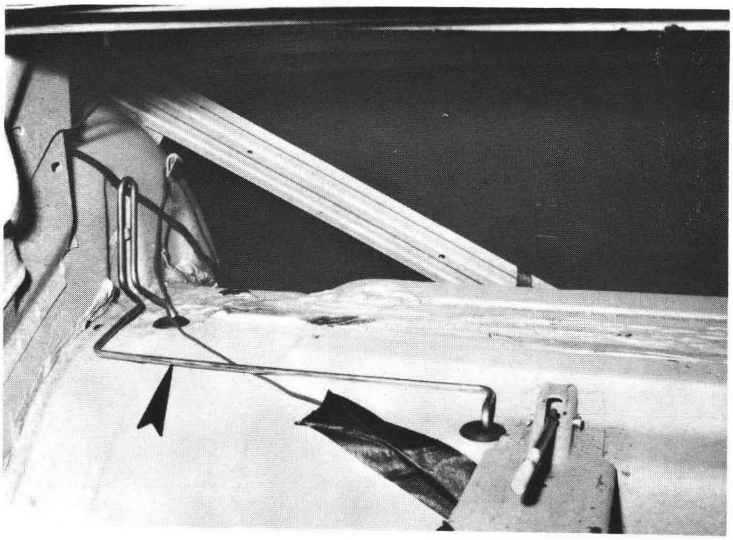


Figure 3-31. 1966 Dodge Polara Vent Line Routing

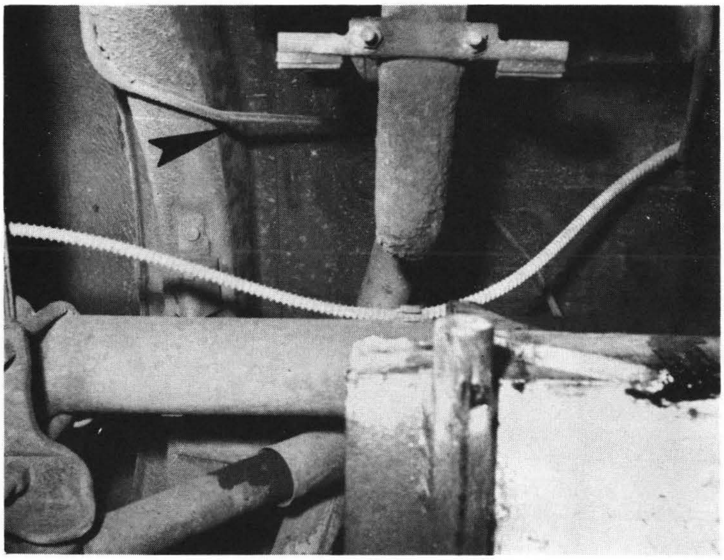


Figure 3-32. 1966 Dodge Polara Fuel Line Routing

Figure 3-33. 1966 Ford Mustang Trunk Compartment

m. 1967 Ford Fairlane Station Wagon

The fuel tank, as shown on Figure 3-35, is located between the outside body metal and the chassis frame at the left rear. The tank is susceptible to side impact damage.

n. 1967 Ford Galaxie 500

The fuel tank is mounted with its flanges in a vertical plane (Figure 3-36). Its location, forward of the luggage compartment provides ample crush space in the event of rear impact; however, the stabilizer bar and mounting accessories are close to the front face of the tank, reducing the rear impact protection. The centralized location of the tank offers protection against side impacts.

The fuel pickup is bent at a 90° angle. A hose connection, with clamps, is used to splice the synthetic rubber fuel line to the pickup tube. An extra connection along the fuel line results from this, with no additional flexibility (Figure 3-37). The fuel line running from tank to engine compartment was 5/16 inch O.D. synthetic rubber with support clips 36 inches apart at some points along the side rail. Some were not secure or had dropped off so that the fuel line hung loosely below the rail (Figure 3-38).

o. 1967 Ford LTD

Figure 3-39 shows the fuel tank and filler pipe. The arrangement is the same as the Ford Galaxie 500 shown in Figure 3-36, with the same characteristics.

p. 1966 Mercury Monterey

Figure 3-40 shows the fuel tank. The arrangement is the same as that shown on Figures 3-36 and 3-39 for the Ford Galaxie 500 and the Ford LTD, respectively.

Figure 3-41 shows an avoidable undesirable feature. The fuel line on the left side of the vehicle touches the flanged edge of the floor pan.

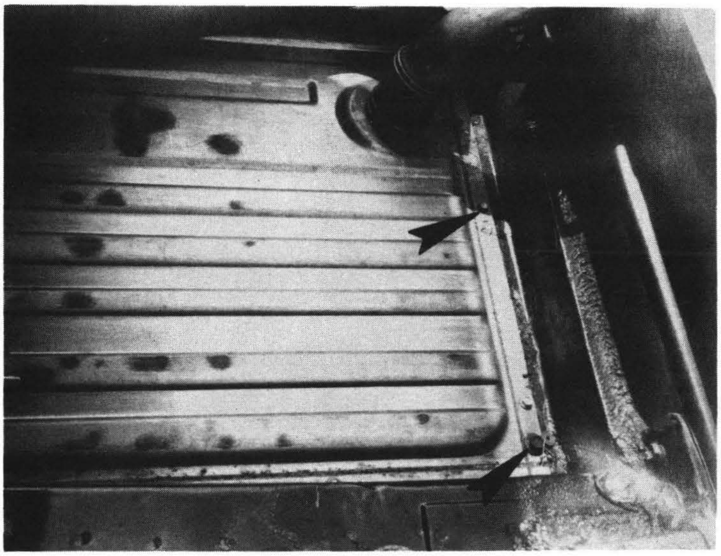


Figure 3-34. 1966 Ford Mustang Fuel Tank Mounting

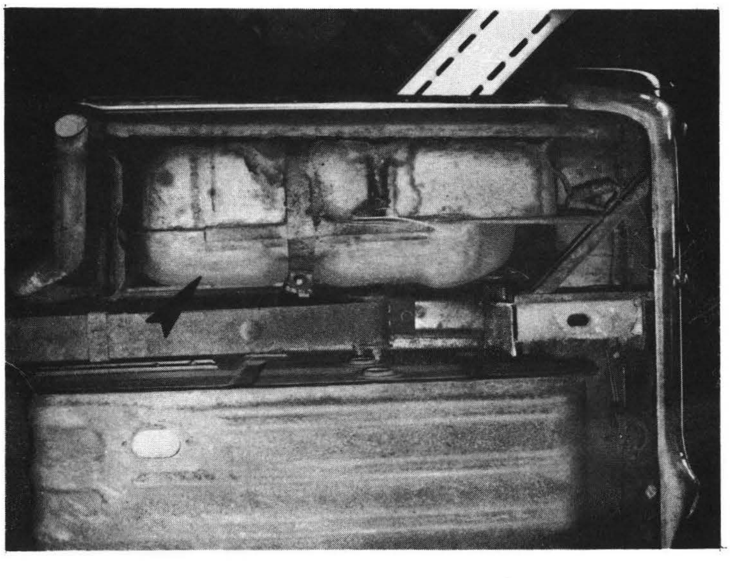


Figure 3-35. 1967 Ford Fairlane Station Wagon Fuel Tank Location

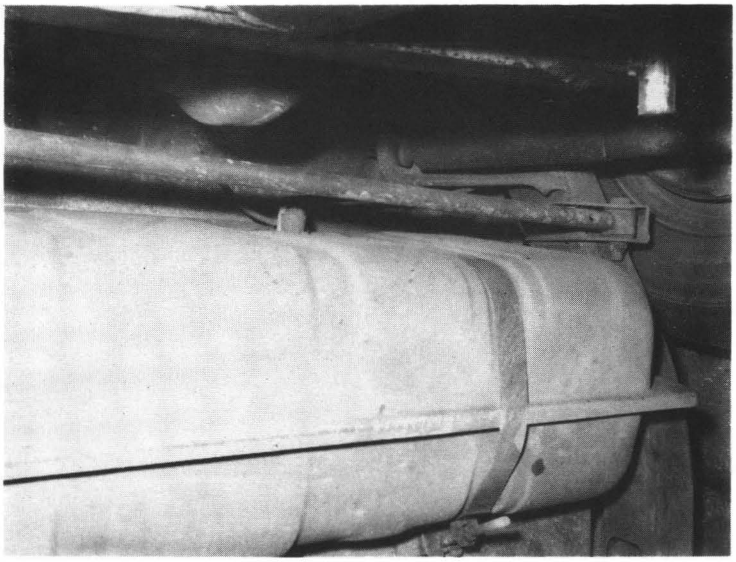


Figure 3-36. 1967 Ford Galaxie 500 Fuel Tank Location

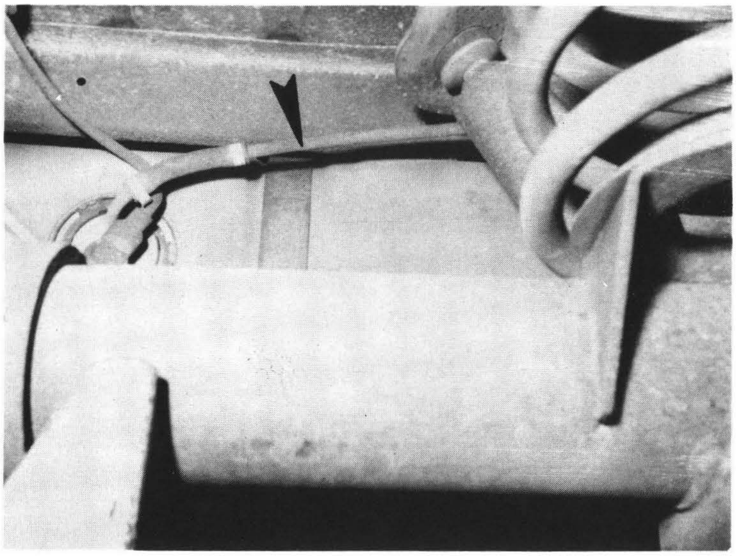


Figure 3-37. 1967 Ford Galaxie 500 Fuel Line at Tank

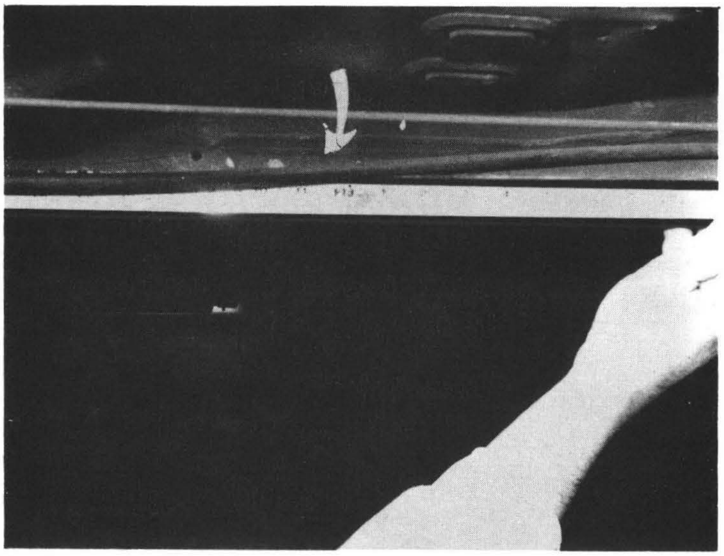


Figure 3-38. 1967 Ford Galaxie 500 Fuel Line

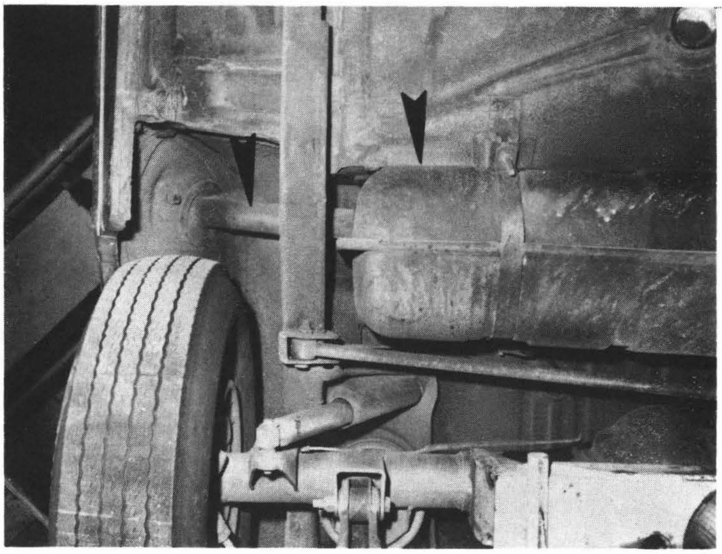


Figure 3-39. 1967 Ford LTD Fuel Tank and Filler Pipe

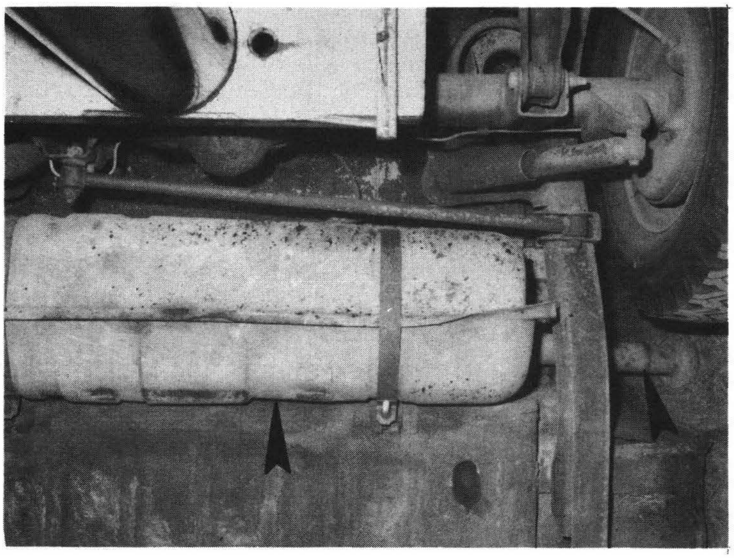


Figure 3-40. 1966 Mercury Monterey Fuel Tank and Filler Pipe

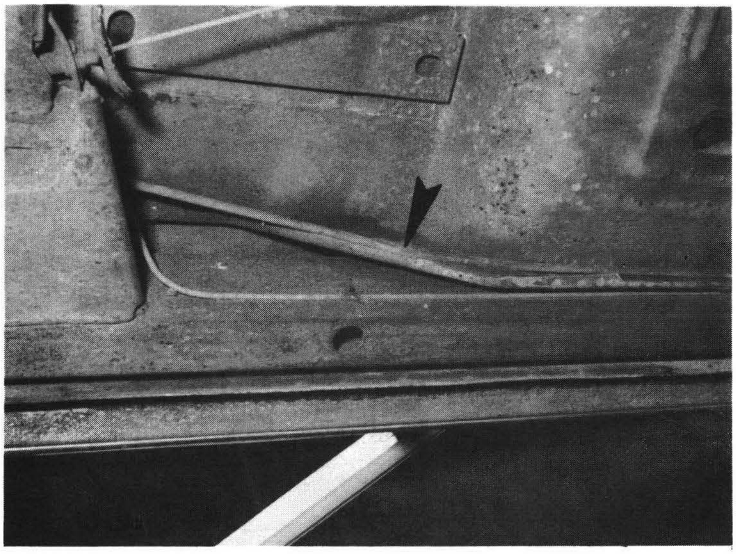


Figure 3-41. 1966 Mercury Monterey Fuel Line Routing

Operational vibration or side impact deformation could cause fuel line abrasion or leakage. A minor change in the fuel line routing would prevent the contact.

Figure 3-42 shows the fuel line running along the left front fender, adequately supported, protected by the fender structure, and clear of any hot components. Figure 3-43 shows the fuel line bending around the distributor and resting against high tension leads.

q. 1968 Oldsmobile Cutlass

Figure 3-44 shows the fuel filler pipe which is manufactured with convolutions that provide impact absorption in the event of a rear end collision. The filler pipe is at the rear center of the vehicle. The illustration also shows sufficient crush space between the rear crossrail and the rear end of the fuel tank.

r. 1967 Pontiac LeMans

Figure 3-45 shows a flexible hose portion of the fuel line passing through an unprotected punched hole in the left front cross member.

s. 1968 English Ford Cortina

Figure 3-46 shows the rear luggage compartment of this vehicle. The tank top is the compartment floor. Figure 3-47 shows the underside of the same area. The rear framing member is light gage metal and the crush space is small. The features shown by these photographs show vulnerability to rear area impacts. Figure 3-48 shows the long, unsupported span of the synthetic rubber fuel line near the fuel pump.

t. Fiat 124 Family Car

This station wagon has its fuel tank under the floor pan. Figure 3-49 shows a protective metal guard shielding the filler pipe from damage by random objects.

u. Fiat 124 Coupe

Figure 3-50 is a view of the right side of the rear luggage compartment. The unprotected fuel tank shows a dent. The vehicle illustrated was new and had not yet been placed in service.

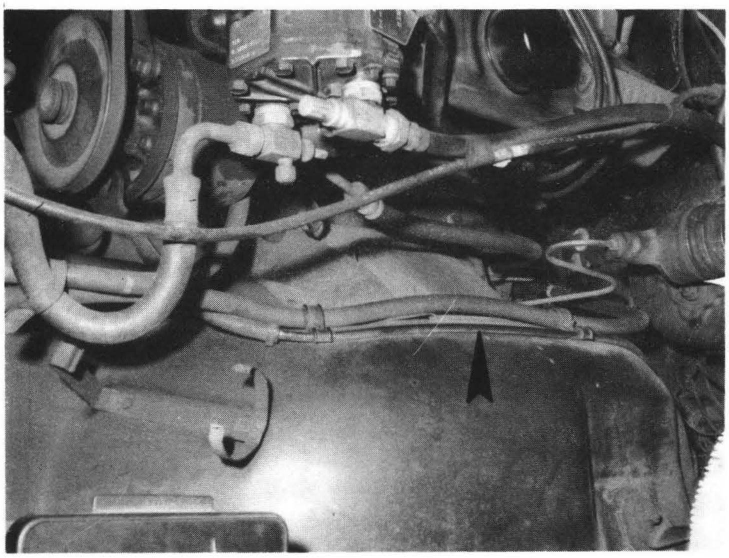


Figure 3-42. 1966 Mercury Monterey Fuel Line Routing at Engine

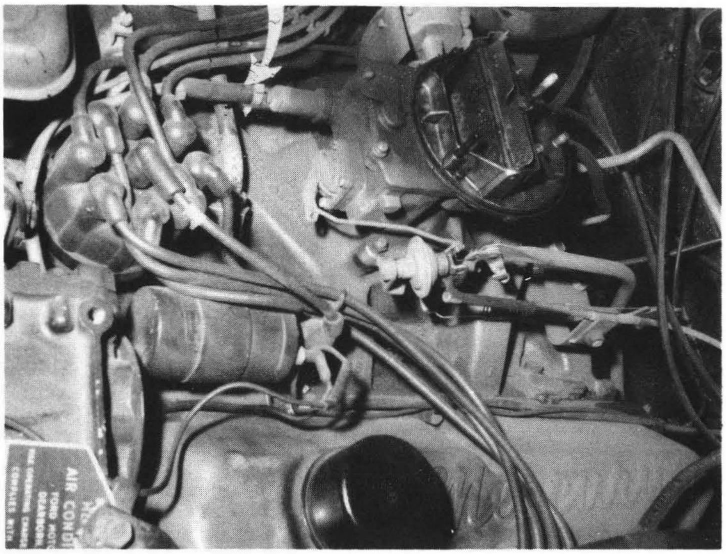


Figure 3-43. 1966 Mercury Monterey Fuel Line Routing at Carburetor

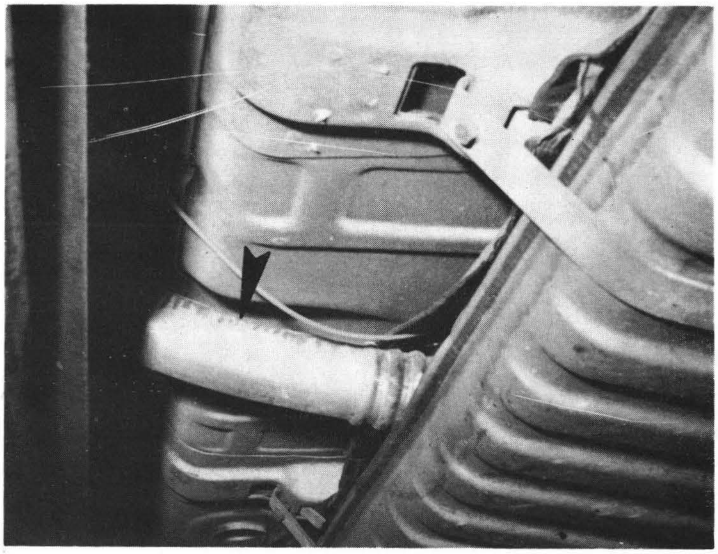


Figure 3-44. 1968 Oldsmobile Cutlass Filler Pipe

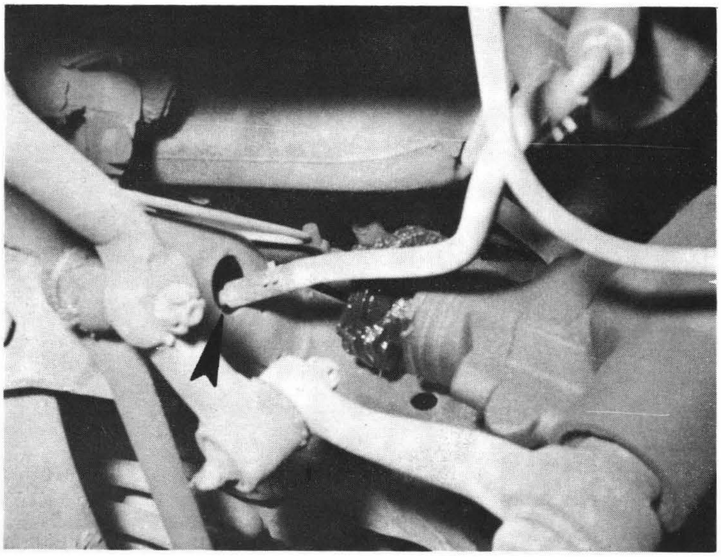


Figure 3-45. 1967 Pontiac LeMans Fuel Line

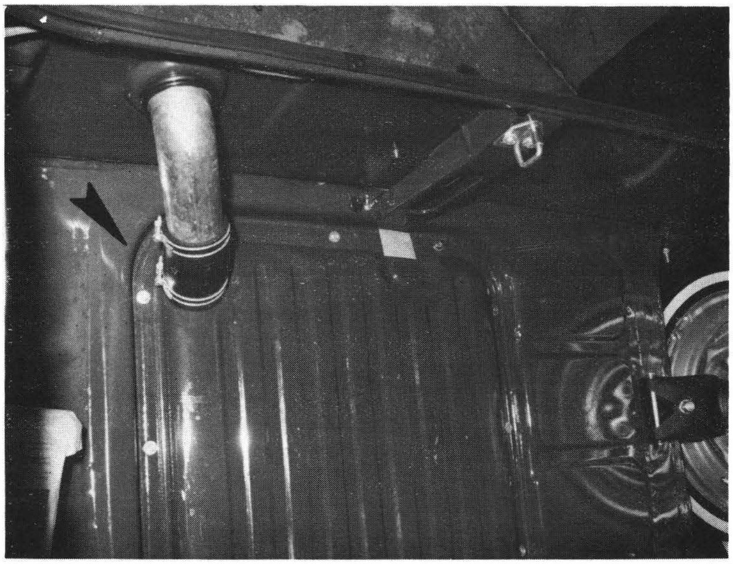


Figure 3-46. 1968 Ford Cortina Luggage Compartment

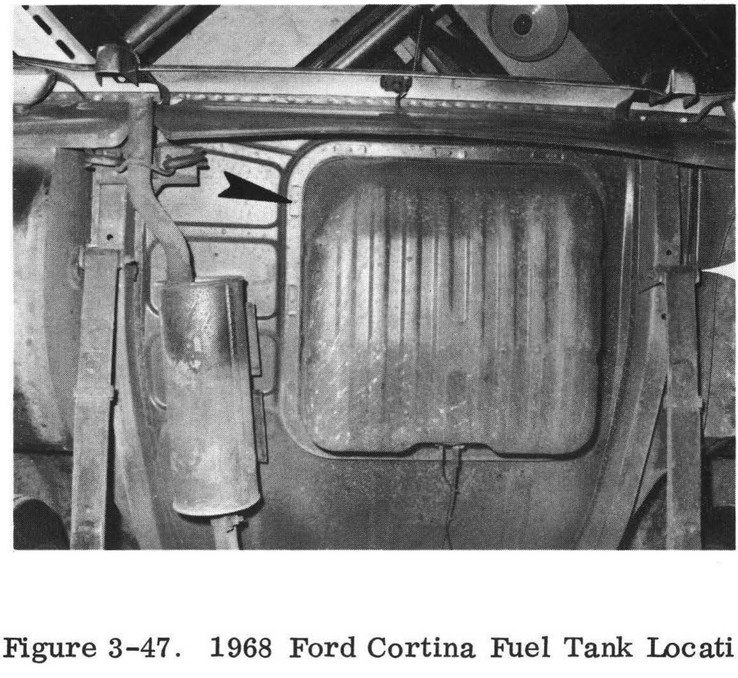


Figure 3-47. 1968 Ford Cortina Fuel Tank Location

Figure 3-48. 1968 Ford Cortina Fuel Line at Engine

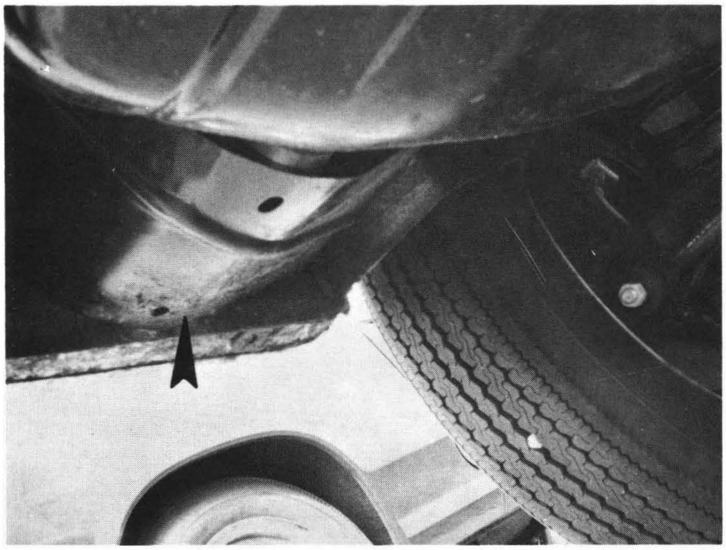


Figure 3-49. Fiat 124 Family Car Filler Pipe Shield

v. Fiat 850 Roadster and Coupe

These vehicles are rear engine powered. A sheet metal partition is between the engine compartment and the fuel tank. The fuel tank is directly behind the passenger compartment. There are several apertures in the firewall, not all of which are sealed. Figure 3-51 (looking forward) shows part of the engine and the firewall. The tank in the Roadster fills from an exterior opening located behind the back window. Consequently, the large opening through which the filler pipe would pass is sealed. However, in Figure 3- 52 the filler pipe and vent line in the Coupe pass through the opening which is grommetted but not sealed. Also note that the end of the vent line is in the engine compartment and only a tub-like structure around the filler pipe prevents spillage of fuel on engine components.

w. 1968 Toyota 2-Door Hardtop

Figure 3-53 shows the luggage compartment floor mat partially removed and the top of the fuel tank exposed. This use of the integral tank and its inadequacies have been previously discussed (See discussion of 1966 Mustang).

Figure 3-54 shows the underside of the fuel tank and the small crush space between the rear of the tank and the rear crossrail.

