Motor Vehicle Fires in Traffic Crashes and the Effects of the Fuel System Integrity Standard

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Abstract

To reduce fatalities and injuries due to fire in motor vehicle crashes, Federal Motor Vehicle Safety Standard 301 was issued. This Standard, which applies to passenger cars, light trucks, school buses, prescribes impact test requirements aimed at reducing the chances of fuel-fed fires caused by fuel system breaching in vehicle crashes. This study is an evaluation of the effectiveness, benefits, and costs of fuel system improvements made in response to the Standard. It is based on analysis of on-road crash data from 5 States, FARS, and on information supplied by automobile manufacturers. The study found that:

- Standard 301 has reduced fires in passenger car crashes; the effect on burn injuries is uncertain; fatalities were not affected. For light trucks, no fire reduction was found. Fires in school bus crashes were too sparse for reliable assessment.
- Fires in fatal passenger car crashes have increased, primarily due to an aging vehicle fleet. Fire risk increases with vehicle age.
- The contributions of fire and impact forces in causing death and injury cannot be separated in crash data files.
- The consumer cost of FMVSS 301 ranges from $9.70 for passenger cars to $234 for Type I (conventional) school buses.

Executive Summary

Introduction

The National Highway Traffic Safety Administration (NHTSA) is required, under Executive Order 12291, to conduct periodic reviews of the regulations it has issued. The purpose of these reviews is to measure the impact of those regulations in terms of both the benefits and costs to the American public.

This study is a review of Federal Motor Vehicle Safety Standard 301 - Fuel System Integrity (FMVSS 301). The Fuel System Integrity Standard is intended to reduce the chances of injury and fatality due to fires which result from motor vehicle crashes.

Though crashes with fires are relatively rare, fires in motor vehicle crashes have long been a topic of interest and concern. By its very nature, the occurrence of fire can significantly increase the risk of injury in motor vehicle crashes. Fire is of particular concern in crashes where entrapment of the vehicle occupants has occurred, due to jammed doors, or other collapsed vehicle structures that may have pinned the occupants inside the vehicle. Fire is also of concern in crashes where the nature or extent of injury prohibits occupants from extricating themselves. In both of these instances, the presence of fire has the significant potential for increasing injury beyond that caused by crash impact forces.

Due to the hazard it creates, and the speed with which it can spread, it is obviously preferable to attempt to reduce the risk of crash fires occurring rather than to rely on potential rescue efforts, once a fire has started. This is the aim of FMVSS 301. The requirements of this Standard are intended to strengthen and protect the vehicle's fuel system, so that in a crash event, the chances of fuel leakage, and consequently the chances of fire and occupant injury, will be reduced. Because of the highly flammable properties of gasoline, it is an obvious first choice as the source of combustible material

in motor vehicle crash fires.

FMVSS 301 was first issued by the National Highway Traffic Safety Administration in 1967. In its initial version, the Standard applied only to passenger cars, manufactured after January 1, 1968, and the fuel system requirements covered only impacts to the front of the vehicle.

Subsequently, the Standard was revised, both to increase the individual performance requirements, and to extend the requirements to other classes of vehicles. In 1975, protection against rollover crashes was added to the frontal requirements for passenger cars. In 1976, these requirements were further increased to include protection against rear and side impacts. In 1976 and 1977, the requirements for cars were extended to light trucks (pickups, vans, multipurpose passenger vehicles, and buses) with gross vehicle weight ratings of 10,000 pounds or less. Finally, in 1977, a fuel system integrity requirement was established for Type I (large) school buses which included frontal, rear, and side protection.

In order to comply with the FMVSS 301 requirements, vehicles must withstand certain specified impact tests ranging from 20 to 30 miles per hour, without leaking fuel in excess of one ounce per minute following the tests.

Study Approach

This study is a statistical evaluation of the effectiveness of the 1975 through 1977 (upgrade) versions of FMVSS 301 in reducing vehicle crash fires, and associated injuries and fatalities. Descriptions of vehicle modifications resulting from the Standard are also included together with estimates of the consumer costs of the these modifications. Thirdly, selected statistics which portray the magnitude and nature of fires in motor vehicle crashes are presented.

The effectiveness analyses are based on the police reported motor vehicle crash files from five States, plus the files of NHTSA's Fatal Accident Reporting System (FARS). Multiple years of data from both sources are used, providing a total of over 14.5 million police-reported crashes from the States and approximately 700,000 fatal vehicle crashes from FARS. Thus, the data represent real-world traffic crashes, and the primary basis for estimating effectiveness is the statistical comparison of fire rates for vehicles manufactured after Standard 301 went into effect, as compared with the fire rates for vehicles produced before the Standard.

Estimates of the costs of Standard 301 are based on information obtained from the motor vehicle manufacturers. Both vehicle modification costs, and fuel penalty costs to cover the added weight of the vehicle modifications are considered.

