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

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16. 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, and 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.

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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 occupant(s) 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

- 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	
Injury Severity	Passenger Cars	Light Trucks
K (fatal)	1,020	345
A (serious)	2,900	600
B (moderate)	4,300	800
C (minor)	2,800	500

- 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.

<u>The Costs of Modifications Made for FMVSS 301</u>:

- 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	
	Passenger Car	Light Truck	Type I	Type II
Per Vehicle				
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 1/2 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.

CHAPTER 1

INTRODUCTION

This report is another in a continuing series of studies that have been completed by the National Highway Traffic Safety Administration (NHTSA) in recent years for the purposes of reviewing and evaluating the effects of certain Federal safety regulations which the agency has promulgated. NHTSA along with other Federal agencies are required to carry out such studies in order to measure the actual benefits and costs which result from their regulations.[1] In addition, a more recent directive requires that agencies develop, and make public, a plan for the review of their existing regulations.[2]

This study is a review of Federal Motor Vehicle Safety Standard 301; Fuel System Integrity (FMVSS 301). The purpose of FMVSS 301 is to provide a specified level of protection to the fuel system of motor vehicles in order to reduce deaths and injuries that result from fires caused by fuel spillage in motor vehicle crashes.

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[1] Federal Register 46, February 17, 1981, 13193.

[2] Federal Register 50, January 8, 1985, 1036.

1.1 REQUIREMENTS OF FMVSS 301

FMVSS 301, the fuel system integrity standard, first became effective in 1968. Only passenger cars were covered by the initial version of the Standard. Subsequently, FMVSS 301 was revised several times, both to upgrade the individual requirements of the standard and to extend the requirements to other classes of vehicles.

Table 1-1 summarizes the test requirements, showing the period, 1968 through 1977, over which FMVSS 301 was implemented, and the classes of vehicles covered.[3] The test requirements show the direction and speed of impacts which the vehicles are required to sustain, during and after which fuel leakage from the vehicle's fuel system shall not exceed specified maximum limits. A static rollover requirement also applies (currently) to all covered vehicles except school buses. Appendix A contains a copy of the detailed FMVSS 301 requirements as listed in the Code of Federal Regulations.

Essentially, the intent of FMVSS 301 is to strengthen, or protect the vehicle's fuel system such that, in a crash event, the chances of fuel system breaching will be reduced. Less chance of fuel leakage, of course, means less chance of vehicle fire which poses an additional hazard and potential source of injury to the vehicle occupants, apart from the crash forces experienced.

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[3] 49CFR 571.301 Standard No. 301; Fuel System Integrity.

Table 1-1
Chronological Summary of Requirements:
Federal Motor Vehicle Standard 301,
Fuel System Integrity

Period of Vehicle Manufacture	Vehicle Type(s):	Test Requirements		
		Impact Velocity	Impact Mode	With Static Rollover
1-1-1968 to 8-31-1975	Passenger Cars	30 mph	Frontal	No
9-1-1975 to 8-31-1976	Passenger Cars	30 mph	Frontal	Yes
after 9-1-1976	Passenger Cars	30 mph	Frontal	Yes
		30 mph	Oblique	Yes
		30 mph	Rear	Yes
		20 mph	Lateral	Yes
9-1-1976 to 8-31-1977	Trucks, MPVs, and Buses (6000#>GVWR<10000#)	30 mph	Frontal	No
9-1-1976 to 8-31-1977	Light Trucks, MPVs, and Buses (GVWR≤ 6000 #)	30 mph	Frontal	Yes
		30 mph	Rear	Yes
after 9-1-1977	Light Trucks, MPVs, and Buses (GVWR≤ 6000 #)	30 mph	Frontal	Yes
		30 mph	Oblique	Yes
		30 mph	Rear	Yes
		20 mph	Lateral	Yes
after 9-1-1977	Trucks, MPVs, and Buses (6000#>GVWR<10000#)	30 mph	Frontal	Yes
		30 mph	Oblique	Yes
		30 mph	Rear	Yes
		20 mph	Lateral	Yes
after 4-1-1977	School Buses (GVWR>10000 #)	30 mph	Any Point and Angle	No

NOTE: MPV - multipurpose passenger vehicle
GVWR - gross vehicle weight rating.

1.2 STUDY OBJECTIVE

The primary objective of this study is to statistically estimate the effectiveness of the Federal Motor Vehicle Safety Standard 301, as it currently applies to three principal classes of vehicles - passenger cars, light trucks (including MPV's), and school buses.[4] Effectiveness is defined in terms of the reduction in motor vehicle crash fires, and the reduction in occupant casualties (fatalities, injuries) that can be attributed to vehicles produced subsequent to the effective date of the Standard, as compared with vehicles manufactured prior to the Standard.