Despite the evidence of painstaking design and construction in the treatment of the fuel line, there is the following inconsistency. Passing through a grommet in the right side rail, the fuel line and an electrical harness are clipped together until they exit from the rail. The connection is secure and well insulated, and, under normal operating conditions, very satisfactory; however, under crash conditions, the proximity of the two systems could be considered a severe hazard.

x. Other

In addition to the previous examples, the following should be noted:

The 1964 through 1968 Corvair fuel tank is mounted under the slanting toe section of the underbody pan. It is so close to the pan that sheet

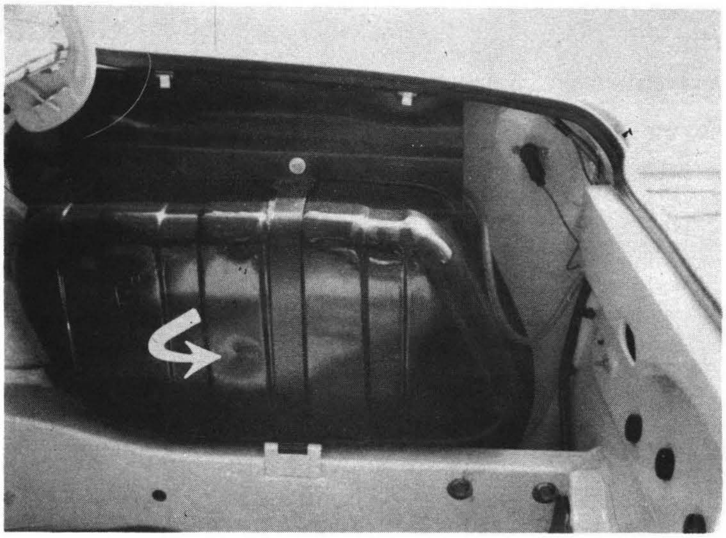


Figure 3-50. Fiat 124 Coupe Fuel Tank

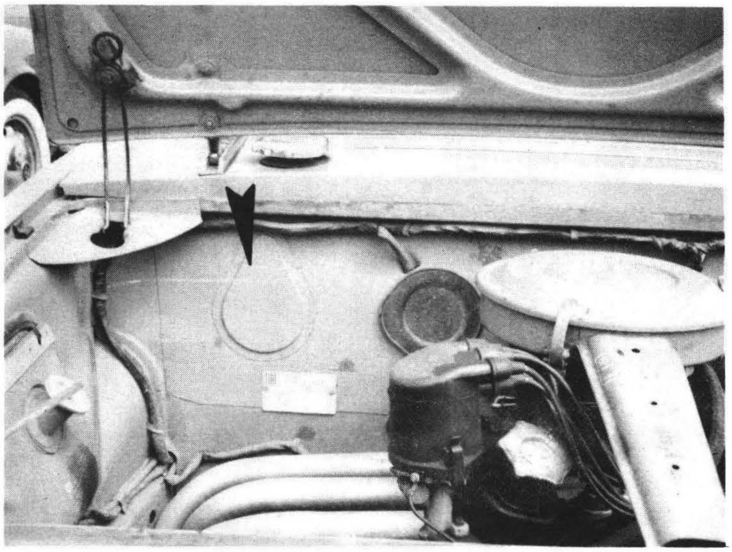


Figure 3-51. Fiat 850 Roadster Firewall

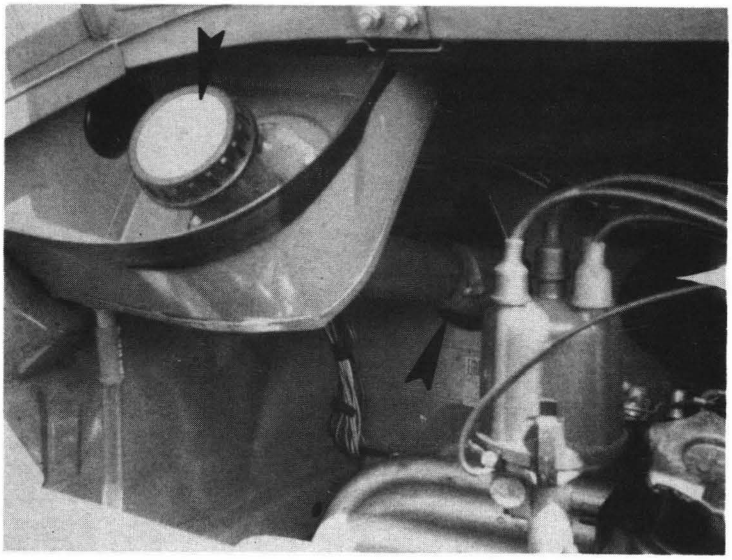


Figure 3-52. Fiat 850 Coupe Filler Pipe

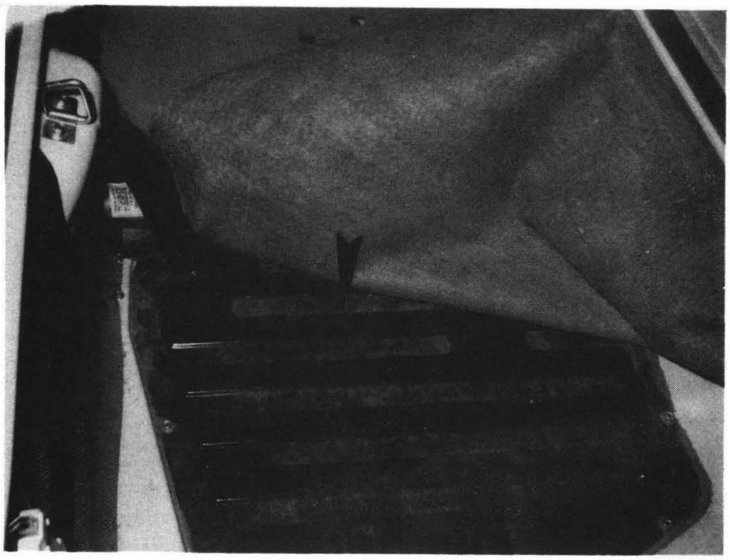


Figure 3-53. 1968 Toyota Hardtop Luggage Compartment

metal assembly screws used to secure the pan may penetrate the tank if there is any crash displacement. The shop manual (Reference 3-3) reveals the following:

> "CAUTION: When installing toe pan cover screws, caution should be exercised to avoid puncturing the fuel tank."

The Volkswagen passenger vehicle fuel tank is in the front luggage compartment. It is some distance away from any structure, with ample "crush space." Yet frontal impacts have resulted in serious fires because the vehicle is so lightly constructed. Refer to Section VI.

y. GMC 4000 V8 School Bus

Since busses have ample space, no problem exists relative to positioning fuel system components so that they are protected by the vehicle structure. Figure 3-55 shows the fuel tank with its sturdy support structure. The tank is at the right side, behind the door, under the floor of the passenger compartment. The exterior view, Figure 3-56, shows the location of the fuel filler cap.

z. 1969 Chevrolet C/10 Small School Bus

School bus designs do not change much in any successive year; the 1969 vehicle that was examined and photographed can be considered typical of earlier models.

The fuel tank is centrally located behind the rear axle. Figure 3-57 shows the tank and the filler/vent pipe which is at the left side of the bus. The illustration also shows the support straps hooked and bolted to a longitudinal chassis frame strut. The arrangement shows a protected tank, with sturdy retention.

3. Conclusion

It is difficult to estimate the degree of danger inherent in some of the above examples which showed potential to start crash fires; however, the fact that they contribute to the hazard is undeniable.

Figure 3-54. 1968 Toyota Hardtop Fuel Tank

Figure 3-55. GMC School Bus Fuel Tank

Figure 3-56. GMC School Bus Filler Cap Location

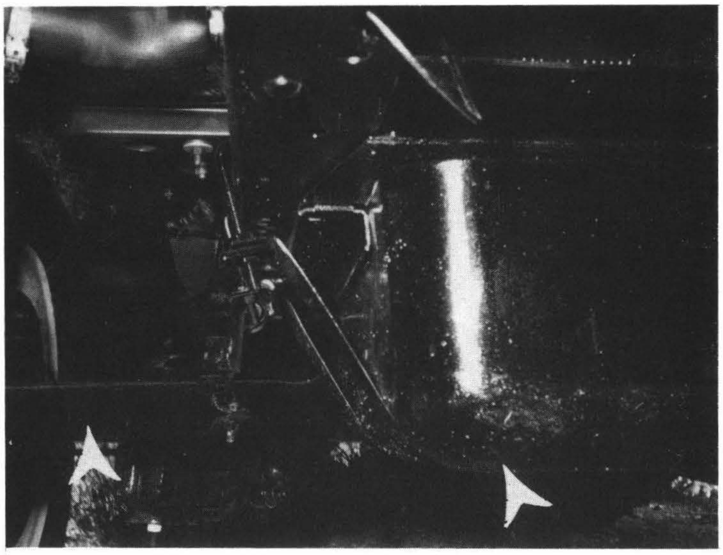


Figure 3-57. Chevrolet Small School Bus Fuel Tank

B. EXHAUST SYSTEM

1. Problem Areas

a. Introduction

The exhaust system is only a secondary source of post crash fires. If the fuel is disregarded, crash dislocated hot components of the exhaust system may start a fire only if they contact combustible vehicle components or cargo. This could occur with tanker trucks or motor carriers loaded with solid or cased liquid combustibles such as insecticides, petroleum products, distilled alcoholic beverages, chemical solvents, etc. None of these cargo items could be considered exotic or rare.

Although trucks carry more combustible material than the average passenger car, the problems of the exhaust system are basically the same. The following is an evaluation of the fire hazards present in passenger vehicle exhaust system components.

b. Front Pipe

This component, by its function, is the hottest part of the exhaust system. Because of its location and temperature which, even under idling conditions, may reach 500°F, the front pipe is a likely candidate for starting a post crash fire. Front pipe temperatures are higher in the high speed range and are further increased when emission control techniques such as leaner jetting, retarded spark timing and afterburning are incorporated.

c. Intermediate Pipe

This component runs at cooler temperatures than the front pipe. Its potential of presenting a fire hazard will therefore be less than the front pipe.

d. Muffler and Resonator

Because of their low operating temperatures, these components do not present a fire hazard.

e. Tail Pipe

This final component in the exhaust system is the coolest, but, in the conventional front engined vehicle with a rear positioned fuel tank, is frequently located close to the fuel tank. The low operating temperature presents no thermal fire hazard; however, displacements of the exhaust system may cause dislocation of the tank by the tail pipe, and the resulting fuel vapor, in conjunction with abraided metal sparking, may then be ignited.

f. Light and Medium Truck Exhaust Systems

Light and medium truck exhaust systems are similar to those of passenger vehicles in arrangement and effects.

g. Heavy Truck or Truck Tractor Exhaust Systems

Heavy truck exhaust systems are generally compact. The large engines, whether gasoline or diesel, emit exhaust gases that are hotter than those of passenger vehicles or lighter trucks. The exhaust system arrangements vary for different models. Most diesel engines, and a few gasoline engines, bring the exhaust pipe around and up to a vertically mounted muffler located outside and behind the cab.

A problem arises from the large quantity of fuel carried in externally mounted, exposed tanks, the high temperature of the exhaust system, and the proximity of the fuel and exhaust systems.

h. Bus Exhaust Systems

Small busses of the school type are front engined and the exhaust arrangements are similar to those of passenger vehicles, with the same problems mentioned previously.

City and intercity busses are rear engined. The exhaust system, except for the tail pipe, is in the engine compartment, isolated from most of the fuel system.

Rear impact may cause structural deformation, but the heavy engine/drive train/structural systems possess high rigidity. It may therefore be postulated that the probability of crash fire due to the exhaust system is low.

2. Examples of Current Practice

Observation and photography of passenger vehicles revealed the following undesirable exhaust system features:

- 1967 American Motors Rambler - The muffler and short tail pipe are closely placed between fuel tank and left side frame rail (Figure 3-58).
- 1967 Buick Riviera - The resonator is approximately 3 inches away from the left side of the fuel tank and 2 inches away from the frame side rail (Figure 3-59).
- 1966 Cadillac Coupe de Ville - The tail pipe is approximately 2-1/2 inches away from the left side of the fuel tank (Figure 3-9).
- 1968 Chrysler New Yorker - The beaded ends of the resonator are 1/4 inch away from the right side of the fuel tank (Figure 3-60).
- 1966 Dodge Polara and 1968 Dodge Coronet 440 - The fuel line crosses above the tailpipe about 6 inches ahead of the right rear axle with approximately 2 inches vertical clearance (Figures 3-32 and 3-61).
- 1967 Dodge Coronet 500 - The front exhaust pipe is approximately 2-1/2 inches from the fuel line which is clipped to the inside of the right side frame rail (Figure 3-62). The tail pipe runs between the fuel tank and the right side frame rail and leaf spring with approximately 2 inches of clearance on each side of the pipe (Figure 3-63).

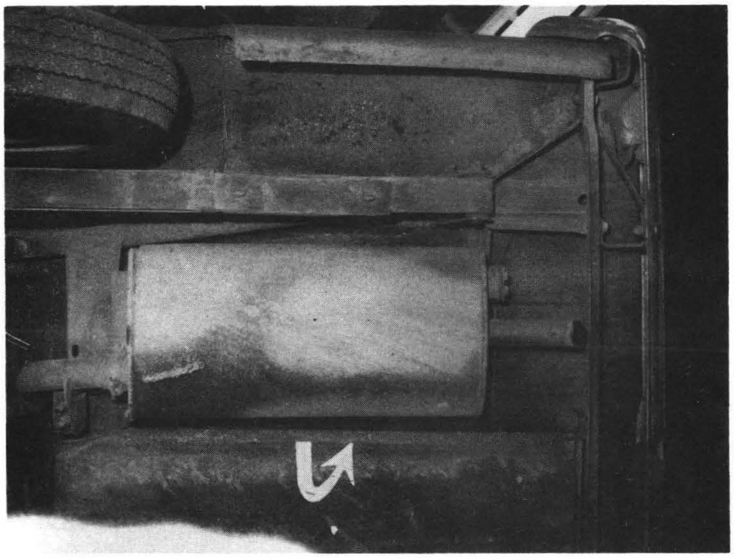


Figure 3-58. 1967 American Motors Rambler - Muffler Proximity to Fuel Tank

Figure 3-59. 1967 Buick Riviera - Resonator Proximity to Fuel Tank

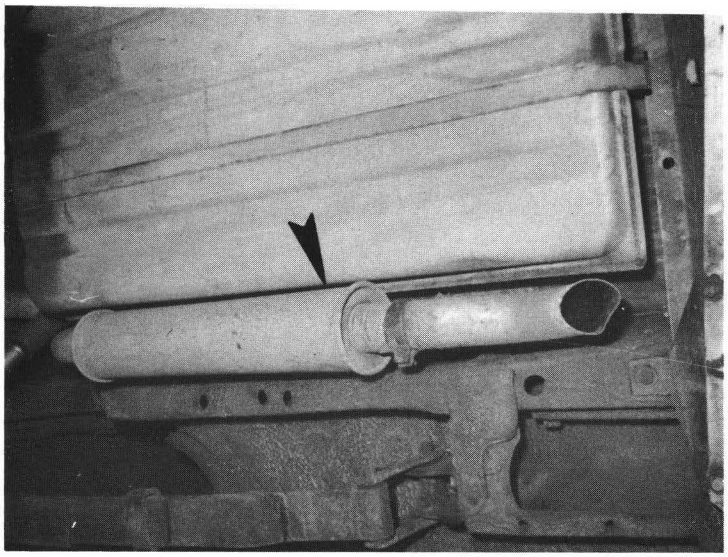


Figure 3-60. 1968 Chrysler New Yorker - Resonator Proximity to Fuel Tank

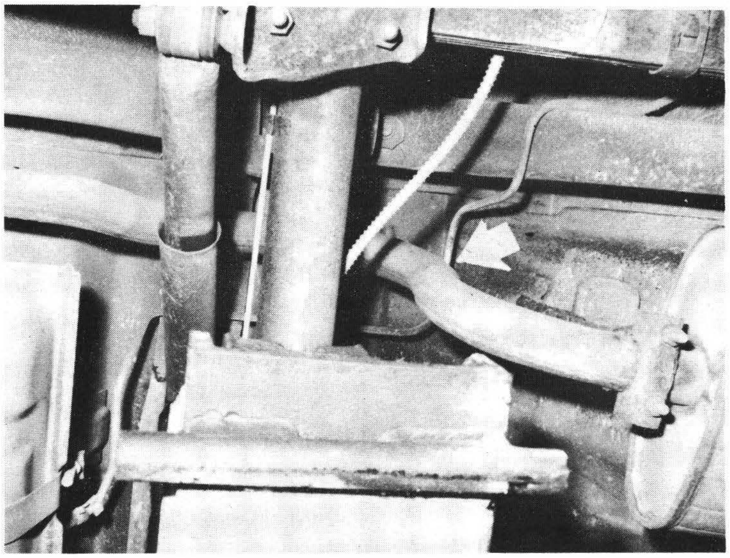


Figure 3-61. 1968 Dodge Coronet 440 - Fuel Line Proximity to Tail Pipe

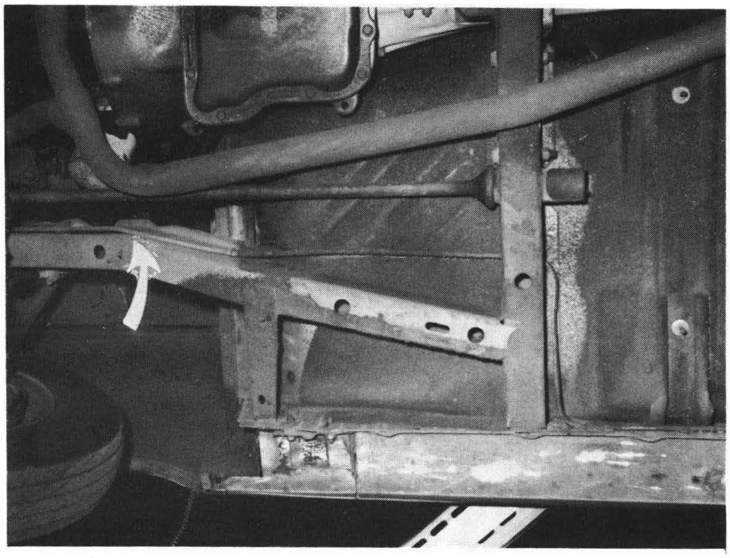


Figure 3-62. 1967 Dodge Coronet 500 - Fuel Line Proximity to Front Exhaust Pipe

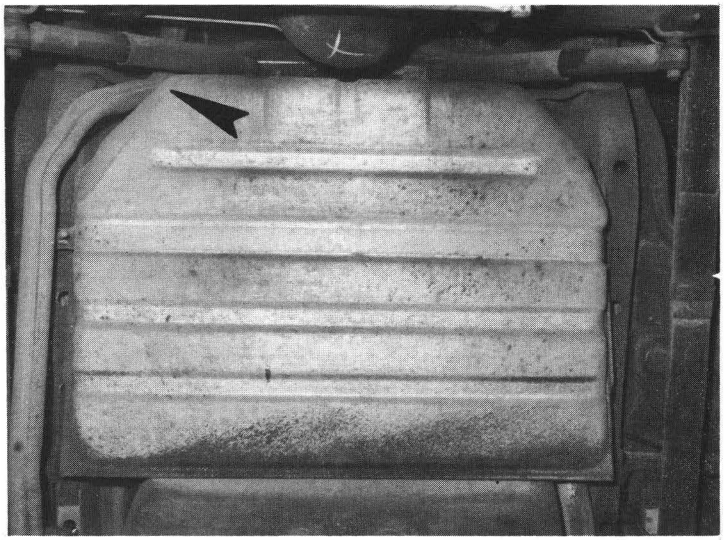


Figure 3-63. 1967 Dodge Coronet 500 - Tail Pipe Proximity to Fuel Tank

- 1966 Ford Mustang - The downstream end of the rear pipe, the muffler, and the upstream end of the tail pipe run transversely approximately 2 inches ahead of the fuel tank in proximity to the tank front, fuel pickup and metering unit, and fuel line. The differential housing is within one inch of the muffler (Figure 3-64).
- 1967 Ford Fairlane Station Wagon - The tail pipe runs into the well space and behind the right rear wheel, separated from the fuel tank by the tank's front shield (Figure 3-65).

3. Temperature Gradient Observations

To determine the actual temperatures of exhaust system components under typical operating conditions, temperature measurements were made on various exhaust system configurations to obtain representative values for a wide range of vehicles.

A Pacific Transducer Corporation Model 314F surface thermometer with a bimetallic element was used for temperature measurement. The conditions under which testing was performed were as follows:

Engine	Idle speed
Wind	5 mph
Ambient temperature	75°F

The temperatures of the vehicle components from exhaust manifold through to the tailpipe exit were recorded while the engine was running.

Figures 3-66 through 3-71 show the exhaust systems, the temperatures, and the points at which they were recorded. Table 3-2 presents all the data for comparison purposes.

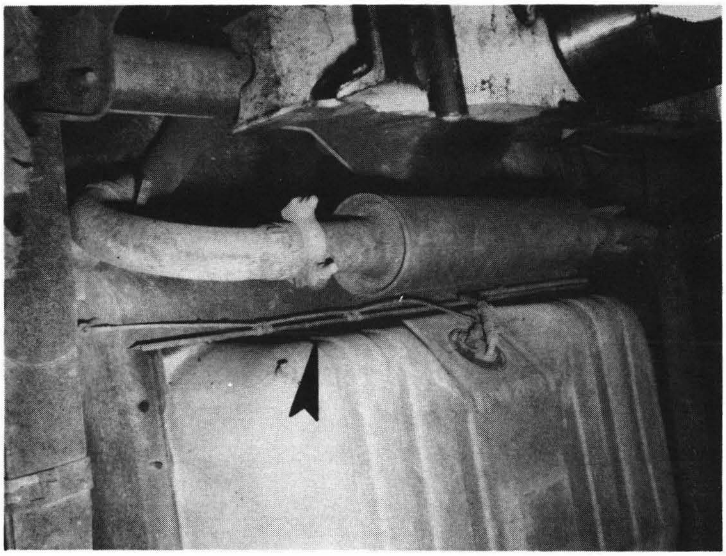


Figure 3-64. 1966 Ford Mustang - Rear of Exhaust System Proximity to Fuel Tank and Accessories

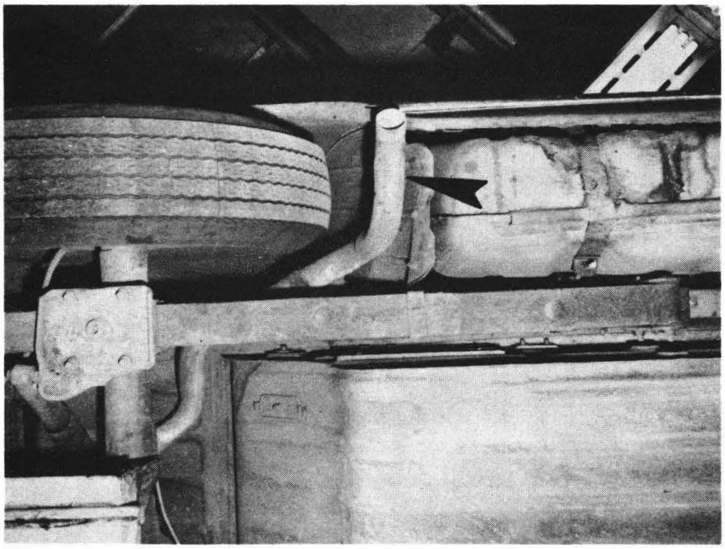


Figure 3-65. 1967 Ford Fairlane Station Wagon - Exhaust Exit Proximity to Fuel Tank