In most of its evaluation projects, NHTSA develops cost information through independently conducted vehicle teardown studies. These studies disassemble affected components from actual production vehicles, and estimate the costs of the component changes by comparison with baseline components produced prior to the issuance of the Federal standard. Due to the more subtle and varied nature of the vehicle modifications made in response to FMVSS 301, the vehicle teardown approach to cost estimation was not practicable.

Data Limitations

While police reported accident files are considered the best source of data on motor vehicle crash fires, they are nonetheless subject to certain limitations.

First, fires in traffic crashes include both those that result from the crash (post-crash fires) as well as those that are initiated prior to the crash (pre-crash fires). While it is not possible to reliably distinguish between post-crash and pre-crash fires, limited data indicate that pre-crash fires could approach 1/2 of all fires reported in police reported traffic crash data. The proportion of total fires that are post-crash would be expected to increase as the severity of the crash impact increases. FMVSS 301 is primarily designed to affect post-crash fires.

Secondly, in police reported accident data. it is not possible to distinguish between injuries caused by fire and injuries caused by crash impact forces. Since both injury severity and the likelihood of vehicle fire increase with increasing crash severity (i.e., impact force)., delineating the role of fire in injury causation is further compounded.

Lastly, the data obtained from motor vehicle manufacturers concerning the cost and type of vehicle modifications made in response to FMVSS 301 was less complete than desirable. While some companies supplied quite detailed data, other

firms were able to provide only limited, or in some instances, no data. One of the hindrances to providing information was the span of several years between the time FMVSS 301 was issued and the time the information was requested from the manufacturers.

Prior Studies

Several prior studies have dealt with fires in motor vehicle crashes and the effects of FMVSS 301 in reducing these fires. Primarily, these earlier efforts studied only fires in passenger car crashes, and all were conducted several years ago when both the available sources and quantity of fire data were much more limited than today. One of the reasons for lack of data at the time the earlier studies were made was that insufficient time had elapsed, following the issue of FMVSS 301, to permit the accumulation of a large sample of on-road accident experience for vehicles incorporating FMVSS 301 modifications.

Generally, the safety effects of Standard 301 found in this study, for passenger cars, are in agreement with those found in the earlier studies, with one principal exception. This study finds no significant reduction for fatalities in fire crashes whereas an earlier (1983) NHTSA evaluation estimated a substantial reduction in fatalities. The principal reason for this difference in findings for fatalities is the limited amount of data used in the earlier study. The study was based on only three years of data from one State and did not analyze data on fatal passenger car crashes.

Principal Findings

The Frequency of Fires in Motor Vehicle Crashes

- Motor vehicle fires in all police-reported traffic crashes are relatively rare, occurring at the rate of approximately 3 fires for every 1,000 vehicles involved in crashes.
- For all vehicles involved in fatal crashes, fires are considerably more frequent, with about 26 fires per 1,000 vehicles In crashes nearly 9 times the rate for all crashes.
- For each of the 3 classes of vehicles of primary interest in this study - passenger cars, light trucks, and school buses, the fire rate and estimated number of fire crashes annually are:

	Fires per 1,000 Vehicle Crashes	**Total Number of Fires Annually**
passenger cars	2.9	23,600
light trucks	2.9	5,200
school buses	2.4	60

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- For injury crashes involving passenger cars or light trucks, the fire rate is higher at 7 to 8 fires per 1,000 crashes.
- Fire in fatal collisions of passenger cars has increased significantly over the last several years, from 20 per 1,000 crashes in 1975 to 28 per 1,000 crashes in 1988. A primary reason for this increase is believed to be an increasing proportion of older vehicles in the car population. Older vehicles are more likely to experience fire, given a crash. The fire rate was not found to be related to car size, as defined by vehicle curb weight. Therefore, the trend to smaller cars over the last several years does not appear to be a factor in the increased rate of fires in fatal passenger car crashes.

Casualties in Fire Crashes

- From 1975 to 1988, over 1,600 people per year died in vehicles involved in fire crashes. The number of fire-related fatalities has increased over the 14-year period, from 1,300 in 1975 to over 1,800 in 1988, due primarily to the increase in fire rate for passenger cars.

- Slightly more than 4 percent of all occupant fatalities occur in fire crashes. For passenger cars, the rate is just under 4 percent, and for light trucks, the rate is 5 percent.
- Over the same period, total estimated occupant casualties in fire crashes involving cars and light trucks, annually, are:

	Number of Casualties	
	Passenger Cars	**Light Trucks**
K (fatal)	1,020	345
A (serious)	2,900	600
B (moderate)	4,300	800
C (minor)	2,800	500

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- The available sample of school bus fires was insufficient for estimating occupant casualties in fire crashes.