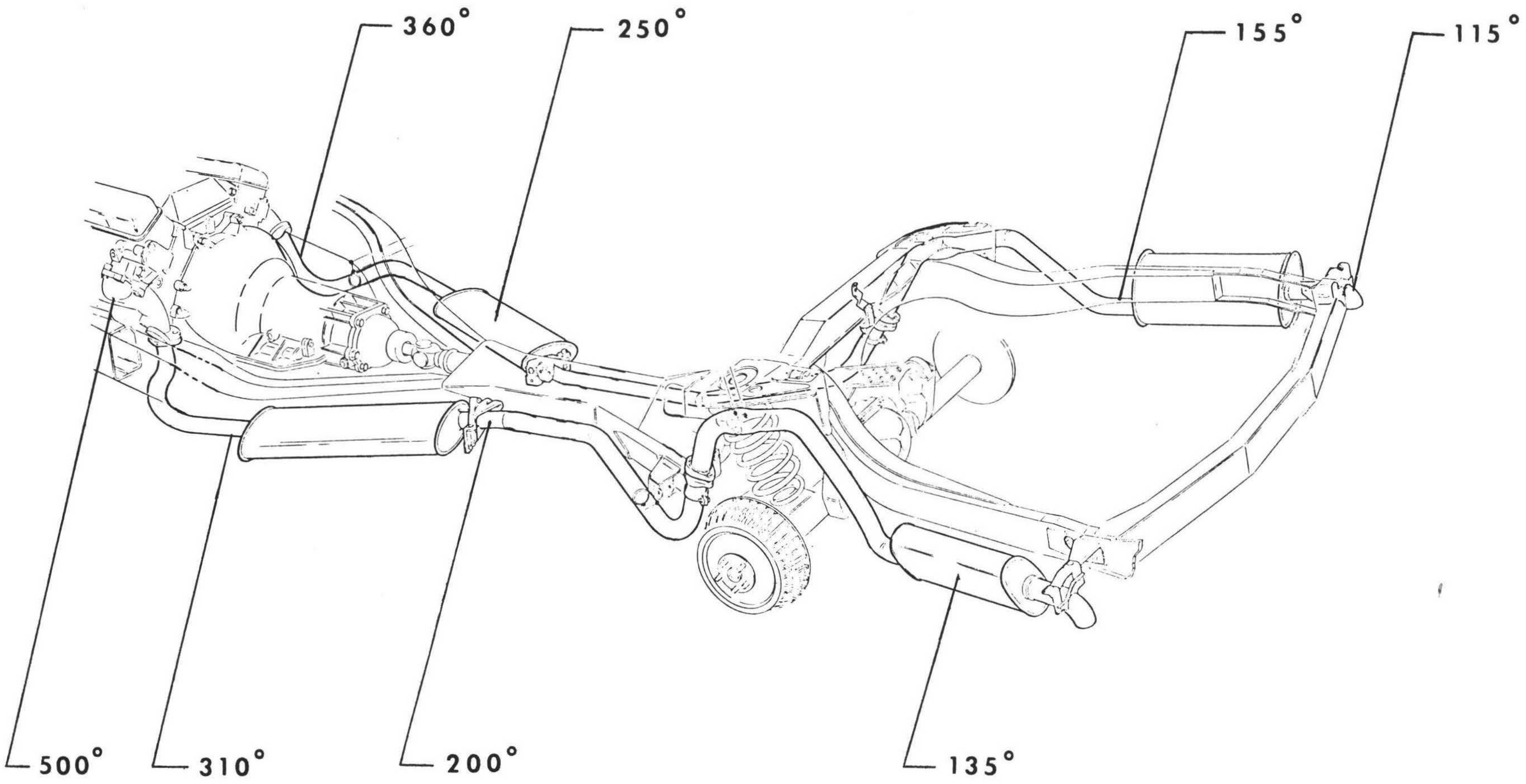


Figure 3-66. 1968 Buick Riviera - V-8 Exhaust System Temperatures

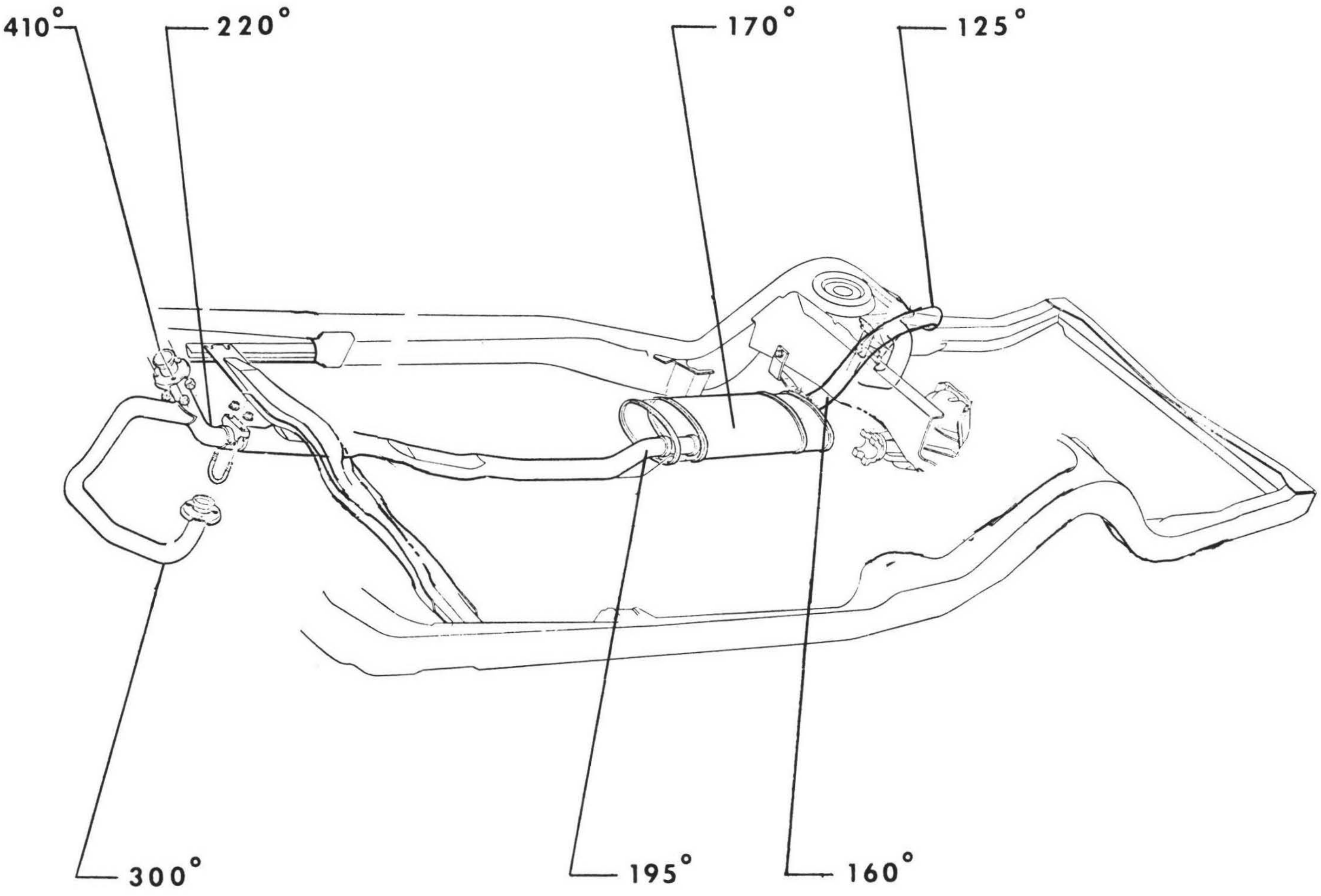


Figure 3-67. 1968 Chevrolet Malibu - V-8 Exhaust System Temperatures

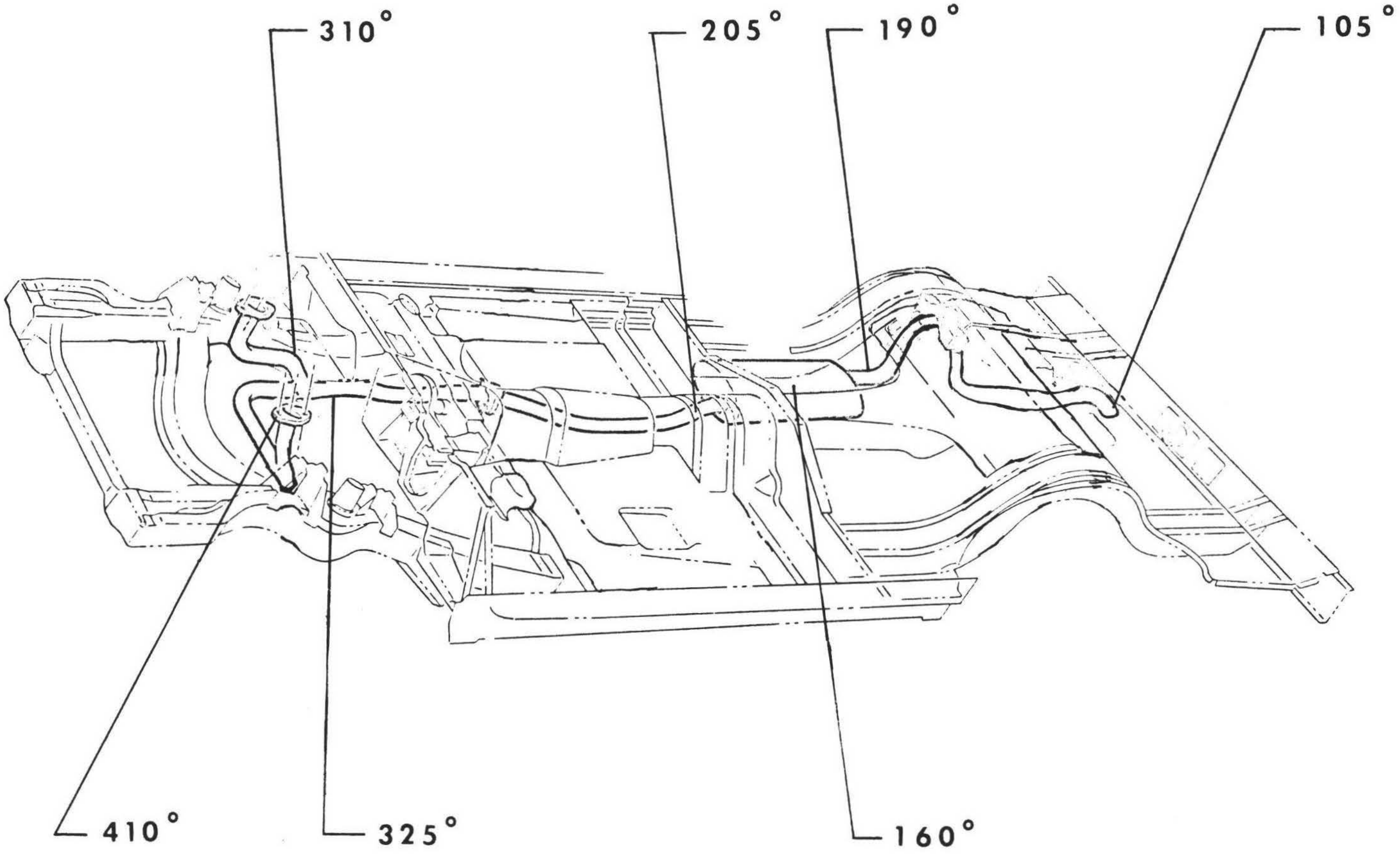


Figure 3-68. 1967 Chrysler Newport - V-8 Exhaust System Temperatures

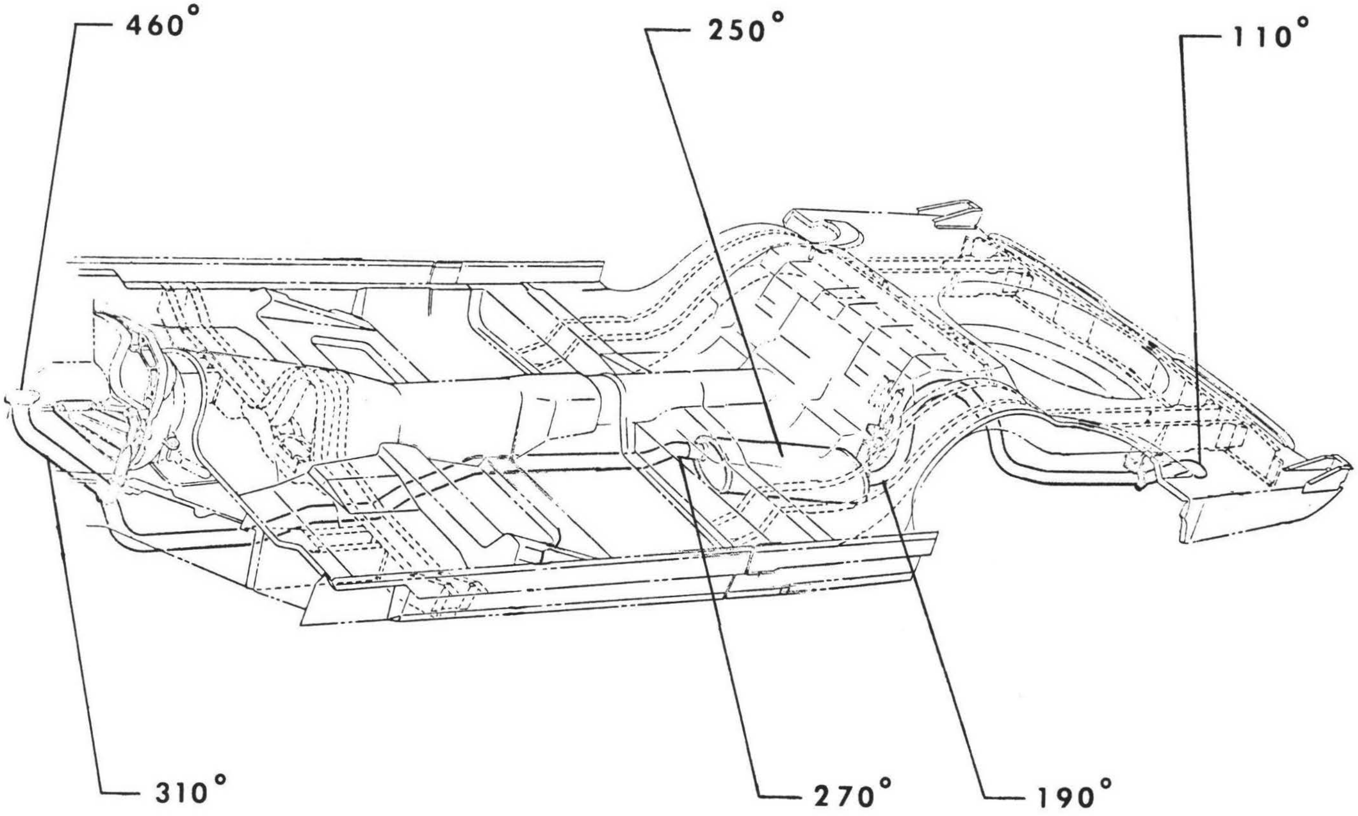


Figure 3-69. 1968 Dodge Dart - Slant 6 Exhaust System Temperatures

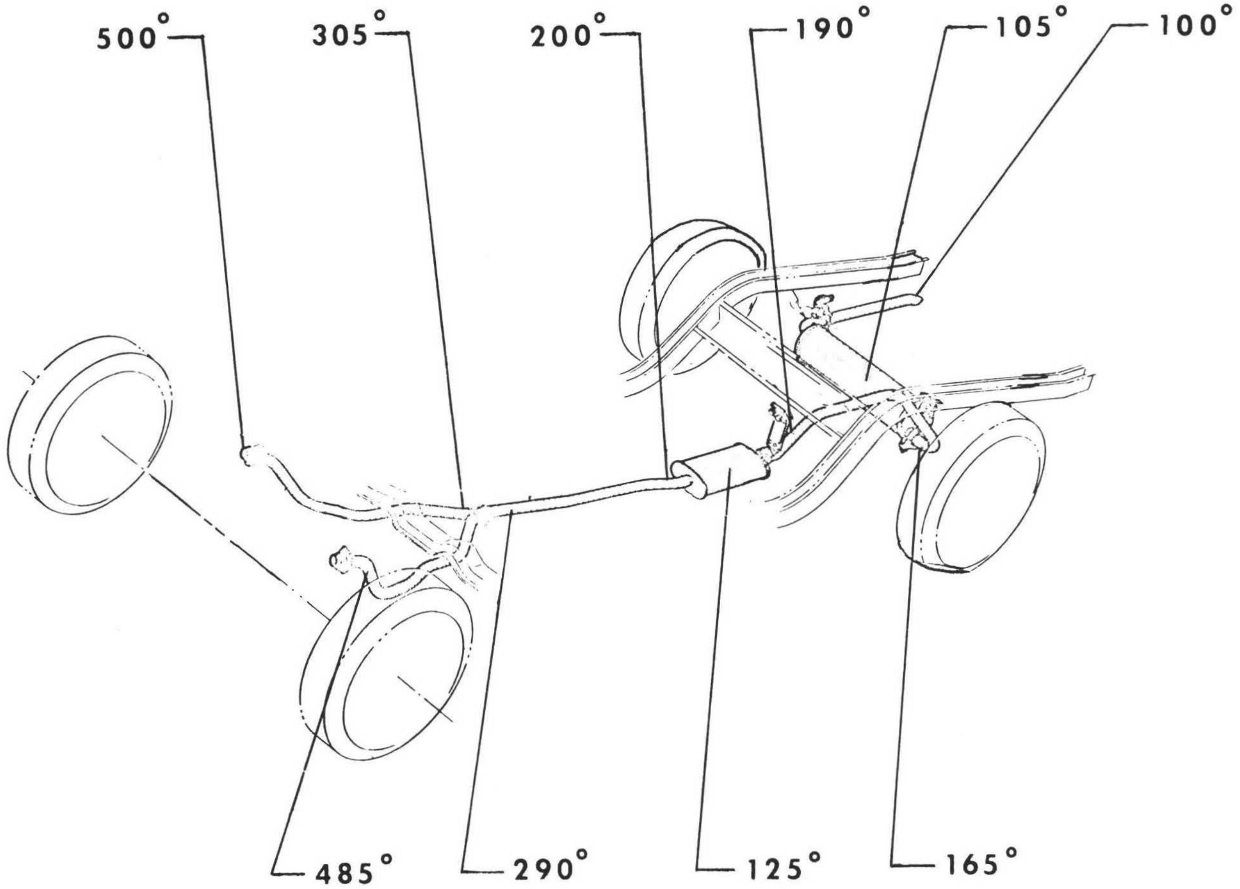


Figure 3-70. 1966 Ford Mustang - V-8 Exhaust System Temperatures

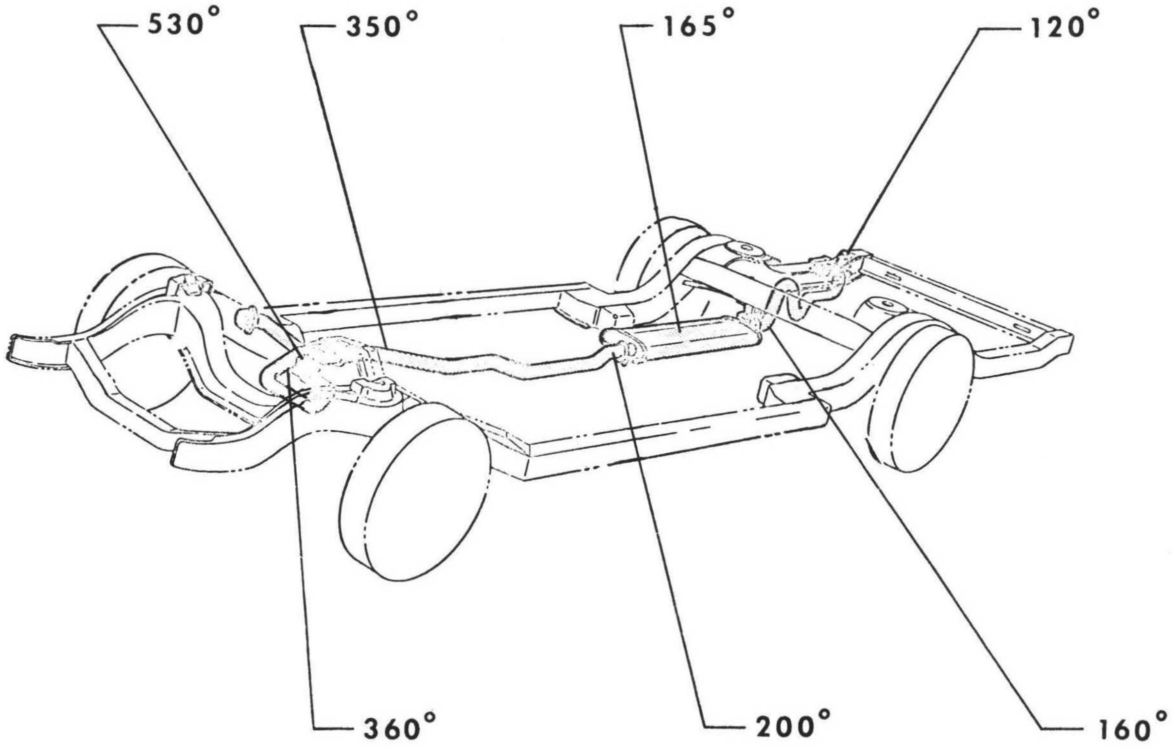


Figure 3-71. 1966 Mercury Monterey - V-8 Exhaust System Temperatures

TABLE 3-2. EXHAUST SYSTEM TEMPERATURE SURVEY

Vehicle Designation and Engine Type	Exhaust System Type	Temperature - Degrees Fahrenheit											
		Exhaust Manifold At Exit Flange	Front Pipe			Intermediate Pipe		Front Sound Absorb.	Rear Pipe		Rear Sound Absorb.	Tailpipe	
			Cross-Over	Front	Rear	Front	Rear		Front	Rear		Front	Exit
1968 Buick Riviera V-8	D	500	-	360	310	-	-	250 M	200	155	135 R	-	115
1968 Chevrolet Malibu V-8	S	410	220	300	195	-	-	-	-	-	170 M	-	125
1967 Chrysler Newport V-8	S	410	310	325	-	-	205	-	-	-	160 M	190	105
1968 Dodge Dart Slant 6	S	460	-	310	270	-	-	-	--	-	250 M	190	110
1966 Ford Mustang V-8	S	500	305	290	200	-	-	125 R	190	165	105 M	-	100
1966 Mercury Monterey V-8	S	530	350	360	200	-	-	-	-	-	165 M	160	120

<u>Key</u>

S - Single exhaust
D - Dual exhaust
M - Muffler
R - Resonator

C. ELECTRICAL SYSTEM

1. Problem Areas

a. Passenger Vehicles

In case of a crash, the battery and the closely related electrical subsystems and components are the main problem items. The battery-ignition circuitry is unprotected by fuse or circuit breaker, and, if the vehicle's engine is still running, the ignition coil secondary high voltage may cause sparking and burning.

Although the cables from the battery to the starting motor, alternator, or ignition coil are at the low potential of 6 or 12 volts, they have sufficient electrical energy to produce sparking if short circuited.

The heavy duty circuits are:

- Battery - alternator
- Battery - starting motor
- Battery - ignition coil primary

These three circuits are unprotected from electrical overload and all are in the engine compartment.

Physical displacement of the battery or destruction of the insulation of the three heavy duty or the many light duty circuits may cause sparking, which in turn may start combustion. Moreover, the complexity, inaccessibility, and operational deterioration of the electrical system are factors which combine to create a problem area.

b. Trucks and Truck Tractors

Light trucks, being similar to passenger vehicles, have the same electrical problems.

Medium trucks, heavy trucks, and truck tractors present different electrical problems. Diesel power eliminates the ignition circuit, but the higher potential of the customary 24 volt batteries increases the severity of electrical failure effects. The battery on the larger trucks is usually mounted externally and is exposed to crash damage.

The larger spaces available in trucks and the heavier construction of these vehicles result in sturdier electrical work. This characteristic tends to minimize crash damage and failures.

c. Busses

Passenger carriers have electrical systems with features and problems common to both passenger vehicles and medium trucks.

However, the higher electrical power required for interior lighting and air conditioning is accompanied by comparably greater electrical power supply and damage potential.

2. Examples of Current Practice

The preceding paragraphs have discussed electrical system arrangements and their effects on post crash fires in general terms. Brief descriptions and photographs showing desirable and undesirable features of the electrical systems of a number of vehicles examined are presented below:

a. 1967 American Motors Rambler

The battery is located at the front left of the engine compartment, and is therefore susceptible to frontal impact damage. Close to and below the battery are loose wires (Figure 3-72). These wires are subject to operational deterioration from acid droplet-splashing as well as from breakage due to displacement of the battery in a crash. Both situations could result in short circuits and possible fire.

Figure 3-73 shows a harness on right side of the firewall that is adequately supported but with individual wires that hang loosely. These are subject to deterioration by vibration fatigue or damage by impacting loose objects.

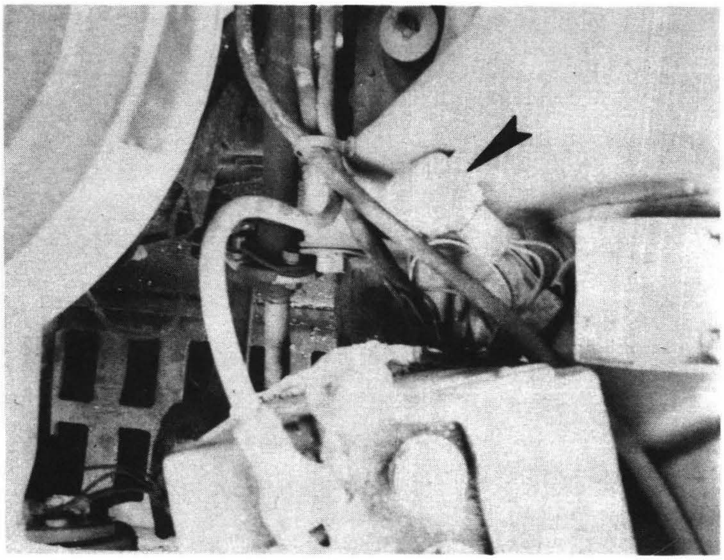


Figure 3-72. 1967 Rambler Electrical Wiring around Battery

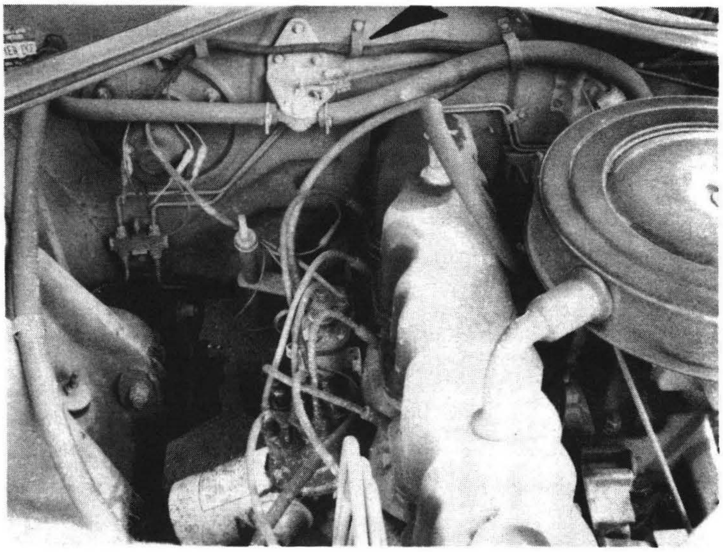


Figure 3-73. 1967 Rambler Electrical Harness Support

b. 1966 Buick Riviera

The battery is located at the extreme front left of the engine compartment. A wiring harness runs over the battery and rests on one of the battery terminals, where it is subject to abrasive and acid deterioration during operation and the possibility of short circuiting in frontal impact (Figure 3-74).

The harness shown in Figure 3-74 terminates at the front right side of the engine compartment in loose individual wires (Figure 3-75). Such loose ends are typical of vehicle wiring and do not have much mechanical strength.

c. 1967 Buick Riviera

The battery-harness arrangement of this vehicle is the same as that of the 1966 model with the same undesirable features. A view of the area between the engine banks shows loose, unprotected wires near the alternator and ignition coil (Figure 3-76). Crash displacement of accessories could break this wiring with the possibility of short circuiting and fire resulting.

d. 1968 Buick LeSabre

The battery is at the extreme right front side of the engine compartment where it is subject to front impact damage and displacement. A wiring harness runs without support over the battery (Figure 3-77). This is an undesirable feature.

The front of the luggage compartment has loose wires running from the floor up to the rear window defogging blower motor and other accessories (Figure 3-78). These loose wires are vulnerable to damage and short circuits, with possible resulting fire.

e. 1968 Buick Special

The valve cover of this vehicle has three clips, two welded and the other held by an assembly screw. Figure 3-79 shows that a wiring harness, which is intended to be supported by the three clips, has slipped out of the rearmost clip. Another wire runs over the valve cover. While the

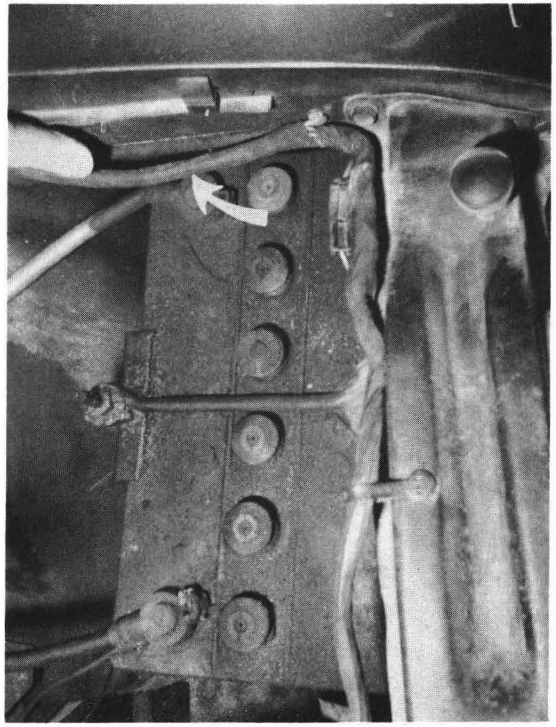


Figure 3-74. 1966 Buick Riviera - Harness Proximity to Battery

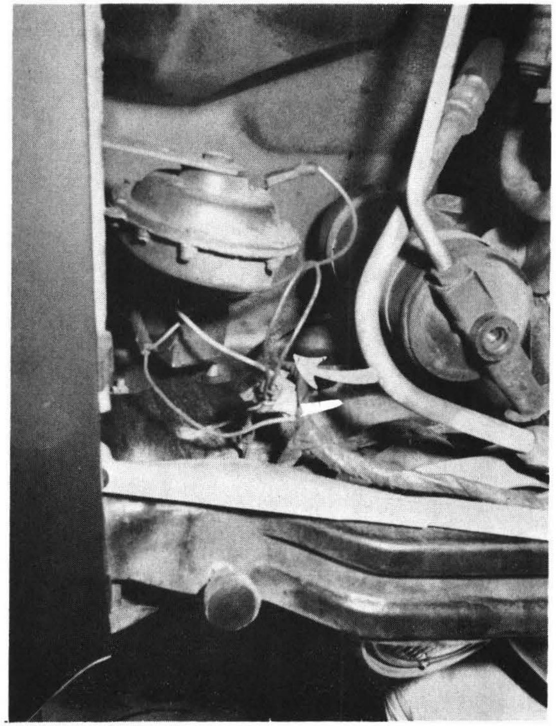


Figure 3-75. 1966 Buick Riviera - Loose Electrical Wires

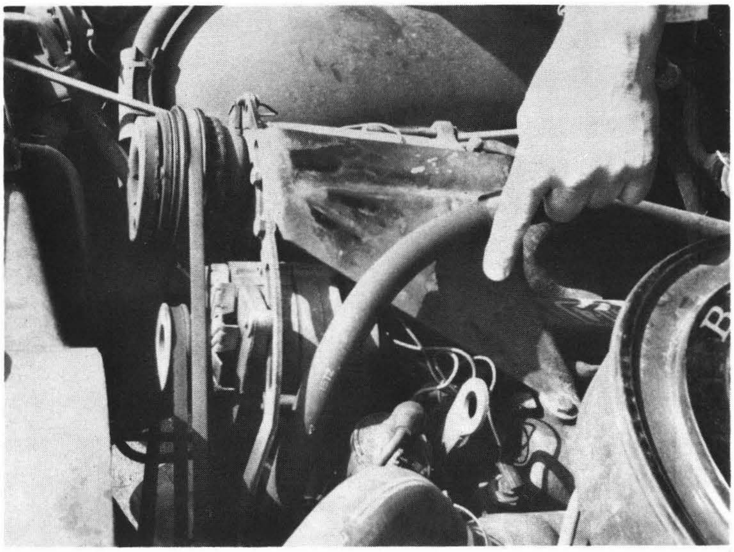


Figure 3-76. 1967 Buick Riviera - Loose, Unprotected Wires

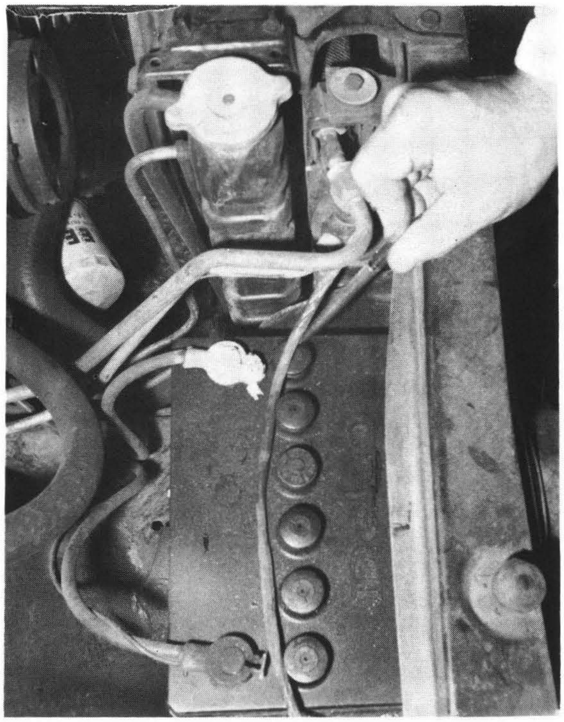


Figure 3-77. Buick LeSabre - Harness Proximity to Battery

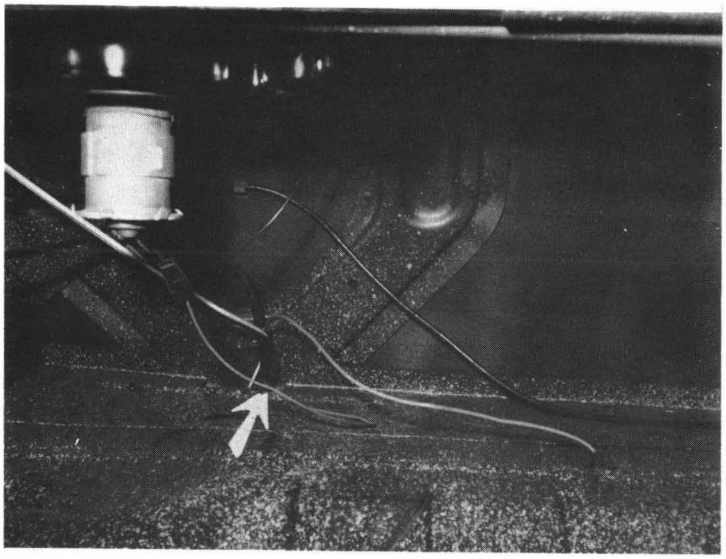


Figure 3-78. 1968 Buick LeSabre - Loose Wires in Luggage Compartment

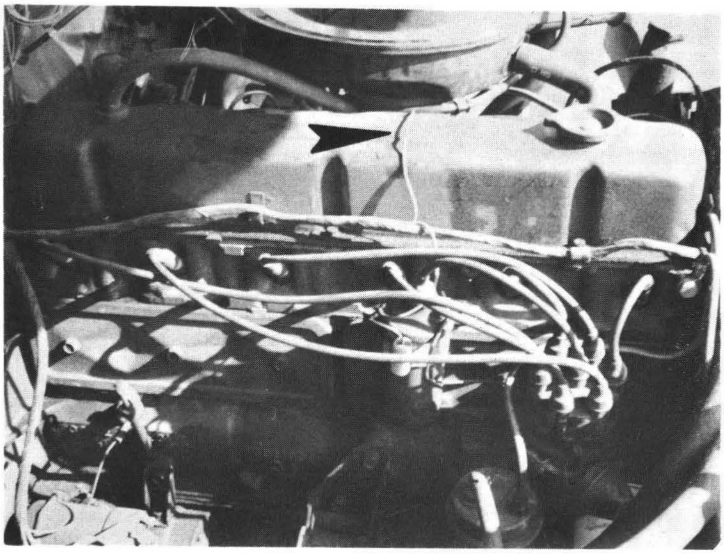


Figure 3-79. 1968 Buick Special - Electrical Wiring over Engine

3. Conclusion

It must be emphasized that the passenger vehicle electrical features observed, described, and illustrated in the foregoing are those that were readily visible. Much of the electrical system is hidden from view and is inaccessible without considerable disassembly. It is difficult to determine the condition of the hidden items, unless they are malfunctioning. What may result after crash impacts and distortions is an unknown of much greater magnitude.

The schematics appearing in the manufacturers' service manuals do not realistically portray the physical character of the components, wiring, connectors, etc. Careful attention to the safety aspects of the construction, spatial relationships and workmanship of the vehicle's electrical system is essential to the development and production of crash resistant electrical systems.

D. SUMMATION OF SYSTEMS INTERACTION

1. Problem Areas

a. Motorcycles

The compact arrangement of these vehicles and the almost total lack of engine or exhaust shielding make them subject to fuel/exhaust/electrical systems related fires. The usual cause is fuel spillage or leakage. The fuel loss may occur without collision or skid. There is always a high probability of fire caused by fuel contacting the hot engine or exhaust components.

b. Passenger Vehicles

The fuel/exhaust/electrical system design features and the principal crash fire threats may be listed as follows:

- The filler pipe assembly usually terminates at the exterior of the vehicle and the tailpipe may be under and close to the filler cap.

- The fuel line to fuel pump is usually metal, but flexible hose connections with clamps are used at tank pickup and fuel pump. Flexible hose connections may be broken by crash impact.

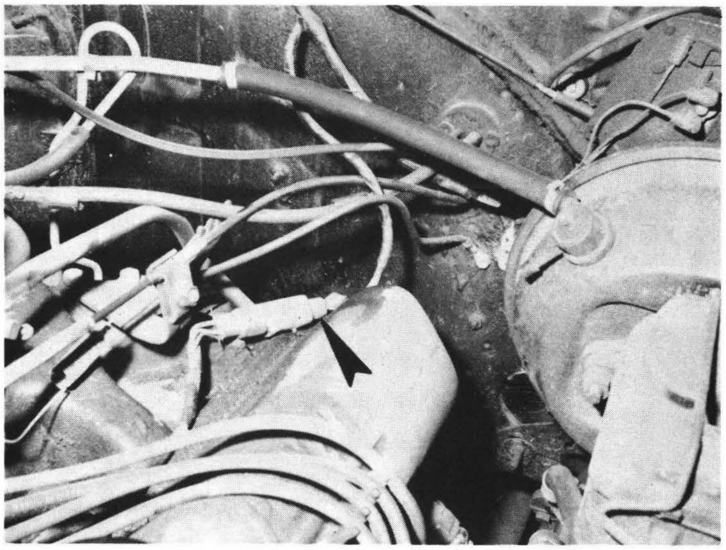


Figure 3-94. 1967 Ford LTD Electrical Wiring over Valve Cover

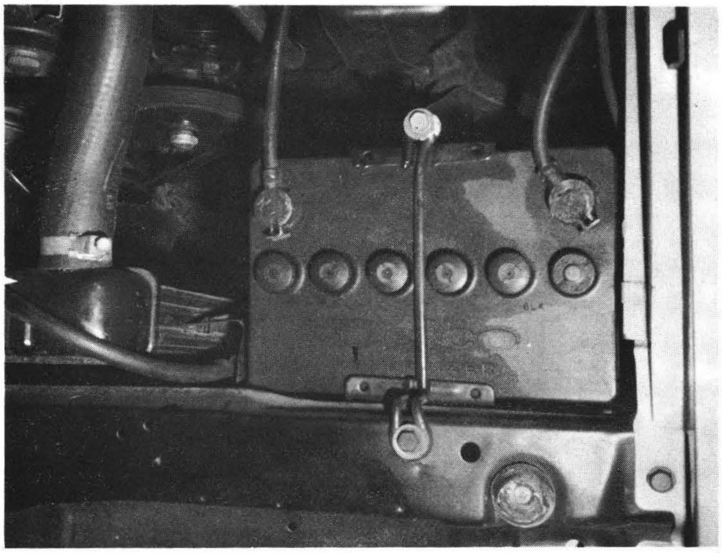


Figure 3-95. 1967 Pontiac LeMans Battery Location

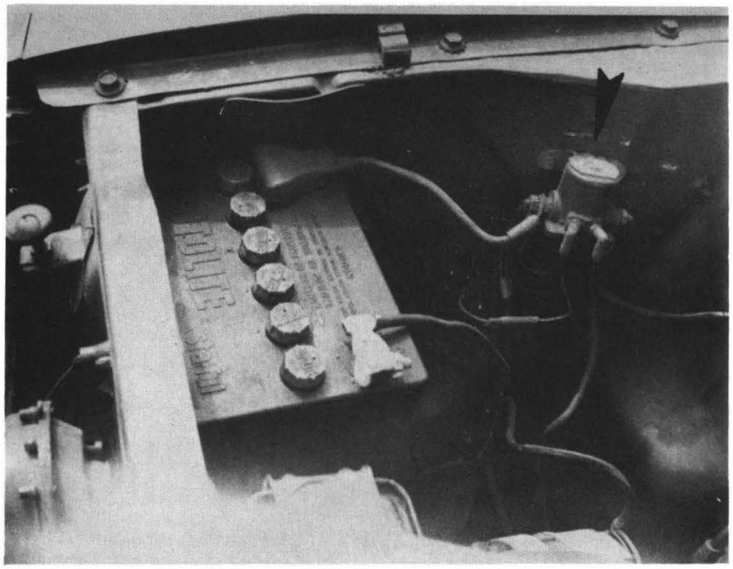


Figure 3-92. 1966 Ford Mustang Battery Location

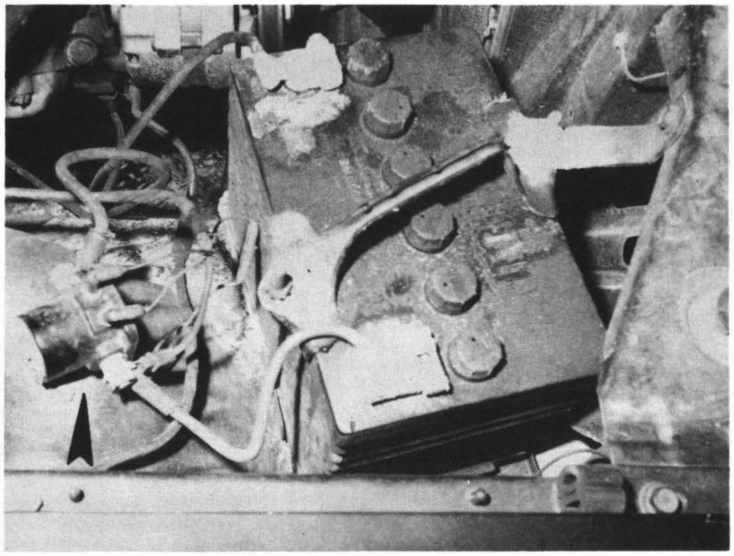


Figure 3-93. 1967 Ford LTD Relay Proximity to Battery

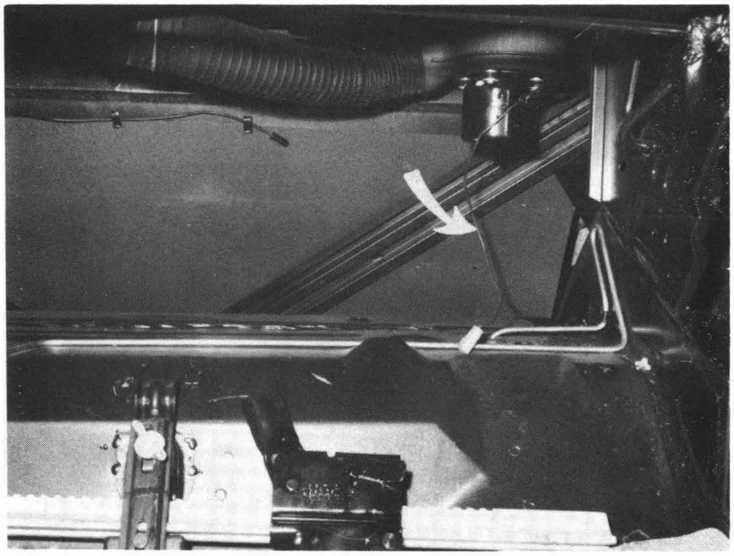


Figure 3-90. 1968 Dodge Coronet 440 Luggage Compartment Wiring

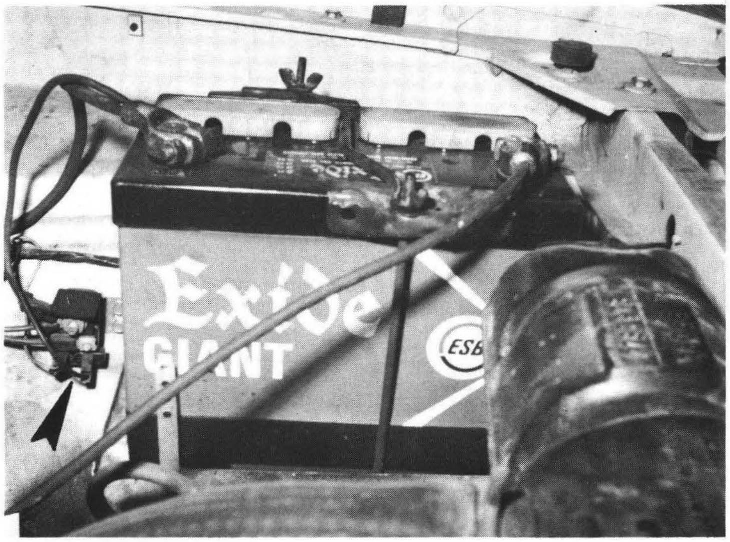


Figure 3-91. 1967 Dodge Dart Relay Proximity to Battery

m. 1967 Dodge Dart

The battery of this vehicle is at the extreme front end of the engine compartment, on the left side. The battery is vulnerable to front impact. Other undesirable electrical features are the relay and the wiring harness shown alongside the battery (Figure 3-91).

The same features are repeated in the 1968 Dodge Dart.

n . 1966 Ford Mustang

The battery is at the extreme front right of the engine compartment, and the lack of crush space makes it vulnerable to front or front-side impact (Figure 3-92). The unprotected loose wires running from the relay are more vulnerable to damage than a grouped, insulation-covered harness and present another undesirable feature. The boot at the battery position terminal is an effective, economical shield against short circuit at a high capacity electrical point.

o. 1967 Ford LTD

The battery is at the engine compartment front right, and, although the crush space is limited, the radiator support affords some protection against front impact. The relay, with its loose wires, below and behind the battery is not a desirable feature (Figure 3-93).

A harness coupling lying on the left valve cover is also not a desirable feature (Figure 3-94). The four high tension spark plug leads that are shown in this photograph are positioned by a rack that helps to keep these leads off the valve cover at one point, but does not succeed in holding them away at other points. In the event of a crash, good condition of the insulation may prevent short circuits from occurring.

p. 1967 Pontiac LeMans

The battery location at the extreme front left of the engine compartment provides little crush space protection against front impact (Figure 3-95).

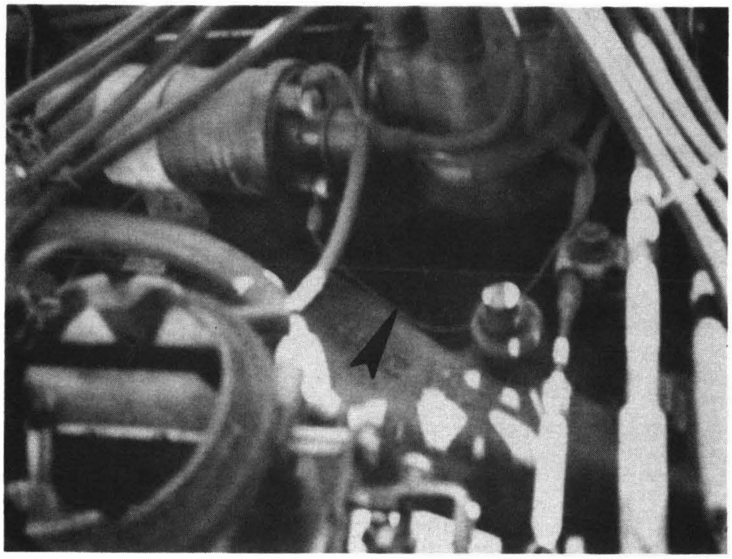


Figure 3-88. 1967 Dodge Coronet 500 High Tension Wire Location

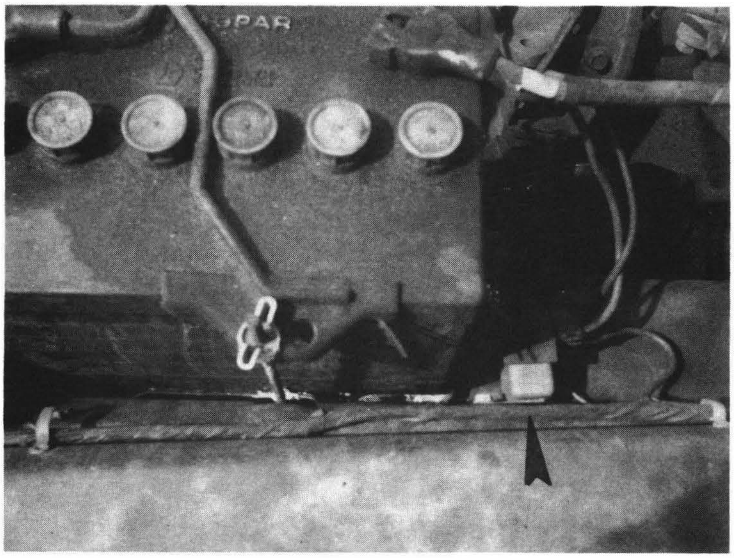


Figure 3-89. 1968 Dodge Coronet 440 Relay Proximity to Battery

Figure 3-86. 1966 Dodge Polara Electrical Wiring

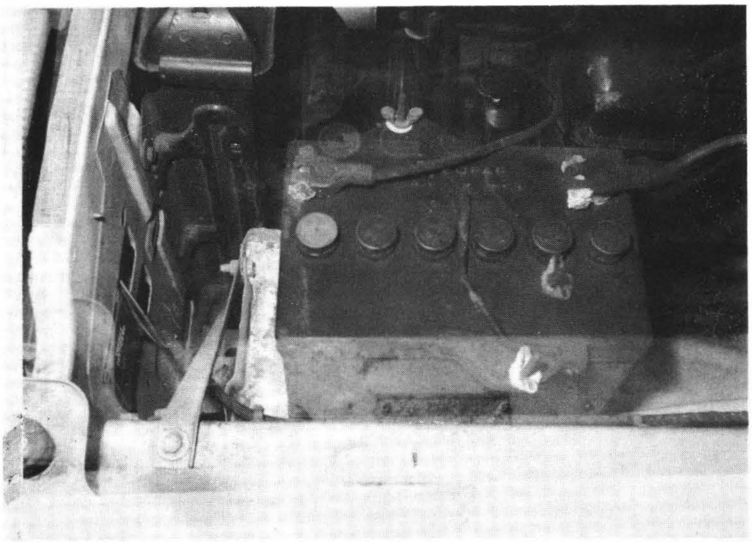


Figure 3-87. 1967 Dodge Coronet 500 Battery Location

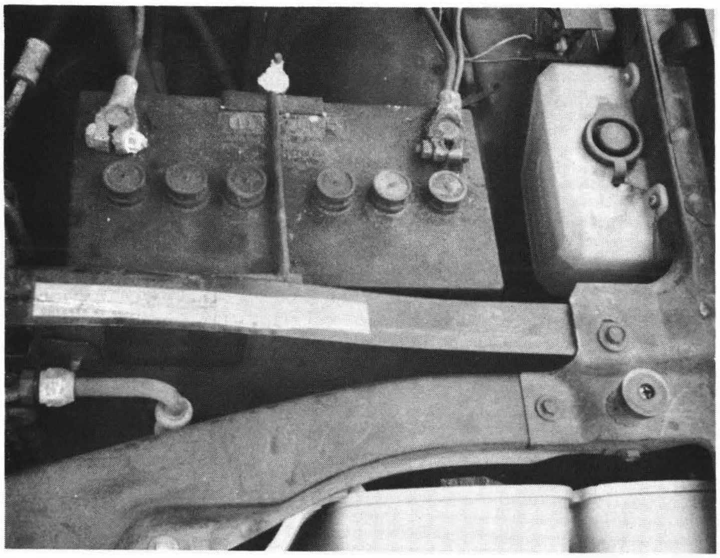


Figure 3-84. 1968 Chrysler New Yorker
Battery Location

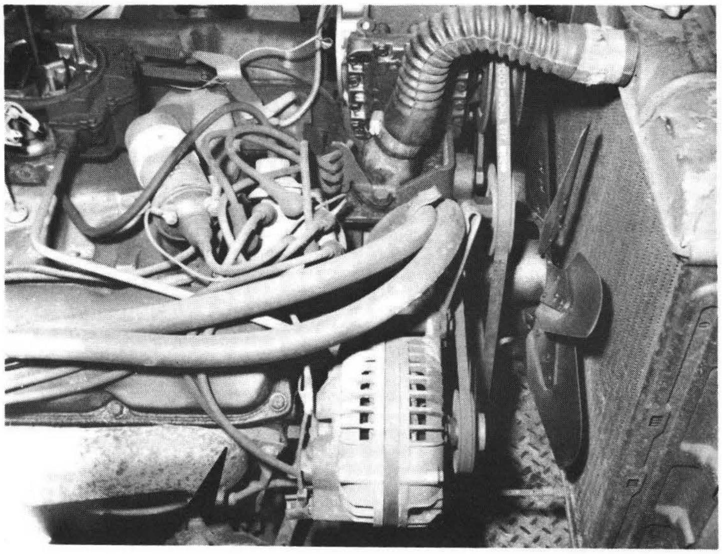


Figure 3-85. 1966 Dodge Polara High Tension Wires
over Exhaust Manifold

j. 1966 Dodge Polara

High tension spark plug leads are shown lying on an exhaust manifold (Figure 3-85). Longer leads, with supports to keep the leads away from hot engine parts would lessen the possibility of short circuits in operation or crash situations. The wiring routing and retention at the left front fender shows good design (Figure 3-86). The harnesses are isolated from the exhaust components, and the engine and the fender structure act as barriers to crash damage to the wiring. It is interesting to note that in the same vehicle there are both desirable and undesirable electrical features.

k. 1967 Dodge Coronet 500

The battery in this vehicle is at the left side, near the front of the engine compartment (Figure 3-87). The means of support are typical. A desirable feature is the space between the battery and the front structure, which gives a degree of protection against the effects of front impact.

An undesirable feature, however, is the high tension wire running from the ignition coil to the distributor. As shown in Figure 3-88, it lies against the intake manifold. Abrasion and temperature approximating 200° F may degrade the insulation with the possibility of short circuiting during operation or from impact effects.

l. 1968 Dodge Coronet 440

A connector and relay are placed below the top and immediately behind the battery. This subjects a vulnerable electrical component to operational deterioration or to the effects of battery displacement from front impact, which could lead to short circuiting that could cause a fire (Figure 3-89).

A view of the forward end of the trunk compartment shows the rear window defogger motor connected by a loose wire rising from the floor. Another wire (not connected to any light or accessory in this vehicle) is firmly clipped to the rear fire wall. Desirable and undesirable wiring methods are contrasted in this illustration (Figure 3-90).

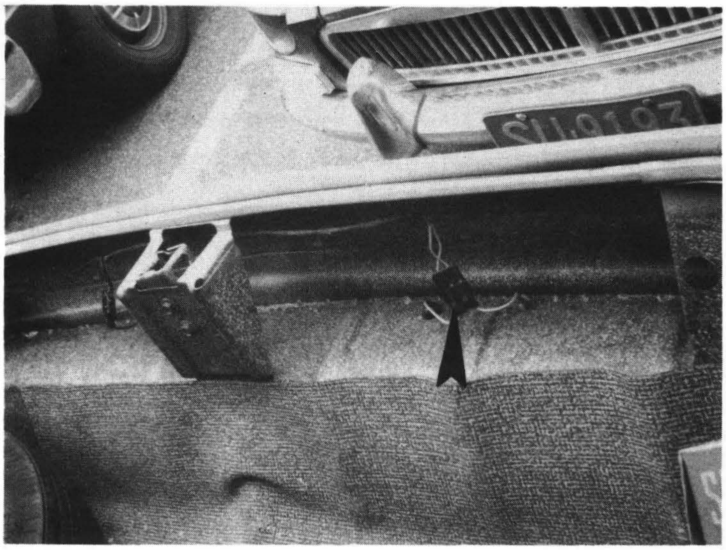


Figure 3-82. 1968 Chevrolet Chevelle Trunk Compartment Wiring

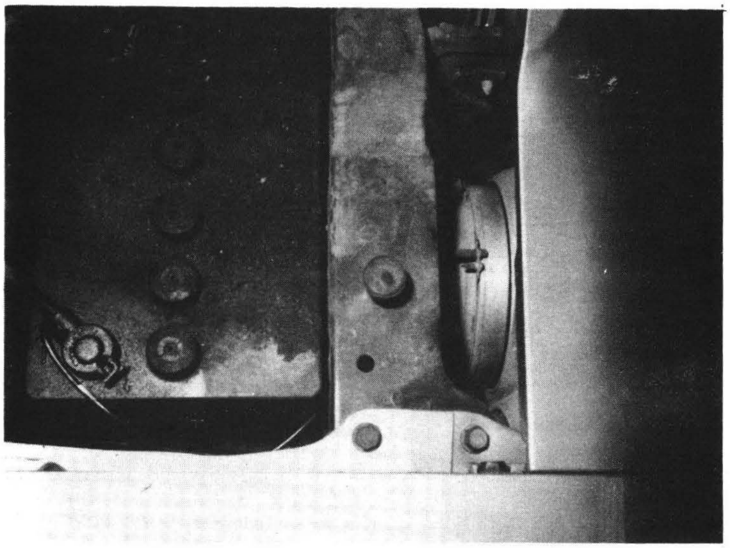


Figure 3-83. 1968 Chevrolet Impala SS Battery Location

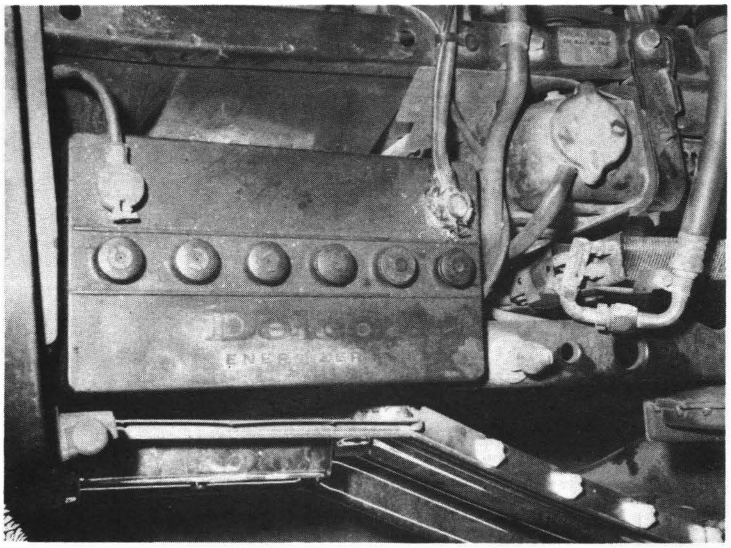


Figure 3-80. 1966 Cadillac Coupe de Ville Battery Location

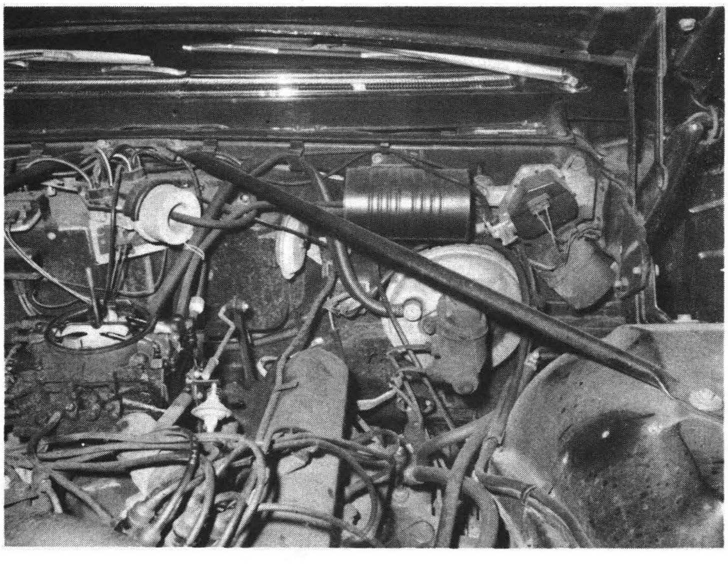


Figure 3-81. 1966 Cadillac Coupe de Ville Electrical Wiring

operating temperature at the valve cover would probably not exceed 250°F, this is sufficient to cause insulation deterioration. With the insulation embrittled, crash deceleration could cause short circuiting and possible fire. The routing of this harness is not good design, whereas running the harness away from the engine is feasible and would result in greater safety.

f. 1966 Cadillac Coupe de Ville

The battery is at the extreme front right side of the engine compartment, and vulnerable to front impact damage and displacement (Figure 3-80). Except for a cable at the left end, the immediate battery area is clear of any other wiring which could be affected by the battery acid.

The left side of the firewall, as shown in Figure 3-81, carries a complex maze of wires that would probably not be electrically safe after damage in this region.

g. 1968 Chevrolet Chevelle Convertible

The wiring for the entire rear end of this vehicle, including the tail, stop, directional signal, and license plate lights is made up in a harness which runs loosely at the rear panel of the trunk compartment (Figure 3-82). The wiring is vulnerable to damage from loose objects in the trunk compartment.

h. 1968 Chevrolet Impala SS

The battery is at the right front of the engine compartment. The body metal, radiator support, and right front fender provide some protection against crash impact (Figure 3-83).

i. 1968 Chrysler New Yorker

The battery is at the left side, near the front of the engine compartment. The location provides crush space guarding the battery against front and side impacts. If the relay (visible at the edge of Figure 3-84) had been positioned farther to the rear, it would be better protected from the effects of battery acid corrosion. The arrangement shown is better than that of most passenger vehicle battery mountings.

- The fuel line is clip supported by frame members. Crash-caused frame failure may break the fuel lines.

- The exhaust system front piping is usually well separated from the fuel system components, but the rear pipes may run in proximity to the fuel line and terminate close to the tank.