The Effectiveness of FMVSS 301

Passenger Cars:

- It is estimated that FMVSS 301 has reduced fires in all passenger car crashes by 14 percent. This translates to 3,900 fewer fires annually, once the entire car fleet has been modified in accordance with the Standard's requirements. Presently. about 85 percent of the car fleet contain these modifications.
- Some evidence exists that fire rates in injury crashes may be lower for post-standard vehicles, but the information is insufficient for definitive statistical conclusions.
- In fatal passenger car crashes, there was no significant reduction in the fire rate for vehicles produced after the Standard took effect. Fire is associated with the more severe impact crashes which also tend to be fatal crashes.

Light Trucks:

- No significant reduction in crash fires was found for post-standard light trucks, both for all police-reported crashes, and fatal crashes alone. While data were insufficient for analysis of fire rates in injury crashes, the finding of no fire reduction for all crashes or for fatal crashes implies that none would be found for injury crashes as well.

School Buses:

- Data were insufficient to develop reliable estimates of the effect of FMVSS 301 for school buses.

The Costs of Modifications Made for FMVSS 301:

- Various types of vehicle modifications were made in response to FMVSS 301. As would be expected, most of these changes were designed to provide increased protection to the fuel tank. Some of the modifications involved the fuel tank itself, while other changes involved vehicle components in or near the vicinity of the tank. which could come into contact with the tank, and cause fuel leakage during a crash situation.
- The estimated increases in vehicle weight, due to FMVSS 301 modifications, and the resultant cost, in 1988 dollars, to the consumer are:

School Buses

Per Vehicle	Passenger Car	Light Truck	Type I	Type II
Weight Increase	3.1 lbs.	7.8 lbs.	140 lbs.	7.8 lbs.
Cost Increase	$9.70	$30	$234	$25.60

Other Findings

The Age Factor

- The presence of fire in vehicle crashes is strongly related to the age of the vehicle. Older vehicles are more likely to experience fires. This is believed to result from the general degradation (corrosion, weakening of metal structures; hardening, cracking of flexible hoses, etc.) of vehicles over time. Another possible factor that could contribute to the age effect is the probable under-reporting of accidents involving older vehicles, owing to their decreased worth.

The Severity of Fire Crashes

- Fire is associated with substantially more serious accidents, in terms of injury severity to vehicle occupants. Even for crashes at the most extreme level of injury - i.e., fatal crashes - vehicles with fire experience anywhere from 70 to 80 percent more occupant fatalities than do vehicles in all fatal crashes.
- For nonfatal crashes, occupants of vehicles with fire sustain 3 to 4 times the chance of serious (A) injuries as occupants of vehicles in all crashes. For moderate (B) injuries, the risk is about 2 times greater for occupants of vehicles in a fire crash.
- Crashes with fire are also more severe in terms of crash impact forces exerted on the vehicle and its occupants, and in terms of the extent of damage sustained by the vehicle:

  - among all crashes resulting in fatal injury, those that involved fire are 30 percent more likely to occur on roadways with the highest speed limits. Higher speed limits indicate higher traveling speed and hence, higher impact speeds and crash forces.

  - among all fatal crashes, those that involve fire are 70 to 90 percent more likely to be single vehicle collisions with fixed objects; this indicates more severe impacts for crashes with fire.

  - for all police reported crashes, vehicles with fires are 2 ½ to 5 times more likely to have sustained the highest levels of damage due to the crash, as recorded by vehicle damage indices.

Fire Crashes by Direction of Impact

- Impacts to the front of the vehicle account for 60 to 70 percent Of the crash fires, for both passenger cars and light trucks. This applies to fatal, as well as non-fatal crashes.
- Rear impacts are over-represented (3 times as likely) in fatal fire crashes involving passenger cars, but not for light trucks. This may be a reflection of the more vulnerable location of fuel tanks in cars than in light trucks. For less severe, non-fatal collisions, this over-representation of fire in rear impacts does not appear.

Conclusions

- FMVSS 301 has been effective in reducing the incidence of fire in passenger car crashes. No reduction in fire-related fatalities was found; the force levels encountered in fatal fire crashes may generally exceed the levels set by the Standard. Burn injuries may have been reduced, but available information is insufficient for definitive conclusions.

- For light trucks built after FMVSS 301 took effect, no reduction in fires was found, either for all police-reported crashes or for fatal crashes, alone. It is possible that the pre-existing design and location of fuel system components afforded greater impact protection for light trucks than for passenger cars.
- Data on fires in school bus crashes were insufficient to permit reliable conclusions of the effect of FMVSS 301 in these vehicles.
- Older vehicles are more likely to experience fire crashes than new vehicles. One reason for this is believed to be the general degradation and weakening of vehicle structures and components over time.
- The fire rate in fatal passenger car crashes has increased significantly during 1975 - 1988. An increased proportion of older cars in the population (greater longevity of cars) is believed to be a principal reason behind this increase. Vehicle downsizing does not appear to be an important factor since fire rates did not vary with vehicle weight.
- In police accident data, burn injuries cannot be distinguished from injuries caused by impact forces. Since both fire risk and injury severity increase with increasing impact forces, the role of fire in injury causation cannot be determined.