- Mufflers or resonators are frequently close to the fuel tank.

- The rear axle region, in front engined vehicles, is usually crowded with the fuel tank, exhaust piping, and fuel line. Sometimes a muffler or resonator is located between the axle and the front end of the fuel tank.

- Fuel spillage may be accompanied by electrical sparking from any of the three unprotected, heavy current battery circuits.

- Any of the other electrical circuits, although protected, may, by shorting, ignite fuel vapor.

- Fuel, spilled or sprayed on hot exhaust components, may ignite.

c. Trucks

Light trucks have fuel, exhaust, and electrical systems that are similar to passenger vehicles. Their problems are also similar.

Medium trucks present different problems. Cab mounted fuel tanks placed under the seat eliminate direct crash effects. Externally mounted fuel tanks and batteries are susceptible to direct impact. The compact exhaust system, terminating under the body chassis, near the center, is the usual arrangement and is protected from direct impact. The electrical systems vary in accordance with service requirements. Some medium trucks may be special purpose carriers, such as refrigerated trucks, and the refrigeration compressor may be electrically powered. The variety of truck electrical systems applications and the range of problems that may arise can be analyzed only by extensive study.

Some of the interrelating system problems that may arise subsequent to accident are as follows:

- Fuel spillage from fuel line or fuel tank failure or truck rollover contacting hot components
- Electrical failure igniting combustible cargo or spilled fuel
- Electrical sparking from short circuits in cab and vapor from cab fuel tank leakage

Truck tractors and heavy trucks have problems similar to those mentioned for medium trucks. All the parameters involved are larger in magnitude and the effects are greater.

d. Busses

Most small school busses are front engined. Other busses such as large school, local transit, and long distance coach types are rear engined. Front engined busses have systems problems closely related to those of medium trucks. Except for the hazard created by the high quantity of fuel carried by long distance busses, rear engined busses have fewer fire problems created by the fuel/exhaust/electrical systems relation than other vehicles. The heavy construction, and the separation from occupant compartment of the engine and fuel system, decrease the fire hazard. The exhaust system is very compact. In many cases the muffler is in the engine compartment and the tail pipe is the only component outside. The electrical systems of busses are more extensive and complex than those of trucks. Air conditioning controls, public address system, lavatory accessories, door actuator controls, and the interior lighting require many long wiring runs.

An accident may affect many circuits with electrical fires as a result.

Briefly stated, the bus fuel/exhaust/electrical systems problems relevant to post crash fire are as follows:

- Front engined small school busses have the multiple systems problems common to light trucks and passenger vehicles.
- Fuel tanks on small school busses are sometimes located under the body near an exit door adding to a fire danger.
- With the exception of the problems created by the high fuel capacity and complex wiring, large rear engined busses are relatively safer from fire hazard than other types of passenger vehicles.

2. Examples of Current Practice

Some actual cases of design that involve fuel/exhaust/electrical systems relationships and increase fire hazard are listed for passenger vehicles as follows:

- Fuel line with filter and hose connections running over and close to engine components (Figure 3-27)
- Fuel line running close to high tension cables and distributor (Figure 3-43)
- Electrical harness supported on valve cover by bare metal clips (Figure 3-79)
- High tension lead from ignition coil to distributor touching intake manifold and 5 inches away from fuel line (Figure 3-88)
- High tension leads from distributor to spark plugs in close contact with fuel hose running from fuel pump to carburetor (Figure 3-96)

Figure 3-96. Fiat 124 Sedan Fuel Line Contact with High Tension Leads

E. REFERENCES

3-1 Letter with enclosure from Gerald J. Snyder, Snyder Tank Corporation, 3 January 1969.

3-2 "Gravity or Siphon Feed Prohibited," Motor Carrier Safety Regulation § 293.65, Para. c.

3-3 Chevrolet Motor Division, "1965 Chevrolet Corvair Chassis Shop Manual," 1964, p. 8-1.

SECTION IV

TABULATIONS OF FUEL/EXHAUST/ELECTRICAL SYSTEMS CHARACTERISTICS

Data relative to the fuel, exhaust and electrical system features of 1966, 1967 and 1968 domestic passenger cars, 1967 and 1968 models of certain foreign passenger cars, and 1967 and 1968 models of certain trucks, busses and motorcycles were collected and analyzed. In addition to data collection and research, a program of physical examination of vehicles in the field was conducted, and significant findings were derived from these case studies. Tables 4-1 through 4-7 in this section reveal, in tabular form, those vehicle characteristics having a potential relationship to crash fire hazards.

TABLE 4-1. FUEL SYSTEM - FUEL TANK

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
Buick Le Sabre 1968 - V 8	26	Steel terne-coated .03 in.	Rear center under trunk floor, 9 in. from side rails, 4-1/2 in. forward of rear cross member, 13 in. forward of rear bumper	Two 1 in. straps, bolted at rear and hooked at front	None
Buick Riviera 1966 - V 8	20	Steel terne-coated .03 in.	Right rear side between stabilizer bar and rear cross member, and between right side rail and spare tire well	Two straps bolted to spare tire well and hooked to right frame rail	Under severe rear impact the following conditions may result: bumper and rear cross member may become dislodged and puncture the fuel tank, fuel tank may also be driven forward allowing stabilizer to pierce front of tank
Buick Riviera 1967 - V 8	20	Steel terne-coated .03 in.	Right rear side between stabilizer bar and rear cross member, and between right side rail and spare tire well	Two straps bolted to spare tire well and hooked to right frame rail	Under severe rear impact the following conditions may result; bumper and rear cross member may become dislodged and puncture the fuel tank,

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
					fuel tank may also be driven forward allowing stabilizer to pierce front of tank.
Cadillac Coupe deVille 1966 - V 8	26	Steel terne-coated .03 in.	Rear center under trunk floor, 9 in. from left side rail, 4 in. forward of rear cross member, 14 in. forward of bumper, 4 in. aft of axle housing.	Two 1 in. straps bolted at the rear and hooked at the front	In the event of severe rear end collision the bumper and rear cross member may become dislodged, puncturing the fuel tank
Chevrolet Chevelle 1968 - V 8	21	Steel terne-coated .03 in.	Rear center, under trunk compartment floor, 1-1/2 in. from side rails, 10 in. forward of rear cross member, 13 in. forward of rear bumper, and 8 in. aft of rear axle housing	Two, 1-3/16 in. straps bolted at the rear and hooked at the front	None
Chevrolet Impala 1968 - V 8	20	Steel terne-coated .03 in.	Rear center under trunk floor, 5 in. from side rails, 3-1/2 in. forward of	Two 1-1/8 in. straps bolted at rear and hooked at front	None

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
			rear cross member, 11 in. forward of rear bumper, 10 in. aft of rear axle housing		
Chrysler New Yorker 1968 - V 8	25	Steel terne-coated .03 in.	Rear center under trunk floor, 2 in. from left side rail, 4-1/2 in. from right side rail, 1 in. forward of rear cross member, and 6 in. aft of rear axle	Two straps, 1-1/8 in. wide, 1-1/8 in. thick, bolted at the front and hooked at rear	The rear of the fuel tank is in contact with the rear cross member. In the event of rear impact, the rear cross member may rupture the fuel tank
Dodge Coronet 440 1966 - V 8	21	Steel terne-coated .03 in.	Rear center, 3 in. aft of axle, 11 in. from side rails, and 28 in. forward of bumper	One strap, 1-1/2 in. wide 1/16 in. thick, 8 in. rearward of tank front, bolted to right side rail, and hooked to left side rail	Under severe rear impact the following conditions could result: spare tire well may push tank forward into rear axle rupturing tank; the side rails could buckle and pierce the sides of the fuel tank

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
Dodge Coronet 500 1967 - V 8	21	Steel terne-coated .03 in.	Rear center, 3 in. aft of axle, one in. from side rails, and 28 in. forward of bumper	One strap, 1-1/2 in. wide 1/16 in. thick, 8 in. rearward of tank front, bolted to right side rail, and hooked to left side rail	Under severe rear impact the following conditions could result: spare tire well may push tank forward into rear axle rupturing tank; the side rails could buckle and pierce the sides of the fuel tank
Dodge Coronet 440 1968 - Slant 6	21	Steel terne-coated .03 in.	Rear center under trunk floor, 5 in. from side rails, 1-1/2 in. forward of rear cross member, 10 in. forward of bumper, and 5 in. aft of rear axle housing	Two, 1-1/8 in. wide and 1/16 in. thick, straps bolted at the front and hooked at the rear	The rear cross member is 1-1/2 in. from tank. In the event of rear impact, the cross member may become dislodged and rupture the fuel tank.
Dodge Dart G.T. 1967 - V 8	19	Steel terne-coated .03 in.	Rear center under trunk floor, 1 in. from right side rail, 4 in. from left side rail, 19 in. forward of rear cross member, 28 in. forward of bumper,	Single strap, 1-1/2 in. wide, bolted to right side rail and hooked to left rail	Under severe rear impact the following conditions could result: spare tire well may push tank forward into rear axle rupturing tank; the side

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
			and 3 in. aft of rear axle housing		rails could buckle and pierce the sides of the fuel tank
Dodge Dart 1968 - Slant 6	19	Steel terne-coated .03 in.	Rear center under trunk floor, 1 in. from right side rail, 4 in. from left side rail, 19 in. forward of rear cross member, 28 in. forward of bumper and 3 in. aft of rear axle housing	Two, 1-1/8 in. straps bolted at the rear and hooked at the front	Under severe rear impact the following conditions could result: spare tire well may push tank forward into rear axle rupturing tank; the side rails could buckle and pierce the sides of the fuel tank
Dodge Polara 1966 - V 8	25	Steel terne-coated .03 in.	Rear center under trunk compartment floor, 1-1/2 in. from left side rail, 5-1/2 in. from right side rail, 1 in. forward of rear cross member, 12 in. forward of rear bumper, 3 in. aft of axle housing	Two 1 in. straps bolted at the rear and hooked at the front	In the case of rear impact, the bumper and rear cross member may be driven forward allowing the displaced metal to rupture the fuel tank.

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
Ford Cortina 1968 - Straight 4	10	Steel terne-coated .03 in.	Rear center, 4-1/2 in. from right side rail, 12 in. from left side rail, 7 in. forward of bumper, and 11-1/2 in. aft of rear axle housing	The fuel tank is part of the trunk floor. The top portion has a flange around it with provisions for three hold down screws on each of its four sides	There is very little protection from rear collision. Depending on the extent of impact the damage may vary from tank deformation to tank dislocation or rupture
Ford Fairlane 500 Station Wagon 1967 - V 8	20	Steel terne-coated .03 in.	Left rear quarter panel, 9 in. forward of bumper	Single strap, 1-1/2 in. wide, bolted to side rail and hooked to inside of quarter panel	In the event of a moderate impact to rear section of left quarter panel, or a severe impact to rear, the tank may be ruptured
Ford Galaxie 500 1967 - V 8	25	Steel terne-coated .03 in.	Centered 5 in. aft of rear axle, 2-1/2 in. from side rails, 31 in. forward of rear cross member, 35 in. forward of rear bumper	Two 1-1/4 in. straps bolted at the rear and hooked at the front	None

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
Ford LTD 1967 - V 8	25	Steel terne-coated .03 in.	Centered 5 in. aft of rear axle, 2-1/2 in. from side rails, 31 in. forward of cross member, 35 in. forward of rear bumper	Two 1-1/4 in. straps bolted at the rear and hooked at the front	None
Ford Mustang 1966 - V 8	16	Steel terne-coated .03 in.	Rear center, 7 in. from right side rail, 4 in. from left side rail, and 9 in. forward of bumper	The fuel tank is part of the trunk floor. The top portion has a flange around it, with provisions for two hold down screws on each of its four sides	In the event of rear collision, the fuel tank may be punctured by displaced bumper metal or, if impact is severe, enough, the tank could be dislodged from its mounting and ruptured
Mercury Monterey 1966 - V 8	25	Steel terne-coated .03 in.	Centered, 5 in. aft of rear axle, 2-1/2 in. from side rails, 32 in. forward of rear cross member, and 37 in. forward of bumper	Two, 1-1/8 in. straps bolted at the rear and hooked at the front	None

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
Oldsmobile Cutlass 1968 - V 8	20	Steel terne-coated 0.3 in.	Centered 3-1/2 in. aft of rear axle, 1-1/2 in. from side rails, 8 in. forward of cross member, 17 in. forward of rear bumper	Two 1 in. straps bolted at the front and hooked at the rear	None
Pontiac Le Mans 1967 - V 8	22	Steel terne-coated 0.3 in.	Rear center under trunk floor, 1-1/2 in. from side rails, 2-1/2 in. forward of rear cross member, 12 in. forward of rear bumper, and 11 in. aft of rear axle housing	Two straps, 1 in. wide bolted at rear and hooked at front	In the event of severe rear impact the bumper and rear cross member may be driven forward rupturing the tank
Rambler American 1967 - Straight 6	16	Steel terne-coated .03 in.	14 in. from left frame rail, 4 in. to right frame rail, 1 in. to rear cross member	Single strap from front to rear cross member	In the case of rear impact, the bumper and rear cross member may be driven forward allowing the displaced metal to rupture the fuel tank

TABLE 4-1. FUEL SYSTEM - FUEL TANK (Cont'd)

Vehicle Identification and Engine Type	Tank Capacity (Gal)	Tank Material	Tank Location	Tank Mounting	Tank Vulnerability
Toyota 1900 1968 - Straight 4	11.5	Steel terne-coated .03 in.	Rear center, 2-1/2 in. from right side rail, 8-1/2 in. from left side rail, 8 in. forward of bumper, and 6 in. aft of axle housing	The fuel tank is part of the trunk floor. The top portion has a flange around it, with provisions for three hold down screws on each of its four sides	Depending on the extent of impact, the damage may vary from tank deformation to tank dislocation or rupture

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
Buick Le Sabre 1968 V 8	The filler pipe terminates behind the license plate, located in the center of the bumper, 12 in. rearward of tank	The filler pipe may be damaged in the event of rear collision. Because of the crush distance between the bumper and tank, the impact would have to be severe to cause rupture	The vent pipe is routed upward from the front right side of the tank and terminates at the frame rail	Impact - none Rollover - the fuel could siphon out
Buick Riviera 1966 V 8	The filler pipe exits from top left rear corner of fuel tank, extending upward at approximately a 45° angle over the rear cross member, terminating behind the license plate, located in the center of the rear panel between the trunk hood and bumper. Filler pipe OD is 2 in.	Under rear impact, rear cross member (which filler pipe rests against) could possibly shear filler pipe	Approximately 2 in. of hose connects the vent pipe to the front, top right corner of the fuel tank. The vent pipe is then routed upward along the right rear wheel well into the trunk compartment for 6 in., then loops downward and terminates 5 in. under trunk compartment floor	Impact - none Rollover - the fuel could siphon out

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
Buick Riviera 1967 - V 8	The filler pipe exits from top left rear corner of fuel tank, extending upward at approximately a 45° angle over the rear cross member, terminating behind the license plate, located in the center of the rear panel between the trunk hood and bumper. Filler pipe OD is 2 in.	Under rear impact, rear cross member (which filler pipe rests against) could possibly shear filler pipe	Approximately 2 in. of hose connects the vent pipe to the front, top right corner of the fuel tank. The vent pipe is then routed upward along the right rear wheel well into the trunk compartment for 6 in., then loops downward and terminates 5 in. under trunk compartment floor	Impact - none Rollover - the fuel could siphon out
Cadillac Coupe de Ville 1966 - V 8	The filler pipe exits from the center rear of the tank and is radiused upward through the rear cross member, terminating behind the license plate located in the bumper	A section of the filler pipe, fabricated of rubber hose, is routed through a hole in the rear cross member. This hose may be sheared if impact is severe	The vent pipe exits from the front center of tank, travels upward to trunk floor and is routed in a four inch "U" pattern	Impact - none Rollover - the fuel could siphon out

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
Chevrolet Chevelle 1968 - V 8	The filler pipe exits from the rear top center of the tank, is routed upward for 13 in., and terminates behind the license plate, located in the center of the bumper	Damage to the filler pipe may occur from rear impact. The probability of this damage extending to the fuel tank, unless the impact is severe, is unlikely	There are two vent pipes. They are routed from the front right side of the tank, upward for 10 in. to the trunk floor and terminating there	Impact - none Rollover - Fuel could siphon out
Chevrolet Impala Super Sport 1968 - V 8	The filler pipe exits from the rear top center of the tank and is routed upward for 10 in. terminating behind license plate, located in the center of the bumper.	The filler pipe can be damaged on most rear impacts. The probability of this damage extending to the fuel tank is unlikely, unless the impact is severe	The vent is routed from the front right side of tank upward to trunk compartment floor, right to side rail, into trunk compartment upward in an inverted "U" pattern and terminates at the same location where it entered	Impact - none Rollover - the fuel could siphon out
Chrysler New Yorker 1968 - V 8	The filler pipe exits from the rear top center of the tank, is routed rearward	The filler pipe could be damaged from rear collision. The extent of this damage	Two vent pipes exit from the front upper left of the fuel tank. One vent pipe terminates at the	Impact - none Rollover - the fuel could siphon out

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
	for 10 in. and terminates behind license plate, located in the center of the bumper	will vary with the degree of impact	left shock mount. The second is routed into trunk compartment, upward along wheel well, loops down through trunk floor and terminates there	
Dodge Coronet 440 1966 - V 8	The filler pipe exits from the rear left side of tank, extends rearward for 8 in. left 13 in., upward into middle of quarter panel and terminates behind an access door	Impact to left rear quarter panel may damage filler pipe	The vent pipe is routed next to the filler pipe, terminating 3 in. before filler cap	Impact - Proximity to left rear quarter panel Rollover - the fuel could siphon out
Dodge Coronet 500 1967 - V 8	The filler pipe exits from the rear left side of tank, extends rearward for 8 in. left 13 in. upward into middle of quarter panel and terminates behind an access door	Impact to left rear quarter panel may damage filler pipe	The vent pipe is routed next to the filler pipe, terminating 3 in. before filler cap	Impact - Proximity to left rear quarter panel Rollover - the fuel could siphon out

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
Dodge Coronet 440 1968 - Slant 6	The filler pipe exits the rear top center of fuel tank, is routed rearward for 10 in., and terminates behind license plate, located in the center of the bumper	Under rear impact the filler pipe could be sheared because of its routing through the rear cross member. If impact is severe enough, the filler pipe may also puncture fuel tank	Two vent pipes, 1/4 in. OD each, exit from the left front of fuel tank. They are routed upward to trunk floor. One terminates there and the other proceeds into trunk compartment, crosses trunk floor to right wheel housing and terminates on the underside of the car by the wheel housing	Impact - none Rollover - the fuel could siphon out
Dodge Dart G.T. 1967 - V 8	The filler pipe exits from the left side of tank, travels upward through trunk compartment and out rear quarter	Impact to left rear quarter panel may damage filler pipe but the probability of this damage extending to the fuel tank is unlikely	The vent pipe, after leaving tank, is clipped to the filler pipe and terminates at filler cap	Impact - none Rollover - the fuel could siphon out
Dodge Dart 1968 - Slant 6	The filler pipe exits from the left side of tank, travels upward through trunk	Impact to left rear quarter panel may damage filler pipe but the probability of this	The vent pipe, after leaving tank, is clipped to the filler pipe and terminates at filler cap	Impact - none Rollover - the fuel could siphon out

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
	compartment and out rear quarter	damage extending to the fuel tank is unlikely		
Dodge Polara 1966 - V-8	The filler pipe exits from the rear top center of tank, terminating behind the license plate, located in the lower section of the bumper	The filler pipe could be damaged from rear collision. The extent of this damage will vary with the degree of impact. The most severe condition would drive the rear cross member and bumper forward, shearing the filler pipe and rupturing the fuel tank	Two vent pipes exit the fuel tank from the front upper left corner. One vent pipe terminates at the left upper shock mount. The other procedes into the trunk compartment, upward along left rear wheel well for 8 in. then loops down to trunk floor, extends behind the spare tire mount and through the trunk floor terminating there	Impact - none Rollover - the fuel could siphon out
Ford Cortina 1968 - Straight	The filler pipe is located in the trunk compartment. It exits the tank at the right rear corner and is directed upward	From any rear impact the filler pipe will be dislocated. The pipe is also vulnerable to damage while loading trunk	Vented cap	None

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
	to the rear panel. The filler cap is exposed			
Ford Fairlane 500 Station Wagon 1967 - V 8	The filler pipe begins behind a door in the left quarter panel and is slanted downward to fuel tank top	The filler pipe could be driven into the fuel tank if impacted from the left side	Vented cap	None
Ford Galaxie 500 1967 - V 8	The filler pipe exits the fuel tank from the upper left side, extends upward through left side rail, and travels across the wheel well into the left quarter panel	None	Vented cap	None
Ford LTD 1967 - V 8	The filler pipe exits the fuel tank from the upper left side, extending upward through left side rail and	None	Vented cap	None

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
	across the wheel well into the left quarter panel			
Ford Mustang 1966 - V 8	The filler pipe is located in the trunk compartment. It exits the tank at the right rear corner and is directed upward to the rear panel. The filler cap is exposed.	The filler pipe could be damaged on rear impact. The pipe is also vulnerable to damage while loading trunk	Vented cap	None
Mercury Monterey 1966 - V 8	The filler pipe exits the fuel tank from the upper left side, extends upward through left side rail, and travels across the wheel well into the left quarter panel	None	Vented cap	None
Oldsmobile Cutlass 1968 - V 8	The filler pipe exits from the rear top center of	The filler pipe can be damaged from severe rear	The vent is routed from the front right side of tank upward	Impact - none Rollover - the

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
	fuel tank. It extends upward, terminating behind the license plate	impact. The likelihood of it doing damage to the fuel tank is minimized due to the corrugated filler pipe	to trunk floor terminating there	fuel could siphon out
Pontiac Le Mans 1967 - V-8	The filler pipe exits from the rear top center of the tank, is routed 12 in. rearward, and terminates behind the license plate located in the center of the bumper	The filler pipe could be damaged from rear impact	A 1/4 in. steel pipe exits the top of filler pipe 2 in. before filler cap and is routed straight upward into trunk for 5 in. then looped downward, terminating below the trunk floor	Impact - the vent pipe may be torn loose from filler pipe Rollover - the fuel could siphon out
Rambler American 1967 - Straight 6	The filler pipe exits from the rear center of tank routed upward, terminating behind license plate, located in the rear panel between the trunk hood and bumper	The filler pipe can be damaged on most rear collisions. It may also be driven forward along with the rear cross member and bumper rupturing the fuel tank	The vent pipe exits the filler pipe as it passes through the trunk. It is then routed along rear panel to the right quarter panel where it is looped forward and then back and out the trunk floor terminating there	Impact - none Rollover - the fuel could siphon out

TABLE 4-2. FUEL SYSTEM - FILLER PIPE AND VENTING ARRANGEMENT (Cont'd)

Vehicle Identification and Engine Type	Filler Pipe Arrangement	Filler Pipe Vulnerability	Venting Arrangement	Vent Vulnerability
Toyota 1900 1968 - Straight 4	The filler pipe is located in the trunk compartment. It exits from the left rear corner and is directed upward to rear panel where it terminates	From any rear impact the filler pipe may be dislocated. The pipe is also vulnerable to damage while loading trunk	Vented cap	None

TABLE 4-3. FUEL SYSTEM - FUEL LINE

Vehicle Identification and Engine Type	Fuel Line Material	Size OD	Routing	Maintenance Accessibility
Buick Le Sabre 1968 - V 8	Steel pipe with an anti-rust coating	3/8 in. pickup line 1/4 in. return line	There are two fuel lines beginning at the front center of the fuel tank, travels upward across the floor pan to the right side rail, forward along rocker panel to front suspension area, and connected to fuel pump	Good
Buick Riviera 1966 - V 8	Steel pipe with anti-rust coating	3/8 in.	The fuel line begins at the top right side of the fuel tank, is routed directly to the right side rail, then forward along rocker panel into the front side rail. Fuel line travels through front chassis supports and A-frame to the front right side of engine	The fuel line is easily accessible from the fuel tank until it reaches the front side rail. From this point the fuel line is completely inaccessible for maintenance or inspection
Buick Riviera 1967 - V 8	Steel pipe with anti-rust coating	3/8 in.	The routing is the same as the 1966 model except the fuel pump is located at left side of engine compartment	The fuel line is easily accessible from the fuel tank until it reaches the front side rail. From this point the fuel line is completely inaccessible for maintenance or inspection

TABLE 4-3. FUEL SYSTEM - FUEL LINE (Cont'd)

Vehicle Identification and Engine Type	Fuel Line Material	Size OD	Routing	Maintenance Accessibility
Cadillac Coupe de Ville 1966 - V 8	Steel pipe with an anti-rust coating	5/16 in.	From the center front of fuel tank, upward to body floor and across to right side rail, forward along rail to fuel pump at left side of engine compartment	Good
Chevrolet Chevelle 1968 - V 8	Steel pipe with an anti-rust coating	3/8 in.	The fuel line is routed from the front center of tank, upward to floor pan and right to side rail. The fuel line enters the side rail above the axle and travels forward inside the rail. It exits 4 in. behind the fuel pump at right side of engine	The fuel line is completely inaccessible for the entire length of the right frame rail
Chevrolet Impala Super Sport 1968 - V 8	Steel pipe with an anti-rust coating	3/8 in.	The fuel line is routed from the front center of fuel tank upward across underside of trunk floor, to right side rail, forward along rail to fuel pump at right front of engine	Good
Chrysler New Yorker 1968 - V 8	Steel pipe with an anti-rust coating	3/8 in.	The fuel line is routed from the front center of fuel tank, upward across floor pan and along right side rail to rocker panel, forward along rocker panel into front frame for 2-1/2 ft., exiting frame at right front of engine and connecting to fuel pump	The fuel line is easily accessible except for the portion inside the front frame

TABLE 4-3. FUEL SYSTEM - FUEL LINE (Cont'd)

Vehicle Identification and Engine Type	Fuel Line Material	Size OD	Routing	Maintenance Accessibility
Dodge Coronet 440 1966 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of fuel tank, upward and forward along floor pan, right across right side rail to rocker panel, and forward to front rail and fuel pump	Good
Dodge Coronet 500 1967 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of fuel tank, upward and forward along floor pan, right across right side rail to rocker panel, and forward to front rail and fuel pump	Good
Dodge Coronet 440 1968 - Slant 6	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of fuel tank, upward and forward along floor pan, right across right side rail to rocker panel, and forward to front rail and fuel pump	Good
Dodge Dart G.T. 1967 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of fuel tank, upward and over to right side rail and rocker panel. Forward along rocker panel to front rail and then to fuel pump at right front of engine	Good

TABLE 4-3. FUEL SYSTEM - FUEL LINE (Cont'd)

Vehicle Identification and Engine Type	Fuel Line Material	Size OD	Routing	Maintenance Accessibility
Dodge Dart 1968 - Slant 6	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of fuel tank, upward and over to right side rail and rocker panel. Forward along rocker panel to front rail and then to fuel pump at right front of engine	Good
Dodge Polara 1966 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of fuel tank upward across underside of trunk floor, to right side rail, forward along rail to fuel pump at right front of engine	Good
Ford Cortina 1968 - Straight 4	Non-metallic fiber	1/4 in.	The fuel line is routed from the front center of fuel tank, upward to floor pan, and forward along center line of vehicle to fuel pump at front right of engine	Good
Ford Fairlane 500 Station Wagon 1967 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from front of fuel tank, over wheel well to rocker panel, along panel into front frame, and terminating at fuel pump in front left of engine compartment	The fuel line is inaccessible in the areas of the front frame and rear wheel well

TABLE 4-3. FUEL SYSTEM - FUEL LINE (Cont'd)

Vehicle Identification and Engine Type	Fuel Line Material	Size OD	Routing	Maintenance Accessibility
Ford Galaxie 500 1967 - V 8	Non-metallic	5/16 in.	The fuel line is routed from the front center of fuel tank, upward across underside of trunk floor to left side rail, and forward along rail to fuel pump at left front of engine	Good
Ford LTD 1967 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of fuel tank upward across underside of trunk floor, to left side rail, forward along rail to fuel pump at left front of engine	Good
Ford Mustang 1966 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of the fuel tank, up to the floor pan, forward to rear of transmission, left to front side rail, and into engine compartment to fuel pump	Good
Mercury Monterey 1966 - V 8	Non-Metallic	5/16 in.	The fuel line is routed from the front center of fuel tank, upward across underside of trunk floor to left side rail, and forward along rail to fuel pump at left front of engine	Good

TABLE 4-3. FUEL SYSTEM - FUEL LINE (Cont'd)

Vehicle Identification and Engine Type	Fuel Line Material	Size OD	Routing	Maintenance Accessibility
Oldsmobile Cutlass 1968 - V 8	Steel pipe with an anti-rust coating	3/8 in.	The fuel line is routed from the front center of fuel tank upward across underside of trunk floor, to right side rail, forward along rail to fuel pump at right front of engine	Good
Pontiac Le Mans 1967 - V 8	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the center front of fuel tank, upward to floor pan, across to left side rail, and forward along side rail to front A-frame. The line enters the A-frame behind the front wheel and terminates at fuel pump in left front of engine compartment	Good, except for front A-frame area where it is inaccessible
Rambler American 1967 - Straight 6	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front center of tank, upward to body floor pan, forward along side of floor pan approximately 12 in. from center line of automobile to fuel pump	Good

TABLE 4-3. FUEL SYSTEM - FUEL LINE (Cont'd)

Vehicle Identification and Engine Type	Fuel Line Material	Size OD	Routing	Maintenance Accessibility
Toyota 1900 1968 - Straight 4	Steel pipe with an anti-rust coating	5/16 in.	The fuel line is routed from the front right side of tank, upward and across to right side rail and rocker panel, forward along rocker panel to front side rail, and up to fuel pump at right front of engine	Good

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Buick Le Sabre 1968 - V 8	Single	The exhaust manifolds are cast iron. They connect to the front pipes by means of butt flanges	Steel, 1-3/4 in. OD	Steel 2-1/4 in. OD, with slip connections for front pipe and muffler	Steel with a protective coating
Buick Riviera 1966 - V 8	Dual	The exhaust manifolds are cast iron. They connect to the front pipes by means of butt flanges	Steel, 2-1/4 in. OD	None	Aluminized steel with slip connections for front and rear pipes
Buick Riviera 1967 - V 8	Dual	The exhaust manifolds are cast iron. They connect to the front pipes by means of butt flanges	Steel, 2-1/4 in. OD	None	Aluminized steel with slip connections for front and rear pipes

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Cadillac Coupe de Ville 1966 - V 8	Single	Cast iron is used for exhaust manifold. Butt flanges are used to connect front pipes to manifold	Steel, 2-1/4 in. OD The right and left pipes join at the left of the flywheel	None	Steel with a protective coating
Chevrolet Chevelle 1968 - V 8	Single	The exhaust manifolds are fabricated of cast iron. They connect to the front pipes by butt flanges	Steel, 1-7/8 in. OD. The left front pipe connects to the main front pipe at the right of the flywheel	None	Galvanized steel, welded to the front and tail pipes
Chevrolet Impala Super Sport 1968 - V 8	Single	Fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 2-1/4 in. OD The right and left exhaust pipes join together at left of flywheel	Steel, 2-1/2 in. OD	Steel with a protective coating

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Chrysler New Yorker 1968 - V 8	Single	Fabricated of cast iron, they connect to the front pipes by butt flanges	Steel, 2-1/2 in. OD The right and left pipes join together at right of flywheel	Steel, 2-1/2 in. OD. Joined to front pipe by a 2 bolt butt connection and welded to muffler	Steel with a protective coating
Dodge Coronet 440 1966 - V 8	Single	The exhaust manifolds are fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 1-7/8 in. OD. Right and left pipes join at right of flywheel and are routed rearward parallel to drive train	Steel, 2 in. OD, connected to front pipe and muffler by slip joints	Aluminized steel, supported at rear by a steel-to-rubber hanger
Dodge Coronet 500 1967 - V 8	Single	The exhaust manifolds are fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 1-7/8 in. OD. Right and left pipes join at right of flywheel and are routed rearward parallel to drive train	Steel, 2 in. OD, connected to front pipe and muffler by slip joints	Aluminized steel, supported at rear by a steel-to-rubber hanger

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Dodge Coronet 440 1968 - Slant 6	Single	The exhaust manifolds are fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 1-7/8 in. OD.	None	Aluminized steel, supported at rear by a steel-to-rubber hanger
Dodge Dart G.T. 1967 - V 8	Single	Fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 2 in. OD. The two pipes coming from the manifolds are joined at the left of flywheel housing	Steel, 2 in. OD. Connected to the front pipe and muffler by means of slip connections	Aluminized steel
Dodge Dart 1968 - Slant 6	Single	Fabricated of cast iron, connected to the front pipe by means of a butt flange	Steel, 1-7/8 in. OD Connected to exhaust manifold at left side of engine and routed rearward to muffler	None	Aluminized steel, slip connected to front and tail pipes

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Dodge Polara 1966 - V 8	Single	Fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 1-7/8 in. OD The left and right exhaust pipes are joined together at right of flywheel	Steel, 2-1/4 in. OD, with a butt connection to the front pipe and welded to the muffler at the rear	Aluminized steel
Ford Cortina 1968 - Straight 4	Single	Fabricated of cast iron	Steel, 1-1/2 in. OD connected to manifold at left side of engine by butt flange.	None	Steel with a protective coating and slip connected on both sides
Ford Fairlane 500 Station Wagon 1967 - V 8	Single	Fabricated of cast iron, connected to front pipe by means of a butt flange	Steel, 1-7/8 in. OD Right and left pipes join together behind the transmission	Steel, 1-7/8 in. OD. Connects to front pipe and muffler by slip joints	Steel with a protective coating

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Ford Galaxie 500 1967 - V 8	Single	Fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 2 in. OD. The right and left pipes are joined together behind the transmission	None	Steel with a protective coating. The front and tail pipes are joined to the muffler by slip connections
Ford LTD 1967 - V 8	Single	Fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 2 in. OD. Butt type connections are used at the manifolds. The right and left pipes are joined together behind the transmission	None	Steel with a protective coating. The front and tail pipes are joined to the muffler by slip connections
Ford Mustang 1966 - V 8	Single	Fabricated of cast iron, butt connected to front pipes	Steel, 1-7/8 in. OD. The right and left pipes are joined together behind the transmission	Steel, 1-7/8 in. OD. Slip connected to front pipe and muffler	Steel with a protective coating

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Mercury Monterey 1966 - V 8	Single	Fabricated of cast iron	Steel, 2-1/4 in. OD. Butt type connections used at manifolds. The left pipe crosses under the engine and joins the right pipe before proceeding rearward	None	Steel with a protective coating. The front and tail pipes are joined to the muffler by slip connections
Oldsmobile Cutlass 1968 - V 8	Single	Fabricated of cast iron, they connect to the front pipes by means of butt flanges	Steel, 2-1/4 in. OD. Butt type connections are used at the manifolds. The pipes are joined together to the right of the flywheel. They are routed rearward and join to the muffler by means of a slip connection	None	Steel with a protective coating
Pontiac Le Mans 1967 - V 8	Single	Fabricated of cast iron, connected to front pipes by butt flanges	Steel, 2 in. OD. Right and left pipes connected behind transmission	Steel, 2-1/4 in. OD. Slip connected to front pipe and muffler	Steel with a protective coating

TABLE 4-4. EXHAUST SYSTEM - FORWARD COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Type	Exhaust Manifold	Front Pipe(s)	Intermediate Pipe(s)	Muffler(s)
Rambler American 1967 - Straight 6	Single	Fabricated of cast iron. They connect to the front pipes by means of butt flanges	Steel, 1-7/8 in. OD. Connects to manifold at left side of engine and is routed rearward parallel to the transmission. It is welded to the intermediate pipe at the end of the transmission housing. A steel hanger, attached to the transmission bell housing is used to support the front pipe	Steel, 1-3/4 in. OD. It is slip connected to the muffler and mounted to the frame forward of the muffler	Steel with a protective coating
Toyota 1900 1968 - Straight 4	Single	Fabricated of cast iron	Steel, 1-5/8 in. OD. Ball type connection used at manifold and welded to resonator. Steel clamped to transmission housing	None	Steel with a protective coating

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Buick Le Sabre 1968 - V 8	Steel 2 in. OD, mounted to frame behind muffler by means of a steel-to-rubber hanger	Steel with a protective coating, with a steel-to-rubber hanger at the exhaust exit	Extension from resonator	Front pipes are routed from the manifolds and join at the right side of engine. They are routed rearward and exit at the right rear side of bumper	Good
Buick Riviera 1966 - V 8	2 in. OD. Mounted to frame behind muffler via a steel-to-rubber hanger	Fabricated of stainless steel with a steel-to-rubber hanger at the exhaust exit	Extension from muffler	The exhaust system is routed along the outside perimeter of the frame rails. The exhaust gases exit at the two rear corners under the bumper	Over the right rear axle the fuel line is parallel to and 2 in. away from the exhaust pipe for a distance of 2 ft. Questionable
Buick Riviera 1967 - V 8	2 in. OD. Mounted to frame behind muffler via a steel-to-rubber hanger	Fabricated of stainless steel with a steel-to-rubber hanger at the exhaust exit	Extension from muffler	The exhaust system is routed along the outside perimeter of the frame rails. The exhaust gases exit at the two rear corners under the bumper	Over the right rear axle the fuel line is parallel to and 2 in. away from the rear exhaust pipe for a distance of 2 ft. Questionable

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Cadillac Coupe de Ville 1966 - V 8	Slip connected to resonator and muffler	Fabricated of steel with a protective coating	Steel 2-1/4 in. OD. Connected to muffler with a slip joint and "U" clamp. Hook to the body 5 in. from exhaust exit	The exhaust system is routed rearward, parallel to the drive train at a distance of approximately 4 in.	The fuel line comes within 1 in. of the front exhaust pipe (right side). Questionable
Chevrolet Chevelle 1968 - V 8	None	None	Steel, 1-7/8 in. OD. Mounted by rubber-to-steel hangers behind the muffler and before the exhaust exit	The exhaust system is routed from the right manifold (joined by the front left pipe) rearward, parallel to the drive line, then directed to the right at the rear axle terminating under right side of bumper	Over the right half of the axle, the fuel line crosses over the tail pipe at a distance of 2 in. Questionable

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Chevrolet Impala Super Sport 1968 - V 8	None	None	Steel, 1-7/8 in. OD. Connected to muffler by means of a slip joint. It is hooked to body by a steel and rubber hanger located behind the muffler and 14 in. from exhaust exit.	The exhaust system is routed from the left manifold rearward approximately 10 in. from drive line. Exhaust gases exit behind left rear wheel	Good
Chrysler New Yorker 1968 - V 8	2-1/8 in. OD steel. Mounted over right axle and slip connected to muffler	Fabricated of stainless steel, with a steel-to-rubber hanger at the exhaust exit	Extension from muffler	The exhaust system is routed from the right manifold rearward, exiting at the right rear corner	The front pipe comes to within 2 in. of fuel line as the line leaves the front frame, and in the area of the right rear shock mount, the rear pipe is a distance of 4 in. from fuel line. Questionable

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Dodge Coronet 440 1966 - V 8	None	None	Steel, 1-3/4 in. OD. Mounted 4 in. from right rear exhaust exit	The exhaust system is routed from the right manifold, rearward approximately 2 in. from drive line, and exits at the right rear 12 in. from right side	At the right axle, the fuel line crosses over the tail pipe at a distance of 1 in. Questionable
Dodge Coronet 500 1967 - V 8	None	None	Steel, 1-3/4 in. OD. Mounted 4 in. from right rear exhaust exit	The exhaust system is routed from the right manifold, rearward approximately 2 in. from drive line, and exits at the right rear 12 in. from right side	At the right axle, the fuel line crosses over the tail pipe at a distance of 1 in. Questionable
Dodge Coronet 440 1968 - Slant 6	None	None	Steel, 1-3/4 in. OD Mounted 4 in. from right rear exhaust exit	The exhaust system is routed from the left side of engine, across to right side, rearward approximately 13 in. from drive train, and exits at right rear under bumper	The fuel line is in close proximity to the tail pipe over the right rear axle; and to the front pipe to the right of the flywheel housing. Questionable

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Dodge Dart G.T. 1967 - V 8	None	None	Steel, 1-3/4 in. OD. The tail pipe is connected to muffler by means of a slip joint behind muffler and 14 in. from exhaust exit, the tail pipe is hooked to body by means of a steel-to-rubber hanger	The exhaust system is routed from the left manifold, joined by right front pipe, and is directed rearward near center line of body, and exits at left rear corner	Good
Dodge Dart 1968 - Slant 6	None	None	Steel, 1-3/4 in OD. The tail pipe is connected to muffler by means of a slip joint behind muffler and 14 in. from exhaust exit, the tail pipe	The exhaust system is routed from the left side of engine rearward, approximately 2 in. from drive line, and exits at the left rear under the bumper	12 inches. Good

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
			is hooked to body by means of a steel-to-rubber hanger		
Dodge Polara 1966 - V 8	Steel, 2-1/2 in. OD. Slip connected to muffler. Secured at connection via a steel-to-rubber hanger	Steel, with a steel-to-rubber hanger at the exhaust exit	Extension from muffler	The exhaust system is routed from the right manifold, rearward along floor pan. Exhaust gases exit under bumper at right side of license plate	Fuel line runs generally parallel to exhaust system, coming as close as 3 in. at some points. Questionable
Ford Cortina 1968 - Straight 4	Steel, 1-1/2 in. OD, slip connected to resonator and secured over left axle by a steel-to-rubber hanger	Steel with a protective coating	Extension from muffler with a steel-to-rubber hanger in the middle of tail pipe	The exhaust system is routed from the left side of engine rearward midway between the rocker panel and drive line. It exits at left rear under bumper	9 in. Fair

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Ford Fairlane 500 Station Wagon 1967 - V 8	None	None	Steel, 1-7/8 in. OD. Mounted by two steel-to-rubber hangers located behind muffler and over left axle	The exhaust system is routed from the two exhaust manifolds, downward next to the transmission housing, joined together at rear of housing, and routed rearward to muffler. Exhaust gases exit behind left rear wheel	Exhaust gases exit 4 in. from fuel tank. Fair
Ford Galaxie 500 1967 - V 8	None	None	Steel, 2 in. OD. The tail pipe is mounted to the frame by means of two steel-to-rubber hangers. It is secured behind the muffler and aft of the fuel tank	After connecting to the manifolds, the front pipes are routed parallel to the transmission on their respective sides. They join together aft and to the right of the transmission. The single pipe extends rearward to muffler and exits under bumper at right rear corner of vehicle	Good

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Ford LTD 1967 - V 8	None	None	Steel, 2-1/4 in. OD. Behind the muffler and aft of the fuel tank the tail pipe is mounted to the frame by means of steel-to-rubber hangers,	After connecting to the manifolds, the front pipes are routed parallel to the transmission on their respective sides. They join together aft and to the right of the transmission. The single pipe extends rearward to muffler and exits under bumper at right rear corner	Good
Ford Mustang 1966 - V 8	Steel, 1-7/8 in. OD. Slip connected to muffler and resonator, with one steel-to-rubber hanger	Steel with a protective coating	Steel, 1-3/4 in. OD. Mounted by one steel-to-rubber hanger located behind fuel tank	The right and left front pipes are joined together behind the transmission.after leaving the exhaust manifolds. The single pipe is routed rearward next to the drive line. Exhaust gases exit at the left rear under bumper	As the fuel line leaves the fuel tank, the muffler is 1 in. away for a distance of 16 in. Questionable

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
Mercury Monterey 1966 - V 8	None	None	Steel, 2 in. OD. The tail pipe is mounted to the frame by means of two steel-to-rubber hangers. It is secured behind the muffler and aft of the fuel tank	The front pipes are joined at the right of flywheel after leaving manifolds. The single pipe extends rearward to muffler and exits under bumper at right rear corner	Good
Oldsmobile Cutlass 1968 - V 8	None	None	Steel, 2 in. OD. Behind the muffler and 14 in. before exhaust exit, the tail pipe is mounted to the frame	The exhaust system is routed from the right manifold, rearward along center of floor pan to rear axle, then to right side rail and rearward to exit location under right corner of bumper	Good
Pontiac Le Mans 1967 - V 8	None	None	Steel, 2 in. OD. Slip connected to muffler. Secured by steel to-rubber	The front pipes are routed parallel to the transmission on their respective sides. They join	6 in. Fair

TABLE 4-5. EXHAUST SYSTEM - AFT COMPONENTS (Cont'd)

Vehicle Identification and Engine Type	Rear Pipe(s)	Resonator(s)	Tail Pipe(s)	Routing	Fuel Line Relationship
			hangers behind muffler and next to tank	together aft and to the right of the transmission. The single pipe extends rearward to muffler and exits under right side of rear bumper	
Rambler American 1967 - Straight 6	None	None	Extension from muffler	The front pipe connects to the manifold at left side of engine and is routed rearward parallel to the power train. The pipe exits under the rear bumper to the left of the license plate	Good
Toyota 1900 1968 - Straight 4	Steel, 1-1/2 in. OD. The rear pipe is welded to resonator and muffler. Two steel-to-rubber hangers are used for mounting	Steel with a protective coating	Extension from muffler	The exhaust system is routed rearward from the left side of engine, parallel to drive line, and exits under bumper at left rear	18 in. Good

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
Buick Le Sabre 1968 - V 8	12	Front right side of engine compartment, 7 in. from bumper, and 9 in. from outside of fender	Two brackets fit into grooves located on the base of the battery. The brackets are bolted to the base plate	Cable is exposed to extreme engine heat in its routing	19 in.
Buick Riviera 1966 - V 8	12	Front left side of engine compartment, 12 in. from bumper and 9 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	Positive battery cable is routed from front left to right rear of engine compartment. The cable is exposed to extreme engine heat in its routing	Power steering unit separates battery from nearest fuel system component which is 14 in. away
Buick Riviera 1967 - V 8	12	Front left side of engine compartment, 12 in. from bumper and 9 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	Positive battery cable is routed from front left to right rear of engine compartment. The cable is exposed to	Power steering unit separates battery from nearest fuel system component which is 14 in. away

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY (Cont'd)

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
				extreme engine heat in its routing	
Cadillac Coupe de Ville 1966 - V 8	12	Front right side of engine compartment, 4 in. from bumper, and 8 in. from outside of fender	Two brackets fit into grooves located on the base of the battery. The brackets are bolted to the base plate	None	Battery located so that it cannot affect fuel line
Chevrolet Chevelle 1968 - V 8	12	Front right side of engine compartment, 10 in. from bumper, and 9-1/2 in. from outside of fender	Two brackets fit into grooves located on the base of the battery. The brackets are bolted to the base plate	None	16 in.
Chevrolet Impala Super Sport 1968 - V 8	12	Front right side of engine compartment, 11-1/2 in. from bumper and 11-1/2 in. from outside of fender	Two brackets fit into grooves located on the base of the battery and are bolted to the base plate	None	18 in.

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY (Cont'd)

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
Chrysler New Yorker 1968 - V 8	12	Front left side of engine compartment, 13-1/2 in. from bumper and 12-1/2 in. from outside of fender	Battery mounting consists of one stud hooked to the base plate and bolted through the top hold down bracket. The other end of bracket is hooked to front radiator support	None	18 in.
Dodge Coronet 440 1966 - V 8	12	Front left side of engine compartment, 17 in. from bumper, and 15 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	None	10 in.
Dodge Coronet 500 1967 - V 8	12	Front left side of engine compartment, 17 in. from bumper, and 15 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	None	10 in.

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY (Cont'd)

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
Dodge Coronet 440 1968 - Slant 6	12	Front left side of engine compartment, 17 in. from bumper, and 15 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	See Circuitry Hazard (Table 4-7)	10 in.
Dodge Dart G.T. 1967 - V 8	12	Front left side of engine compartment, 10-1/2 in. from bumper and 13 in. from outside of fender	At the top of the battery, the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	See Circuitry Hazard (Table 4-7	24 in.
Dodge Dart 1968 - V 8	12	Front left side of engine compartment, 10-1/2 in. from bumper and 13 in. from outside of fender	At the top of the battery, the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	See Circuitry Hazard (Table 4-7)	24 in.

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY (Cont'd)

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
Dodge Polara 1966 - V 8	12	Front left side of engine compartment, 12 in. from bumper and 13 in. from outside of fender	Battery mounting arrangement consists of one stud hooked to the base plate and bolted through the top hold down bracket. The other end of hold down bracket is hooked to front radiator support	None	Fuel line is located on opposite side of engine compartment
Ford Cortina 1968 - Straight 4	12	Front left side of engine compartment, 9 in. from bumper, and 15 in. from outside of fender	One bracket fits into a groove located at the base of battery. The battery is bolted to base plate	None	17 in.
Ford Fairlane 500 Station Wagon 1967 - V 8	12	Front right side of engine compartment, 9-1/2 in. from bumper and 13 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	None	13 in.

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY (Cont'd)

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
Ford Galaxie 500 1967 - V 8	12	Front right side of engine compartment, 12 in. from bumper, and 13 in. from outside of fenders	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	See Circuitry Hazard (Table 4-7)	24 in.
Ford LTD 1967 - V 8	12	Front right side of engine compartment, 12 in. from bumper and 13 in. from outside of fenders	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	See Circuitry Hazard (Table 4-7)	24 in.
Ford Mustang 1966 - V 8	12	Front right side engine compartment, 6 in. from bumper, and 10 in. from outside of fender	Two brackets fit into grooves located on the base of the battery. They are bolted to the base plate	See Circiutry Hazard (Table 4-7)	19 in.

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY (Cont'd)

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
Mercury Monterey 1966 - V 8	12	Front right side of engine compartment, 10 in. from bumper, and 11 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	See Circuitry Hazard (Table 4-7)	18 in.
Oldsmobile Cutlass 1968 - V 8	12	Front left side of engine compartment, 11 in. from bumper and 10 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	None	24 in.
Pontiac Le Mans 1967 - V 8	12	Front left side engine compartment, 9 in. from bumper, and 10 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	None	16 in.

TABLE 4-6. ELECTRICAL SYSTEM - BATTERY (Cont'd)

Vehicle Identification and Engine Type	Battery Volts	Battery Location	Battery Mounting	Battery Shorting Possibility	Battery Proximity to Fuel System
Rambler American 1967 - Straight 6	12	Front left side of engine compartment, 11 in. from bumper and 10 in. from outside of fender	At the top of the battery the hold down bracket is bolted to 2 studs which extend downward on either side of the battery and hook to the base plate	See Circuitry Hazard (Table 4-7)	6 in.
Toyota 1900 1968 - Straight 4	12	Front right side engine compartment, 8 in. from both the bumper and outside of fender	There is a full frame around the battery top. Two studs are bolted to it which extend downward on either side of the battery and hook to the base plate	In the event of front impact the nearness of the battery to engine components could be hazardous	7-1/2 in.

TABLE 4-7. ELECTRICAL SYSTEM - WIRING

Vehicle Identification and Engine Type	Wire Abrasion Possibility	Circuitry Hazard
Buick Le Sabre 1968 V 8	Wire harness rests across full length of battery, leaving it exposed to battery acid and abrasion from battery terminal	Poorly harnessed wires hang loosely in many areas.
Buick Riviera 1966 V 8	Wire harness lays across the positive terminal of the battery. It is exposed to battery acid and abrasion from battery terminal	Poorly harnessed wires hang loosely. In such a state they are vulnerable to snagging
Buick Riviera 1967 V 8	Wire harness lays across the positive terminal of the battery. It is exposed to battery acid and abrasion from battery terminal	Poorly harnessed wires hang loosely. In such a state they are vulnerable to snagging
Cadillac Coupe de Ville 1966 V 8	None	None
Chevrolet Chevelle 1968 V 8	None	None

TABLE 4-7. ELECTRICAL SYSTEM - WIRING (Cont'd)

Vehicle Identification and Engine Type	Wire Abrasion Possibility	Circuitry Hazard
Chevrolet Impala Super Sport 1968 V 8	None	None
Chrysler New Yorker 1968 V 8	None	None
Dodge Coronet 440 1966 V 8	See Circuitry Hazard	Poorly harnessed wires resting on intake manifold are vulnerable to abrasion and extreme heat
Dodge Coronet 500 1967 V 8	See Circuitry Hazard	Poorly harnessed wires resting on intake manifold are vulnerable to abrasion and extreme heat
Dodge Coronet 440 1968 Slant 6	None	Starter solenoid is located behind the battery. In the event of a front end collision, the battery may be driven into the solenoid, possibly resulting in a shorted condition
Dodge Dart G.T. 1967 V 8	Relay is located behind the battery. In the event of a front end collision, the battery may come into contact with the relay causing a shorting condition	None

TABLE 4-7. ELECTRICAL SYSTEM - WIRING (Cont'd)

Vehicle Identification and Engine Type	Wire Abrasion Possibility	Circuitry Hazard
Dodge Dart 1968 V 8	Relay is located behind the battery. In the event of a front end collision, the battery may come into contact with the relay causing a shorting condition	None
Dodge Polara 1966 V 8	None	None
Ford Cortina 1968 Straight 4	None	None
Ford Fairlane 500 Station Wagon 1967 V 8	None	None
Ford Galaxie 500 1967 V 8	See Circuitry Hazard	Starter solenoid is located behind the battery. Wires connected to solenoid are not clipped to fender or sufficiently harnessed. In the event of a front end collision, the battery may be driven into the solenoid, possibly resulting in a shorted condition

TABLE 4-7. ELECTRICAL SYSTEM - WIRING (Cont'd)

Vehicle Identification and Engine Type	Wire Abrasion Possibility	Circuitry Hazard
Ford LTD 1967 V 8	See Circuitry Hazard	Starter solenoid is located behind the battery. Wires connected to the solenoid are not clipped to the fender or sufficiently harnessed. In the event of a front end collision, the battery may be driven into the solenoid, possibly resulting in a shorted condition
Ford Mustang 1966 V 8	None	Starter solenoid is located behind the battery. Wires connected to the solenoid are not clipped to the fender or sufficiently harnessed. In the event of a front end collision, the battery may be driven into the solenoid, possibly resulting in a shorted condition
Mercury Monterey 1966 V 8	See Circuitry Hazard	Starter solenoid is located behind the battery. Wires connected to solenoid are not clipped to fender or sufficiently harnessed. In the event of a front end collision, the battery may be driven into the solenoid, possibly resulting in a shorted condition
Oldsmobile Cutlass 1968 V 8	None	None
Pontiac Le Mans 1967 V 8	None	None

TABLE 4-7. ELECTRICAL SYSTEM -- WIRING (Cont'd)

Vehicle Identification and Engine Type	Wire Abrasion Possibility	Circuitry Hazard
Rambler American 1967 Straight 6	**Harness comes into contact with heater hose**	Starter solenoid is located behind the battery. Wires connected to the solenoid are not clipped to the fender or sufficiently harnessed. In the event of a front end collision, the battery may be driven into the solenoid, possibly resulting in a shorted condition
Toyota 1900 1968 Straight 4	None	None

SECTION V

POST CRASH OCCUPANT ESCAPE CONSIDERATIONS

In considering occupant escape in post crash situations, it is apparent that there are certain basic approaches to the problem:

1) The elimination of obstacles which could impair the ability of the occupant to exit from the vehicle.
2) The incorporation of alternate escape provisions.
3) The design of the passenger compartment to shield the occupant from fire.

In passenger cars, the dropped floor with the raised side rails and center drive train tunnel form obstacles that impede the egress of occupants from a vehicle. A floor-mounted shift lever with an over-sized console also presents an obstacle to easy exit. In such designs, the degree of difficulty in escaping from a vehicle is greatly increased if the door the occupant would normally use were blocked or jammed. The rear seat occupants of a two door model have similar problems, since the handles for the doors are usually out of their reach. It should be noted, however, that some luxury model vehicles have improved this situation by installing an additional handle on each door specifically for the rear seat passengers. Some passenger vehicles are equipped with sliding roof panels that can be used as a means of escape.

Busses are required to provide certain occupant escape provisions. The current coach or local transit bus carries forty-eight seated passengers. On all these vehicles, the eight side windows (four on each side) are of the "popout" type, furnishing an ample number of emergency exits. A school bus, on the other hand, carries the same number of seated passengers but has only five emergency exits (the windshield, one popout window on each side, a rear emergency door, and the front normal entrance-exit door).

In a truck, the egress of a driver, who may be occupying the sleeping berth, is made more difficult because he must first move from a confined space into the main cab area before he can exit from the vehicle.

While firewalls or bulkheads cannot be considered as offering occupant excape facilities as such, their effect in preventing or delaying the spread of fire to the occupied areas of the vehicle must be recognized. Some passenger vehicles actually have no true fire barriers. In many cases, when such barriers are installed, there is still the possibility of failure because of the frailty or flammability of materials used in the construction of firewalls. In the event of a post crash fire, the safety of the occupants in the passenger compartment may well depend upon the efficiency of the fire barriers.

In conclusion, the summation of escape considerations are:

- Clean interior space
- Alternate means of escape
- Fire retarding body construction capable of maintaining its integrity under crash conditions

SECTION VI

POST CRASH FIRE CASE STUDIES

A. INTRODUCTION

Because automotive vehicle post crash fires result in so much damage, it is difficult to isolate the source of ignition. In almost all cases, the vehicle is completely destroyed by the fuel fed fire. Rarely is a detailed examination of the wreckage made, as the immediate objectives are the rescue of survivors and removal of the wreckage. A description of a fire destroyed vehicle rarely goes into more detail than to state "burned, total loss."

Published data, Reference 6-1, indicates the following general observations of fire in automobile accidents:

- Among front impact accidents involving fire, most are reported as starting in the engine area
- As a rule, in rear impact accidents, fire is reported as having started in or about the gasoline tank
- The incidence of fire varies from less than one in a thousand for the least severe accidents, up to nearly four percent for those rare accidents so severe that the vehicle is totally destroyed.
- There is no indication (based on 33,000 cases) of a difference in fire susceptibility between front engine and rear engine cars.

B. SIDE IMPACT COLLISION

Collision tests between 1966 Chevrolet four door sedans and the 1960 Chevrolet Liberty Mutual Safety Car conducted by D. M. Severy (Reference 6-2) have produced data applicable to fuel system response to collision.

A side impact of a 1966 Chevrolet at the area of the passenger compartment by the 1960 LM Chevrolet was conducted. Each car was travelling at 40 mph. Maximum penetration was 12 inches. The peak acceleration of 16 g's at 20 milliseconds after initial impact was recorded.

The fuel tank anchor strap at the right side of the tank tore loose on the impacted car and permitted the tank to drop to the pavement causing rupture.

C. REAR IMPACT COLLISION

Rear end collision data for 1967 Ford four door sedans were obtained from a series of collision tests conducted by D. M. Severy (Reference 6-3). New 1967 Ford Custom four door sedans were used for the impacted and impacting vehicles. The struck vehicle was stationary and the rear impact had no offset. All the vehicles were equipped with 25 gallon fuel tanks. The results of the tests were as follows:

- 10 mph
  - Peak frame deceleration of 5 g's at 15 milliseconds was recorded. The impacted car was bowed inward at the central area of the bumper approximately 2.5 inches. A slight trunk lid indentation was caused by the forward edge of the striking car's hood. The right rear tail light lens cover was cracked. A slight buckling of the rear bumper support brackets was observed.
  - No damage occurred to the fuel tank and no fuel spillage was recorded.
- 20 mph
  - Peak frame deceleration of 8 g's at 35 milliseconds was recorded. The low deceleration peak was attributed to the "excellent force modulating properties" of the rear end structure of the vehicle. The impacted car was deformed 11 inches at the top edge of the rear fender. It was deformed for a distance of 13 inches at the bumper elevation. Bumper heights above the ground were adjusted to 21.5 inches to provide a good match between the bumpers. Rear frame members were observed to buckle forward of the bumper attachment point. The tail lights were lighted and remained operating after the collision. The trunk lid remained closed.
  - The fuel tank filler pipe was pulled free allowing the fuel to be dispersed. There appeared to be a liberal amount of the simulated fuel sprayed from the struck car's damaged fuel tank.

- 30 mph
  - A peak frame deceleration of 9 g's at 15 milliseconds was recorded. The impacted car was deformed 3.0 feet at the rear fender/trunk body above the level of the bumper. Deformation of 2.5 feet was recorded at the bumper level.
  - A liberal diffusion of fuel sprayed from the struck car's ruptured fuel tank. The simulated fuel was deposited on the pavement 10 feet beyond the point of impact.
- 30 mph
  - Peak frame deceleration of 11 g's at 25 milliseconds was recorded. The impacted car was compressed 3.2 feet at the rear fender/trunk section above the bumper and 2.2 feet at the level of the bumper. The installed spare tire was observed not to change its position and the shelf was still intact.
  - Fuel was liberally sprayed from the struck car's fuel tank.
- 30 mph
  - Peak frame deceleration was 9 g's at 25 milliseconds. Permanent deformation for the fender/trunk section above the level of the bumper was 2.9 feet and at bumper level the deformation was 2.5 feet. Sheet metal was pushed against the spare tire located on the floor pan axle step over the rear axle.
  - The fuel tank was punctured by the lower transverse stabilizer attachment bolt. Fuel was sprayed out the left wheel well because the fuel filler tube separated from the tank. Post collision inspection indicated that the fuel tank had adequate space and was not fully compressed during the impact at 30 mph. A separation occurred between the fuel filler spout and the tank. Compression of the tank forced fuel from this opening.
- 40 mph
  - Peak frame deceleration of 19 g's at 100 milliseconds. Bumper heights were matched by applying air to the shock absorber system. Trunk lid opened. Deformation at the level of the bumper was 3 feet and at the level of the rear tail light the deformation was 3.5 feet. The trunk was compressed sufficiently to push the spare tire two inches into the rear seat panel.
  - No visible dispersion of fuel from the filler spout was observed but the fuel tank was ruptured and fuel drained onto the pavement for 17 feet beyond the impact point. The filler spout remained

attached to the tank. Fuel leakage occurred from a puncture on the front side of the tank near the center.

- 30 mph
  - Peak frame deceleration was 12 g's at 35 milliseconds. Rear end structure collapsed 2.5 feet at the trunk lid elevation and 2.3 feet at the bumper. Spare tire was impacted by the collapsing sheet metal but showed no evidence of forward displacement.
  - The trunk well was collapsed to the floor pan axle step and fuel tank. No significant amount of fuel leakage was observed during the crash.
- 30 mph
  - Peak frame deceleration of 10 g's at 45 milliseconds was recorded. There was overriding action of the striking car bumper. Deformation of 2.3 feet at the rear bumper was observed and 2.5 feet of deformation occurred at the level of the tail lights. Spare tire remained firmly bolted and was not pushed forward. The tail lights were pushed flat against the forward wall of the trunk well. The trunk lid folded almost double.
  - Improvements made in the fuel tank filler spout accounted for a significant reduction in fuel leakage around the dented filler cap compared to the previous 30 mph tests.
- 30 mph
  - Peak frame deceleration was 11 g's at 25 milliseconds. Deformation was 2.4 feet at tail light level and 2.1 feet at bumper level. The trunk lid was forced forward and upwards and collapsed to a single fold.
  - The fuel tank filler spout remained attached to the fuel tank and only a small amount of fuel was sprayed from the vented filler cap.
- 30 mph
  - Peak frame deceleration was 11 g's at 25 milliseconds. Deformation of 2.3 feet occurred at bumper level and 2.9 feet at the tail light elevation. The trunk lid popped open and the trunk frame members buckled downward. This was the first 30 mph experiment in which the forward wall of the trunk well was damaged. Longitudinal frame rails were

buckled at a position one foot forward of the ends of the frame where the bumper hangers are attached. The spare tire was firmly attached.

  - The fuel tank was ruptured but the fuel was not forced from the filler spout.

- 55 mph

  - Peak frame deceleration of 19 g's at 85 milliseconds was recorded. Spare tire was removed. Deformation at bumper level was 3.0 feet and also 3.0 feet at the tail light elevation. Slight buckling of the roof side panels occurred and the rear sheet metal was crushed around the rear wheels.
  - A large volume of fuel erupted at high velocity from the underside of the vehicle. Compression to the rear end of the vehicle caused gross splitting of the bottom seam of the fuel tank and resulted in a liberal dispersion of fuel.

More recent studies have been conducted by D. M. Severy, Reference 6-4. The tests involved actual fire conditions and were not limited to fuel dispersion as previously done. The following is the procedure and observations:

Experiment 106, was a 55-mph rear-end collision between two 1967 Ford 4-door sedans. The fuel tank of the struck car was filled with 25 gallons of gasoline. Engines of both vehicles were operating and the wheels of the rear-ended vehicle were slightly raised, with provisions for maintaining normal bumper height, even though the rear wheels were rotating at 20 equivalent mph when rear-ended. The headlights were also turned on, to evaluate the usual potential sources of postcrash fires.

A backup fire-ignition device was used because of the improbability of the exacting conditions necessary for natural postcrash fuel ignition occurring.

The inertia of the rear-ended vehicle was sufficient to force mutual structural collapse of 4 feet before the struck car passenger compartment was significantly displaced forward. Maximum collapse (3 ft, 5 in.) of the rear-ended structure occurred 0.15 sec after bumper-to-bumper contact. At this instant the striking vehicle had advanced 9 ft beyond the initial contact position.

The rear-ended vehicle accelerated to a peak of 17 g at 105 ms. Maximum mutual collapse was 7 ft. The cars separated at 350 ms, after the striking vehicle had advanced 15. 5 ft.

The struck car was propelled 140 ft along the precollision axis, and was offset 8 ft to the right of its original heading. The striking car traveled 68 ft after contacting the stationary vehicle, and came to rest offset 12 ft to the right of its pre-crash heading. Permanent collapse of the struck car, as measured at the rear bumper level, was 3 ft, 2 in.

When the rear-ended car had advanced about 2 ft, gasoline could be seen spurting forward from the rear-wheel area. By the time the car had advanced 8 ft, gasoline had erupted forward to the front-wheel area, and had extended out several feet on each side of the car. At 0. 3 sec after impact (Figure 6-1), the car had reached a position 20 ft past the impact point and made contact with the electrical switch controlling the igniter. At this point the gasoline vapor cloud was within 2 ft of the igniter. When the vehicle reached the 48-ft position, the fuel vapor cloud had passed over the igniter and general ignition from that point occurred by the time the front end of the vehicle was 50 ft from the impact point. Thereafter, the burning rate of the fuel cloud progressed in an explosive-like manner and the runout of the vehicle continued as the fuel cloud frame front progressed, catching up with the vehicle as it slowed to a stop.

A substantially greater volume of fuel was projected forward and to the left side of the vehicle than to the right side; however, as the vehicle continued forward and the flame front advanced to the car, a cross wind that developed shortly before the crash caused a greater amount of flame to show on the right side of the car than on the left side.

The vehicle was 70% engulfed in flames as it reached its position of rest 140 ft from impact. Thereafter, the fire burned violently outside the rear of the passenger compartment for 7 sec without flames showing inside, even though the rear window had been broken out. But then a small flame appeared at the right of the right rear passenger; 2 sec after this a ball of flame appeared at the left hand of the same passenger. It seemed to have burned from the opened

Figure 6-1. Gasoline Spray after Impact

trunk area through the base of the rear seat. A fire wall between the trunk and passenger compartment would certainly have delayed entrance of the fire into the passenger compartment.

Since the car had not stopped totally on a puddle of gasoline, at first only the rear half was on fire. But there still was little time for escape through the left doors, which had remained functional, and which were not covered by flames. The rate of heat rise within the compartment was so great that a dazed person, improperly restrained during the collision, would not have been likely to have responded within the 60 sec that were judged potentially survivable.

The striking car rolled squarely onto the layer of gasoline that the rear-ended car trailed from its ruptured tank as it was catapulted to its position of rest (Figure 6-2). Within 2 sec after the cars contacted each other, the striking car was also completely engulfed in flames. Successful escape from this car was also considered highly unlikely.

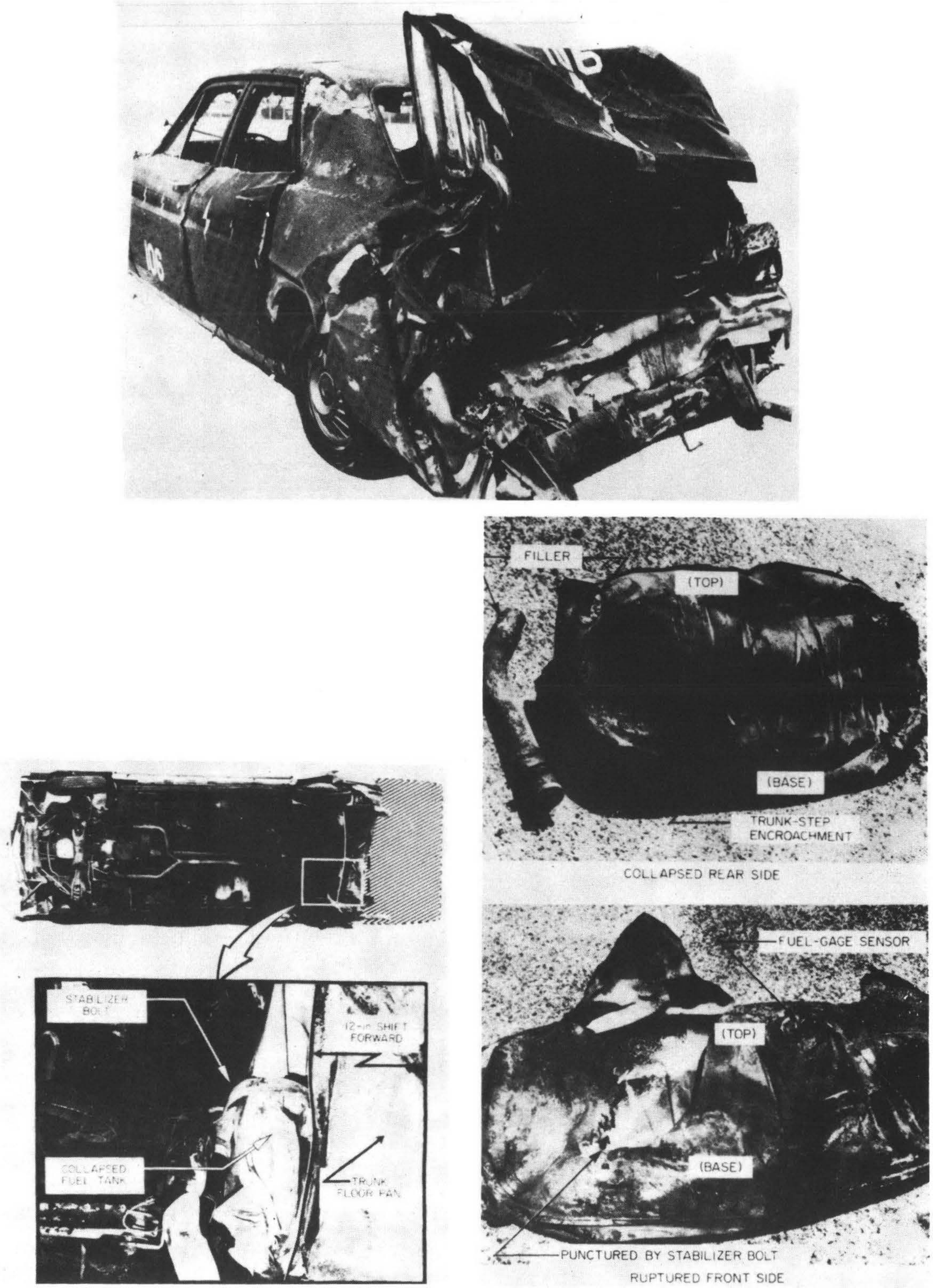


Figure 6-2. Results of Impact at 55 MPH

D. FIRE ACCIDENT OBSERVATIONS

1. New England Thruway

The accident shown in Figure 6-3 occurred on July 7, 1969 and was reported in the New York Daily News of July 8, 1969. A 1966 Corvair impacted a wall while traveling on the New England Thruway. Detailed information concerning this accident was unavailable at press-time of this report.

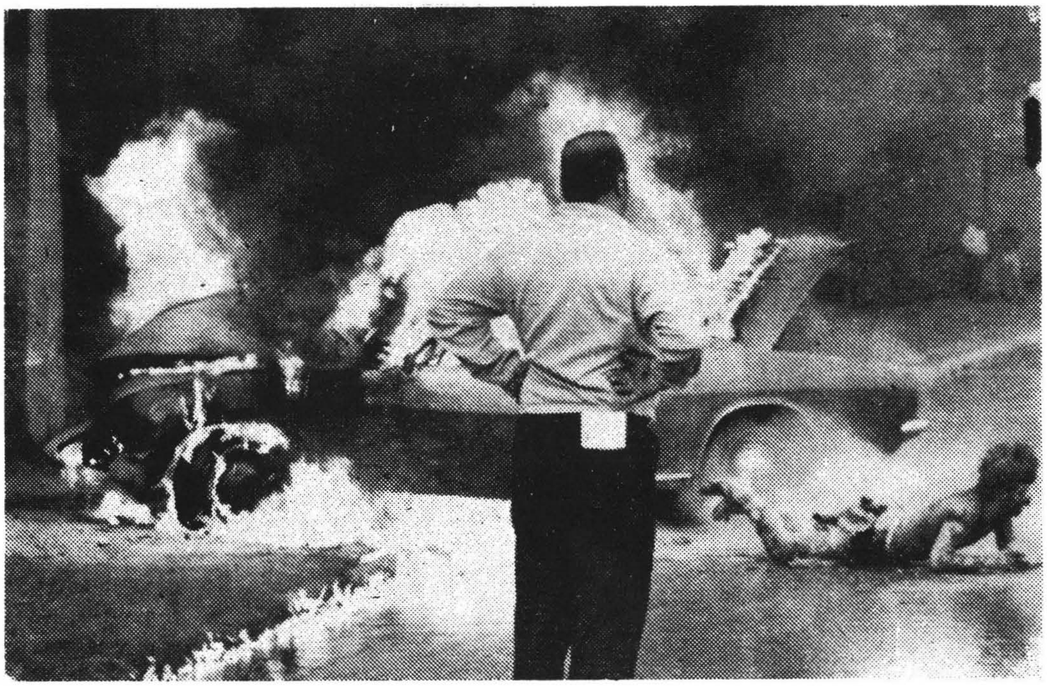


Figure 6-3. 1966 Corvair after Impacting a Wall

2. New York State

The following are summaries of accident reports compiled by New York State agencies on accidents involving fire:

- 1968 Chevrolet Sedan
  - Expressway on bridge, fog, wet road, 12 midnight
  - Operator lost control of vehicle and struck a metal pole. The vehicle burst into flames.
- 1968 Valiant Sedan
  - Expressway, rain, wet road, 11:45 p.m.

  - Vehicle was stopped while driver was changing a tire. A 1968 Pontiac with unlicensed operator (uninjured) struck the 1968 Valiant Sedan in the rear causing it to catch fire and destroying the vehicle.

- 1967 Ford Van

  - Urban street, clear weather, wet road, 1:30 p. m.

  - Vehicle stopped suddenly and a 1965 Volkswagen convertible skidded into its rear. The rear of the 1967 Ford Van was damaged. A small electrical fire started and was extinguished.

- 1967 Plymouth Hardtop

  - Rural state road, rain, wet road, 2 a. m.

  - Operator, affected by oncoming car headlights, pulled to the right. The vehicle went over a soft shoulder into a ditch and caught fire. Vehicle was destroyed.

3. University of California (ITTE)

The following summary, prepared by D. M. Severy of the Institute of Transportation and Traffic Engineering, Reference 6-4, describes a crash and the ensuing fire.

A 1968 sedan was rear-ended by a small sports car. The speed differential was 20-25 mph. The driver of the sedan lost control and the vehicle rolled down an embankment, upsetting into a culvert. The top was sufficiently collapsed to trap the occupants inside.

Impact damage had been small, but the rear bumper had been indented 6 in. at its center, where the filler cap for the fuel tank (which also served as luggage compartment floor) was located. This intrusion had forced the filler neck forward, causing compression folds in the top of the tank sheet metal about the forward surface of the filler spout. At one of these folds, the metal had stretched to failure, developing a small crack.

Flames, fed by a trickle of gasoline into the luggage compartment from the cracked fuel tank, augmented by leakage from the adjacent fuel vent, gradually worked their way from the luggage compartment into the passenger compartment. As the flames increased, rescue attempts had to be discontinued, making it necessary to abandon the occupants struggling to find an escape from the vehicle.

There was no metal partition between the fuel tank and the passenger compartment, so the burning fuel could flow directly from the gasoline tank into the passenger compartment.

The rear side of the fuel tank is directly adjacent to the forward face of the rear bumper. A light to moderate rear-end collision will, therefore, directly impact the fuel tank. There is no protective or buffer zone. The absence of a vapor-sealed metal partition between the fuel tank and the passenger compartment exposes the passengers to raw gasoline vapors, should the vent flexible coupling become detached or should any other topside leak occur. Gasoline fumes are toxic, and they can also provide an explosive mixture within the passenger compartment. In addition, any damage to the rear end or sides at the rear of the car may develop a break in the tank that will allow gasoline to be forced directly into the passenger compartment. The placement of the filler spout at the rear end of the vehicle positions it for direct impact for the most frequently occurring car-to-car accident type - the rear-end collision.

4. Fairchild Hiller, Republic Aviation Division

The following are summaries of three accidents involving post crash fires that were investigated by Fairchild Hiller Motor Vehicle Safety program personnel.

ACCIDENT SUMMARY NO. 1

VEHICLES:	1964 Volkswagen convertible and garbage truck
TYPE ACCIDENT:	Collision with rear of parked garbage truck
DATE AND TIME:	Saturday, 15 June 1969, approximately 2:40 a.m.
LOCATION:	Bay Shore Road and Skidmore Road, Deer Park, L.I., N.Y.
ROADWAY:	Two lanes, one in each direction, running east and west, no separation. Roadway straight, with street lights every 200 feet; asphalt surface, each lane 14 feet wide with an 8-foot gravel and asphalt shoulder (Figure 6-4).

SPEED LIMIT: 40 mph

WEATHER: Intermittent light rain

THE ACCIDENT: The Volkswagen, traveling west, underran the rear of a parked garbage truck. The Volkswagen, which was crushed up to its windshield by the underside of the truck, caught fire (Figures 6-5 through 6-8).

The fuel tank, located forward of the passenger compartment was dislocated and the filler pipe was bent rearward (Figure 6-9). The 19 year old driver was removed from the burning car by a passing police officer. His 19 year old female companion, who was killed in the crash, could not be reached until the fire had been extinguished. The driver died several days after the accident.

A typical garbage truck, similar to the one involved in the accident (93 inches across rear) is shown in Figure 6-10.

ACCIDENT SUMMARY NO. 2

VEHICLES: 1968 Mercury Montego and 1966 Pontiac

TYPE ACCIDENT: Stopped Mercury impacted from rear by Pontiac

DATE AND TIME: Friday, 16 May 1969, 6:15 p.m.

LOCATION: Route 25 (Jericho Turnpike), one-quarter mile west of Commack Road, Commack, L.I., N.Y.

ROADWAY: Four lanes, two lanes in each direction, running east and west, marked by a double yellow line. Roadway straight, concrete surface with 6-foot dirt and gravel shoulder on each side.

SPEED LIMIT: 50 mph

WEATHER: Clear, 65°F

THE ACCIDENT: The Pontiac, traveling east at approximately 60-70 mph, collided with the rear of the Mercury (Figure 6-11), which was stopped in the right traffic lane. Investigation indicated that the driver of the Pontiac, which was traveling in left lane, applied his brakes just before the impact, thus causing his vehicle to swerve into the left rear of the Mercury. As a result of the collision, the Mercury caught fire.

Figure 6-4. 1964 Volkswagen Accident Site

Figure 6-5. Front View of Volkswagen

Figure 6-6. Interior Views of Volkswagen

Figure 6-7. Side View of Volkswagen

Figure 6-8. Volkswagen Trunk Compartment Showing Damage to Fuel Tank

Figure 6-9. Volkswagen Filler Neck

Figure 6-10. Rear View of Typical Garbage Truck

The collision caused 24 inches of deformation to the rear of the Mercury (Figure 6-12). The fuel tank (which forms part of the trunk floor) was ruptured and turned downward from its normal horizontal position to a vertical position (Figure 6-13), causing it to contact the road surface (Figure 6-14). Both the driver and passenger of the Mercury were severely burned. The driver of the Pontiac was injured.

Probable causes of the fire were: (1) the rupture and dislocation of the fuel tank; and (2) sparks created by the fuel tank as it contacted the pavement. Figure 6-15 shows a view of the interior of the Mercury after the fire had been extinguished.

ACCIDENT SUMMARY NO. 3

VEHICLES:	1966 Cadillac and unidentified vehicle
TYPE ACCIDENT:	Minor side impact
DATE AND TIME:	Tuesday, 3 June 1969, Time unknown
LOCATION:	Hempstead, L. I., N. Y.
ROADWAY:	Unknown
THE ACCIDENT:	The Cadillac was side-swiped on the left side by an unknown vehicle. The impact, though minor, was sufficient to cause a short in the electrical system. The fire engulfed the engine, but did not travel beyond the engine compartment. Figures 6-16 through 6-21 show the results of the fire.

E. CONCLUSION

No conclusive findings relative to the origin of post crash fires can be drawn from information presently available. In the studies of D. M. Severy (References 6-2, 6-3 and 6-4), the spillage and dispersion of fuel and the spreading of fire was studied. In spillage tests the simulated fuel used was purposely inert. In fire study tests the fuel used was purposely ignited. In typical accident reports submitted by law enforcement officials the possible cause of post crash fire is neglected because the extensive damage destroys all evidence relevent to cause.

Figure 6-11. Rear View of 1968 Mercury

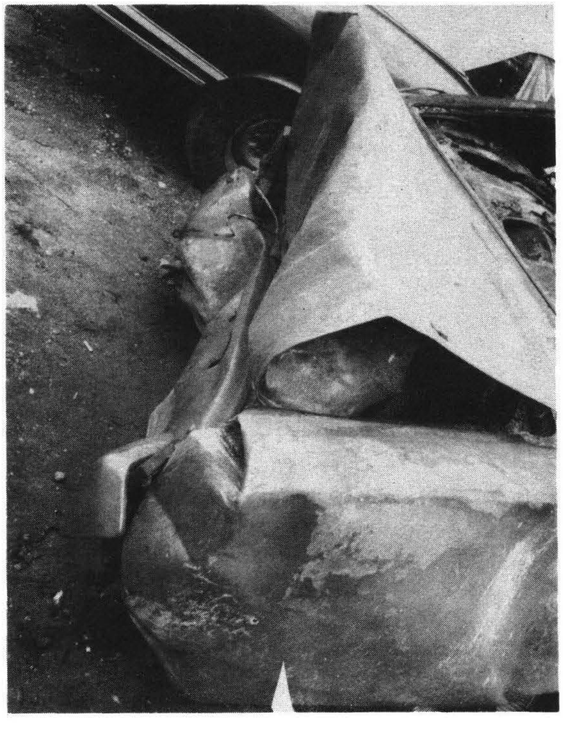


Figure 6-12. Side View of Mercury Showing Extent of Rear Deformation

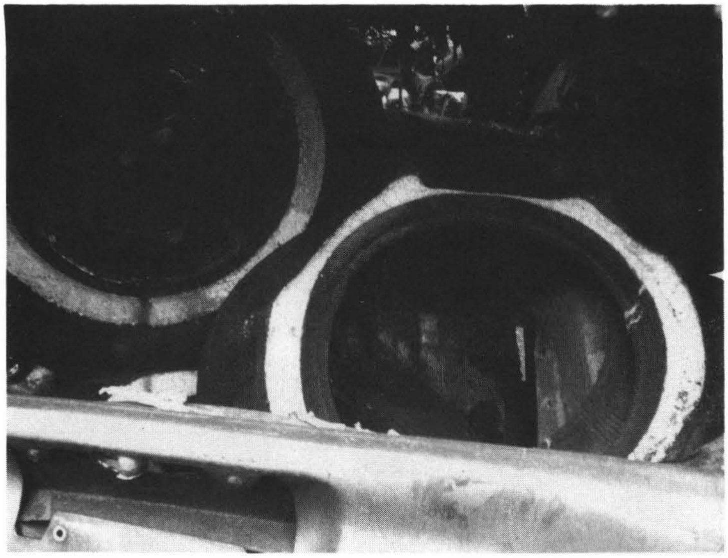
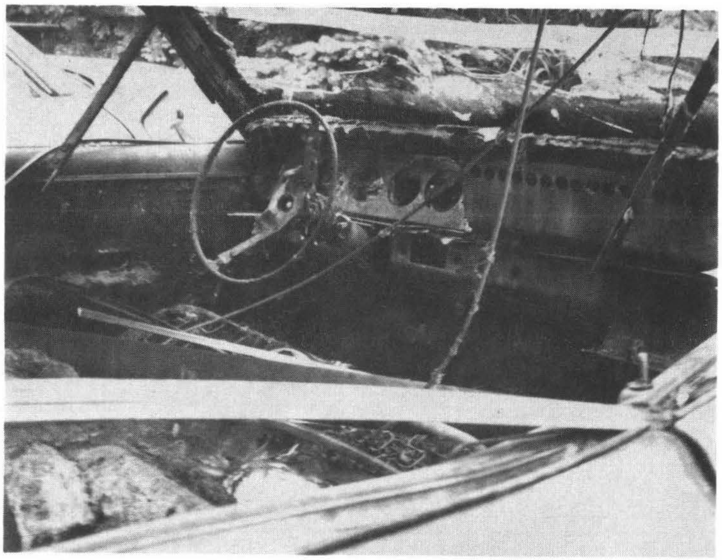


Figure 6-13. Mercury Trunk Compartment

Figure 6-14. Mercury Fuel Tank in Contact with Ground



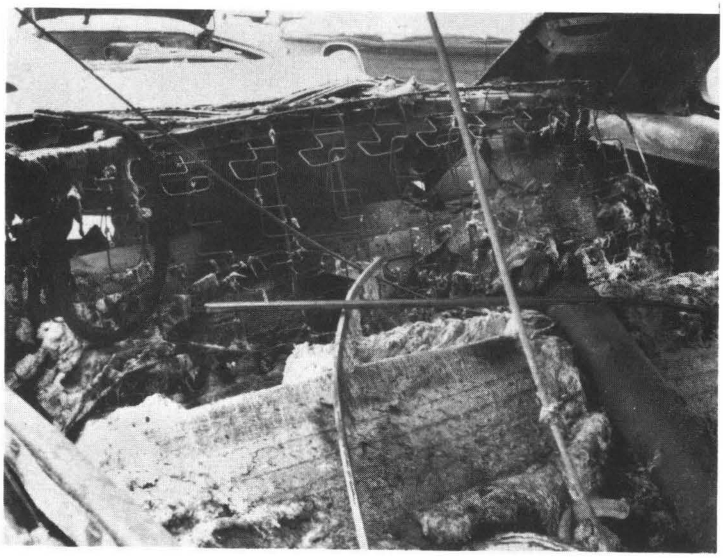


Figure 6-15. Interior Views of Mercury

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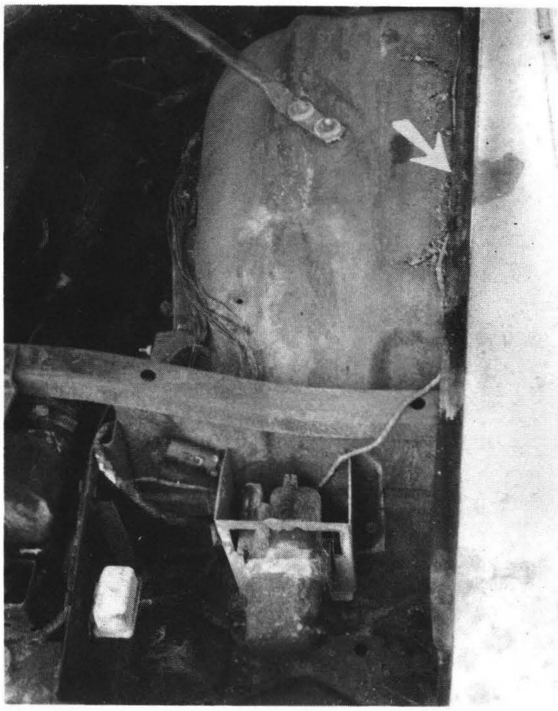

AFTER

Figure 6-16. Cadillac Harness Passing Over Wheel Well

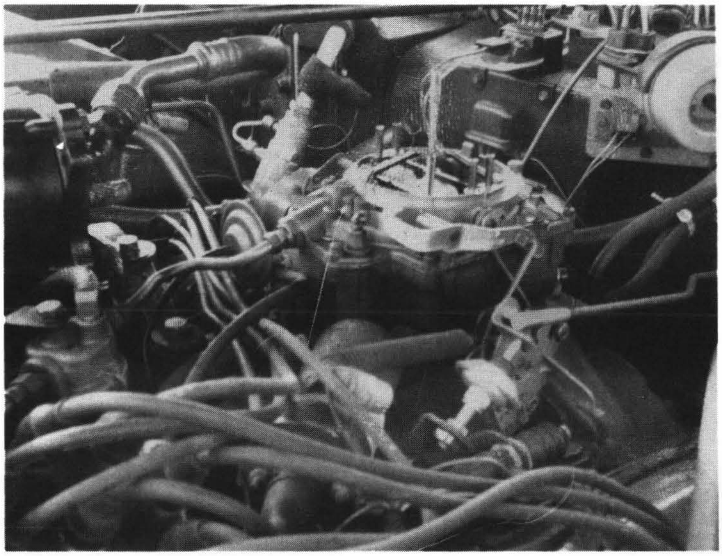

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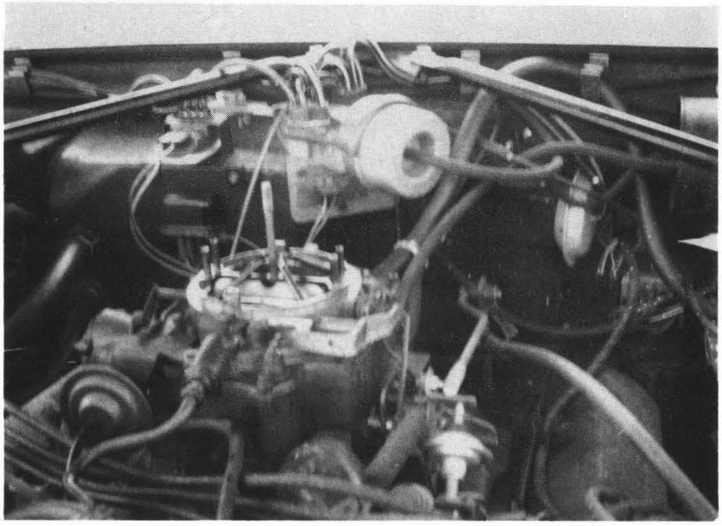
Figure 6-17. View of Left Side of Cadillac Engine Compartment



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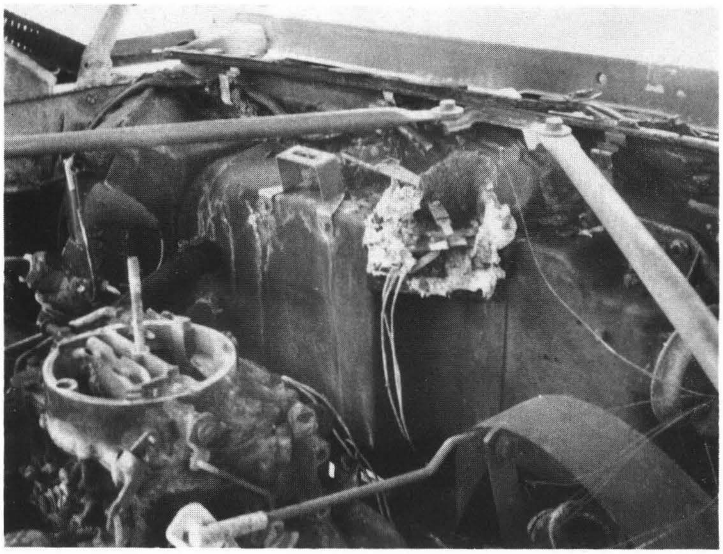

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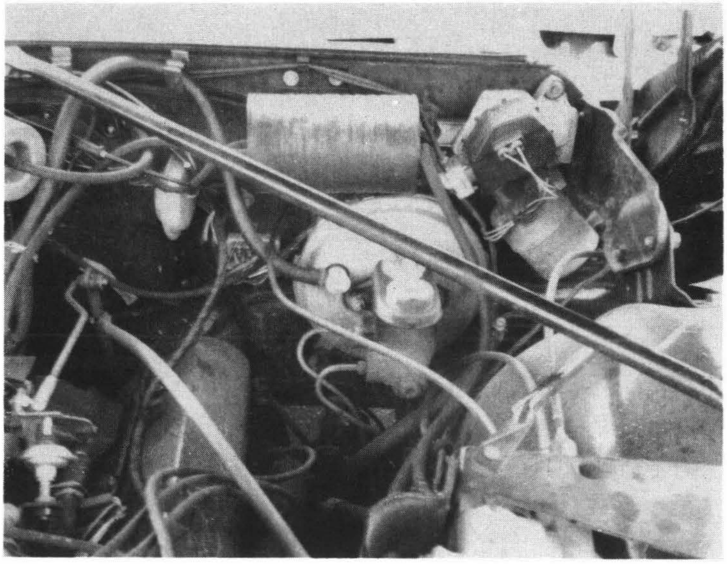
Figure 6-18. View of Cadillac Engine Compartment Firewall



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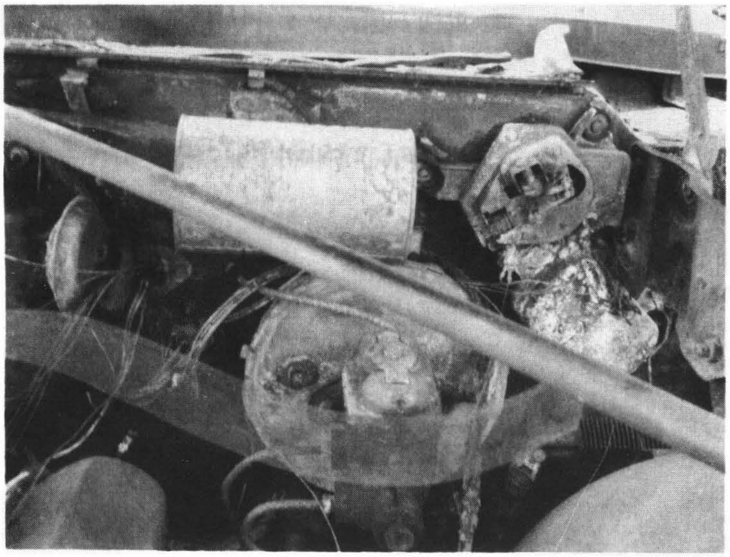


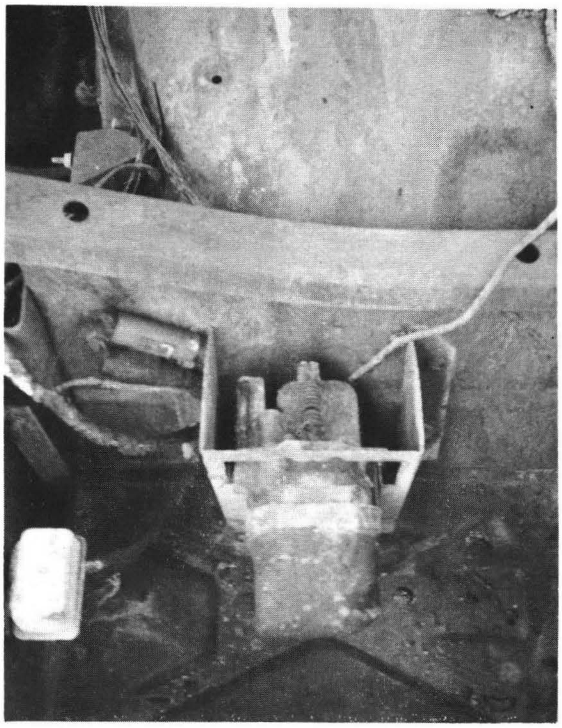
AFTER

Figure 6-19. Closeup of Left Side of Cadillac Firewall

BEFORE AFTER

Figure 6-20. Cadillac Battery Location

BEFORE



AFTER

Figure 6-21. Cadillac Cruise Control Unit

Consequently, unless tests are conducted with the prime objective of isolating the cause of ignition, such data will not be available for evaluation.

F. REFERENCES

6-1 S. J. Robinson, "Observations on Fire in Automobile Accidents," Cornell Aeronautical Laboratory Report No. VJ-1823-R21, July 1966.

6-2 D. M. Severy, et al, "Collision Performance, LM Safety Car," Society of Automotive Engineers Paper No. 670458, May 1967.

6-3 D. M. Severy, et al, "Backrest and Head Restraint Design for Rear End Collision Proection," Society of Automotive Engineers Paper No. 680079, January 1968.

6-4 D. M. Severy, et al, "Postcrash Fire Studies Show Need for Rear Seat Firewall and Rupture-Proof Fuel Tank," The SAE Journal, Vol. LXXVII, No. 7 (July 1969), pp. 18-24.

SECTION VII

ELEMENTS FOR CONSIDERATION IN FORMULATING POST CRASH FIRE SAFETY STANDARDS

A. INTRODUCTION

The dominant criteria that were applied in Republic's selection process considered the potential reduction in deaths and injuries due to vehicle fires, as against effort, time, and costs needed to achieve such improvements. The selection of specific areas of vehicles where steps could be taken to avoid fuel, exhaust, and electrical problems was guided in part by considerations of feasibility, acceptability, expediency, and numbers of occupants exposed. Other criteria applied in recommendations were those of reasonableness, appropriateness, practicability, and potential for early implementation.

B. TEST PROCEDURES

To determine the structural integrity and environmental endurance capability of materials used in fuel, exhaust, and electrical system construction, it is recommended that the following tests would be effective:

- Environmental (temperature, corrosion resistance, etc.)
- Hydrostatic pressure
- Dynamic loading

These tests alone would not determine the crashworthiness of a material, but a combination of these and others would assist in determining the performance capability of the material tested.

C. SUGGESTIONS FOR IMPROVING CURRENT PRACTICE

1. Placarding

Design features that are not, in themselves, hazardous may become so if certain modifications are attempted. The creation of hazards in such cases may be prevented by a warning placard in the critical area. An example of a possible modification-produced hazard is the unprotected fuel tank top of the

Ford Mustang which is the luggage compartment floor (Section III, Figure 3-34). The fuel tank is covered by a plastic floor mat. Any modification requiring the installation of anchorages in the floor of the trunk would penetrate the tank.

2. Grommets

Flexible hose or rigid fuel line components may run through holes punched in structural or body metal members (Section III, Figure 3-8). Abrasion from normal usage or crash impact may result in fracture or cutting of the fuel line. The same conditions apply to electrical wiring similarly routed. Elastomer grommets installed in holes that are used for fuel line/electrical wire runs may prevent failure at crash.

3. Prevention of Fuel Line Leakage

A check valve or other means of providing fuel shut-off should be included in the fuel pickup unit to prevent fuel spillage or leakage in cases of severe damage to the fuel line.

4. Fuel Tank Accessories Connection

Fuel line, vent line, and metering unit connections should be located so that their failure under crash conditions would not cause spillage of raw fuel or fuel vapors over hot exhaust system components.

5. Fuel Line Strengthening and Retention

At critical points in the fuel line, wound-wire or elastomer outer reinforcement should be used to increase resistance to failure at crash. The means of support, such as clips, brackets, or similar retainers, should be fabricated of materials capable of withstanding operating service conditions and maintaining adequate strength. The design, quantity, and positioning of these supports should provide for the maximum retention of the fuel line by the structural or mechanical anchorage component.

6. Wire Support and Retention

Random, unsecured wiring can be modified to result in ordered and well-supported wire groupings. In Figure 7-1, the battery cable to starting motor is secured by metal clamps mounted to the left side body metal. In Figure 7-2, a sheet elastomer forming a support sleeve is mounted to the firewall at the rear of the engine compartment.

Use of similar or additional supports will improve the ability of the wiring to withstand crash conditions.

7. Length of Fuel Line and Electrical Wiring

Short or direct runs of the fuel line position this component in proximity to the engine or exhaust system elements. A similar problem has been noted in the routing of electrical wiring.

This situation could probably be improved if the fuel line or electrical wiring were lengthened, routed around hazardous areas, and attached to the chassis or body metal.

8. Rear Firewall

With few exceptions, the passenger compartment of passenger vehicles is located between the engine compartment and the fuel tank. The major fire threats to this area are posed by the fuel tank and the engine, respectively. For greater fire protection, the passenger compartment of front engine cars should also have effective barriers, or firewalls at the rear, isolating it from the fuel tank and trunk.

In addition to fire protection, the firewalls can serve as structural bulkheads to impede or prevent the intrusion of vehicle components, or objects being carried in the trunk, into the passenger area. The floor pan of the passenger compartment should also be considered as a firewall and constructed to function as such.

To be effective in retarding or preventing fire from entering the passenger compartment, particularly in crash situations, the firewalls and floor pan should be:

- Non combustible
- Sufficiently strong to withstand rupture from survivable impact
- Continuously joined to adjacent body structure

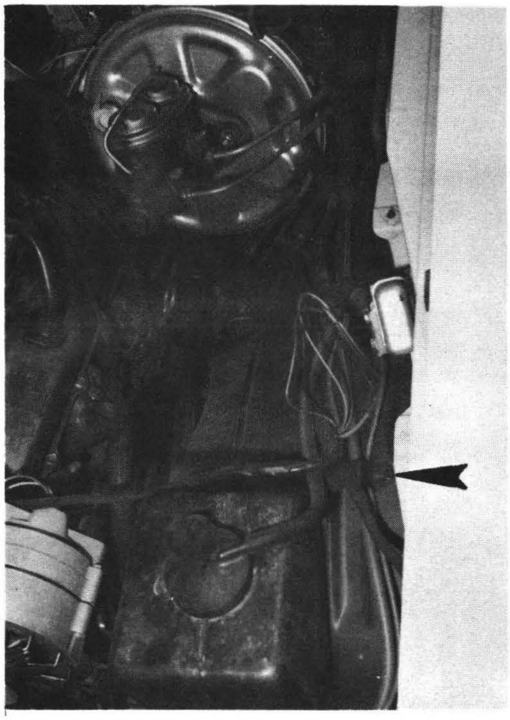


Figure 7-1. 1968 Oldsmobile Cutlass Wiring Retention Device

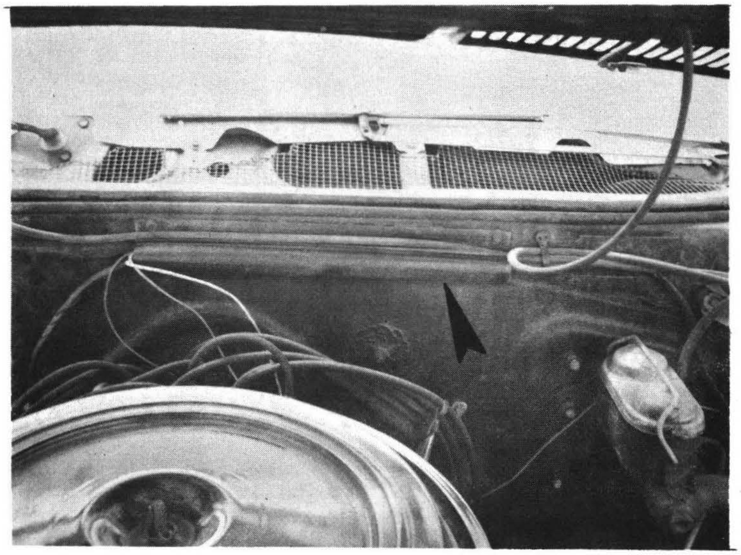


Figure 7-2. 1968 Chevrolet Impala Wiring Retention Device

- Free from voids or openings. If holes or openings are necessary for manufacturing processes, or for wiring, duct work passages, or maintenance access, such openings should be sealed by metal or metal and high temperature resistant, flame retarding elastic grommets securely fastened to the basic sheet.

9. Bumper Heights

SAE recommended Practice J681a specifies a bumper height of 20 inches above the ground. The 20 inch dimension is measured on a passenger vehicle under two loading conditions. The first, called "curb height," is when the vehicle is not loaded, but is filled to capacity with fuel, lubricants, and coolants. Factory installed options are also included. The second, called "design height," is the height above ground when the same vehicle is loaded. The load is considered to be the weight of three passengers (two at 150 pounds each in the front seat, one at 150 pounds in the rear seat) or, in the case of a two passenger vehicle, the weight of two passengers at 150 pounds each in the driver and passenger seats.

The objective of the recommendation is to establish a uniform bumper height, minimize bumper profile projections and depressions, and set minimum acceptable distances from datum points on the bumper to sheet metal, lamps, and ornamentation and thus decrease damage "during parking maneuvers."

This document only skims the surface of passenger vehicle bumper height requirements. No recommendations or requirements are stipulated for other types of vehicles to prevent the scalping of passenger vehicles in crash situations with the other types. The "nose dive" effect of braking just prior to collision is also disregarded, as is any capability for elastic or elastic plus crush deformation.

Examples of the existing disparity of passenger vehicle front-to-rear bumper heights are shown in Figures 7-3 through 7-5. All the vehicles shown were stationary.

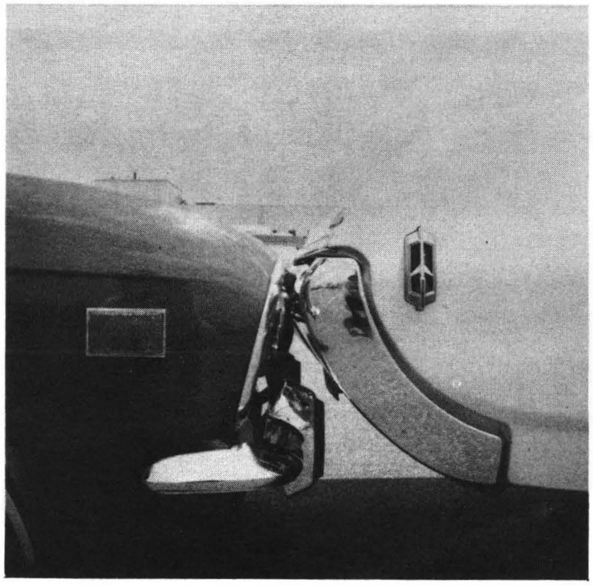


Figure 7-3. Bumper Height Comparison - 1968 Ford Cortina and 1968 Oldsmobile Cutlass

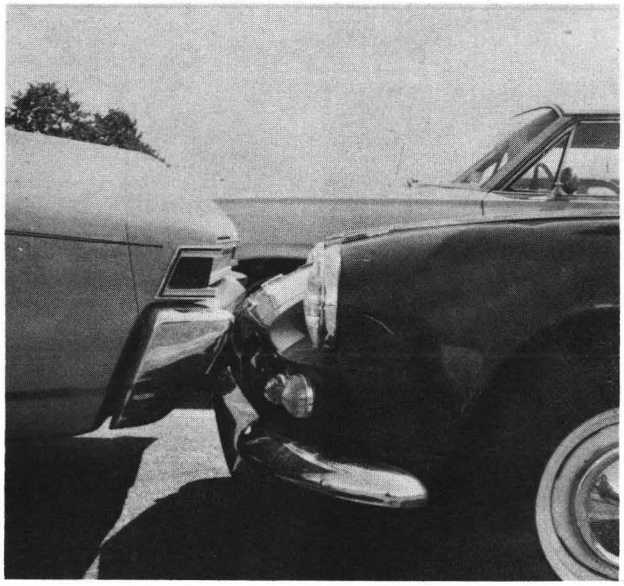


Figure 7-4. Bumper Height Comparison - 1968 Chevrolet Chevelle and 1967 Triumph Spitfire

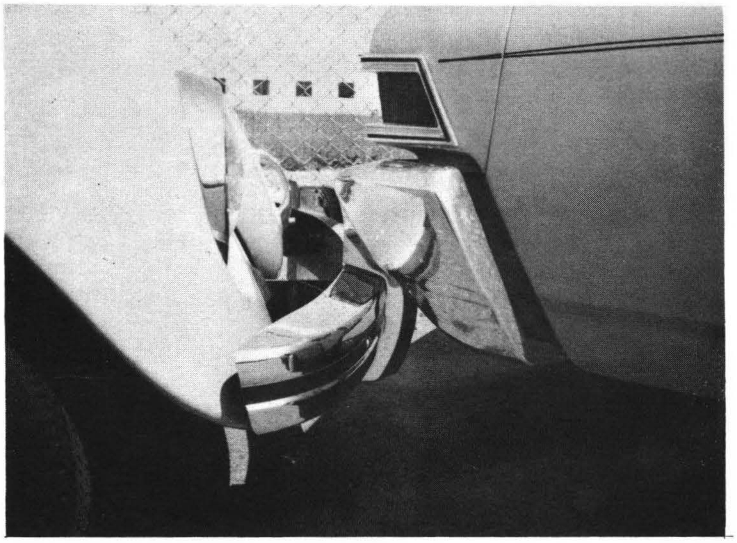


Figure 7-5. Bumper Height Comparison - 1968 Volkswagen and 1968 Chevrolet Chevelle

The figures show that car manufacturers have made little or no effort to maintain uniform bumper heights and that the location and configuration of passenger car bumpers are determined more by styling aspects than by safety considerations.

It is recommended that more definitive standards be set for establishing and mandating uniform bumper heights and contact areas. In the context of this study, proper bumper interfaces would preclude the possibility of a striking vehicle underriding the rear bumper and invading the fuel tank area of the impacted vehicle. The risk of hot engine and sparking electrical components igniting the contents of, or vapors emanating from, a ruptured fuel tank could be lessened by the adoption of effective bumper safety performance standards.

A meaningful Federal Standard to extend and strengthen SAE Recommended Practice J681a, for example, should include specification of the following:

- Uniform bumper height for passenger vehicles
- Bumper contact areas sufficient to prevent underrunning in "nose dive" rear end accidents
- Energy absorption capability of passenger vehicle bumpers
- Barriers or bumpers on trucks, busses, and special purpose vehicles that would provide contact surfaces compatible with those of passenger vehicle bumpers
- Increasing the minimum horizontal bumper projections from other components of the vehicle.

SECTION VIII
RECOMMENDATIONS FOR FUTURE PROGRAMS

Investigators both at the Republic Aviation Division of Fairchild Hiller and elsewhere suspect that the incidence of post crash fires is increasing. While definitive statistical data have yet to be compiled, authoritative researchers have reason to believe that a significant increase in the frequency and severity of accidents resulting in post crash fires is developing. Apparently, this is due to the rapid expansion of "thruway" highway systems which permit higher operating speeds which, in turn, impose more critical demands on the driver, and, in the event of a collision, a higher degree of structural deformation to the vehicles involved. These factors combine to magnify and further aggravate the consequences of rear end collisions.

Also, it is expected that the post crash fire will become responsible for an ever-increasing proportion of highway fatalities as advances are made in the crashworthiness of automotive vehicles. At one time it was presumed that certain crashes serious enough to produce a fire would be fatal to the vehicle's occupants. In the not too distant future, however, passenger compartment energy management will reach a state of advancement where the crash itself results in little or no injury to the vehicle's passengers, but where an ensuing fire might cause them to become fatalities. Thus, the post crash fire, which has heretofore been a secondary effect, may now become a primary effect in the cause of accident fatalities. This is a problem to which airplane designers have addressed themselves for many years and which now requires equal attention by the automobile designer. Advances in fire protection must therefore keep pace with other safety measures so that this problem can be kept under control. Neglect would raise the serious possibility of a dramatic increase in crash fire fatalities.

For this reason, it is strongly recommended that, as a minimum follow-on program, highway crash fire statistics be collected and analyzed on a continuing basis, and that each new model introduced by an automobile manufacturer be surveyed so that its principal characteristics with respect to fire safety can be tabulated in the same manner as that used in the study described in this document. Such a program would serve to reveal glaring deficiencies which were not previously the subject of standards and regulations and would enable appropriate remedial action to be taken. Also, continued cataloging will provide the data necessary for a quick response to an emerging pattern of crash fires for specific vehicles.

In addition, it is desirable as a follow-on program to evaluate the worth of fire inhibiting devices and techniques being developed by the industry. A majority of these innovations will relate to the elimination of fuel spillage in crashes and rollovers. The NHSB contractor would analyze the designs, claims, and test results of the manufacturer. Conclusions would include an opinion regarding the conformance of the devices to existing standards and regulations, its overall effectiveness in reducing crash fires, and the advisability of modifying the standards and regulations to adapt to new technology.

A test program is also recommended for determining the actual performance of existing vehicles, components, and subsystems and for evaluating new or proposed improvements. The results of tests would provide additional practical guidance for the formulation and establishment of automotive safety standards.

A brief work statement for each of the four items of recommended follow-on work is as follows:

A. Crash fire accident reporting and analysis.

   1. Develop a reporting system which identifies the significant parameters in a crash fire

   2. Integrate the above informational requirements into the accident reporting procedures being developed under the auspices of the NHSB as a standardized, nation-wide accident data acquisition procedure

   3. Analyze the data received and make continuing annual reports in monthly increments

B. Analysis of manufacturer's new designs.

1. The interaction of the fuel, exhaust, and electrical systems of new designs, both domestic and foreign, employed in passenger and commercial vehicles should be studied. Individual reports would be submitted for each case.

C. Evaluation of new systems and developments designed to inhibit or eliminate crash fires.

1. This effort would include liaison with manufacturers in the development of new ideas. The data analyses derived from the statistical program would be furnished to the manufacturers to provide guidance for their developmental activities.

2. Objective reports of new developments would be prepared for dissemination to interested manufacturing and consumer groups for formal evaluation and proposed rule making. Performance standards could then be established based upon the effectiveness of the system, as well as on the determination of need.

D. Test planning and implementation

1. The data analyses from the statistical program would be furnished to a selected contractor for the purpose of developing vehicle tests that would provide realistic and reliable guidance for the promulgation of safety performance standards to attain the highest levels of fire crash safety consistent with the state-of-the-art and cost effectiveness.

2. The test programs would include crash testing of complete vehicles, as well as tests of individual vehicle components and subassemblies. Evaluations would be made of the strength, fire resistance, corrosion resistance, mechanical properties, and other characteristics of materials tested.

3. Objective testing of modifications, improvements, and technological advancements relating to post crash fire safety would also be conducted.

4. Data on the test results and any conclusions or recommendations arising therefrom would be made available to manufacturers and standards setting agencies.