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[4] The 1968 version of FMVSS 301 for passenger cars is not studied in this report. An insufficient sample of data to cover this period would be available in current crash data files. Two earlier studies of effects of the 1968 version found no significant difference in fire rates between pre-1968 and post-1968 vehicles. Also, an earlier study of the costs associated with pre-1968 version of Standard 301 found the costs to be negligible and that most pre-1968 passenger car designs already met the requirements imposed by this first version of the Standard. (Ref: Evaluation of Federal Motor Vehicle Safety Standard 301-75, Fuel System Integrity: Passenger Cars, DOT HS-806-335, January 1983).

A second objective of the study is to describe the vehicle modifications which were made in response to the Standard, and to estimate the cost, to the consumer, of these modifications.

Thirdly, it is intended to present selected statistics which assist in describing the frequency, nature, and severity of fires which accompany motor vehicle accidents.

1.3 DATA SOURCES

Data for the study come from three principal sources. For the estimation of effectiveness, State compiled motor vehicle accident files are used, together with fatal motor vehicle crash data from NHTSA's Fatal Accident Reporting System (FARS). The presence of fire in motor vehicle accident data is recorded in only a few States. A review of the State reporting procedures for data files available at NHTSA resulted in 5 States, Michigan, Ohio, Maryland, Illinois, and Indiana being selected as the best sources for fires as reported in police accident data. For each of these States, six calendar years of data, spanning the period from 1982 through 1987, were used. For fatal accidents, FARS data from 1975 through 1988 are used. FARS has contained a data element for reporting vehicle fires since the system's inception in 1975. Altogether, data from over 14.5 million State reported vehicles in accidents plus data from nearly 700,000 vehicles in fatal crashes are represented in the effectiveness analyses.

To support the cost side of the study and to provide information on vehicle modifications due to FMVSS 301, special data were solicited from the motor vehicle manufacturers.

1.4 LIMITATIONS OF FIRE DATA IN MOTOR VEHICLE ACCIDENT FILES

While police reported accident data are the best source of information on fires accompanying motor vehicle crashes, certain difficulties emerge in using these data to evaluate the safety impacts of FMVSS 301.

The first issue involves the cause of fire, whether it was a result of the crash, or whether it resulted from other causes -- i.e., occurred before the crash. Of course, FMVSS 301 can only be expected to have an effect on post-crash fires. However, in the available accident data, it is generally not possible to distinguish between post-crash and pre-crash fires. It can be expected that, as accident or crash severity increases, the proportion of reported fires that are post-crash in nature would also increase. For fatal crashes, while some reported fires could have a pre-crash origin, it is believed safe to assume that the vast majority of the fires would have stemmed from the crash forces involved.

A second concern in police reported data on crash fires is the contribution the fire may have had on injury to the vehicle occupants, as distinguished from the injury due to the forces experienced from the crash itself. Only injuries (for fatalities) that result from fire (i.e., burn injuries) can be expected to be affected by FMVSS 301. Again, such distinctions as to cause of injury are not available in either the State data or the FARS data.

A third, less important concern is whether a fire, given it was post-crash in nature, resulted from leakage from the vehicle's fuel system. Once more, this level of detail is not available in the data. However, it is assumed that post-crash fires would most likely be fuel fed-fires.

In summary, it is emphasized that the last two deficiencies noted above - contribution of fire to injury, and role of fuel in post-crash fires - are not deficiencies peculiar to the data used in this study. While some fragmentary estimates exist, no source is known that provides reliable information on these issues. To attempt to acquire this information would require intensive accident follow-up studies involving medical and autopsy specialists, vehicle/fire specialists, etc. Even then, the phenomenon of our study, fire, would doubtless have destroyed, or consumed, much of the evidence needed to successfully complete such studies.

1.5 PRIOR FIRE STUDIES

Other studies of motor vehicle crash fires and the effects of FMVSS 301 have been conducted. These studies began in the late 1970's and were either conducted by NHTSA or were contractor studies sponsored by NHTSA. The earliest efforts were searches for data which recorded fire in motor vehicle crashes in sufficient quality and quantity to support a definitive evaluation of the effects of the Standard. All earlier studies of the benefits of Standard 301 were based on limited quantities of State accident data. Fatal accident data were not analyzed in any of the studies. These prior studies are discussed in Chapter 3 of this report.

1.6 REPORT OUTLINE

The study is presented in the three chapters which follow. Chapter 2 contains a detailed discussion of the statistical analyses conducted to estimate the effects of FMVSS 301 in reducing vehicle fires and associated injuries and fatalities. Analyses are conducted for each of three vehicle classes, passenger cars, light trucks, and school buses. In this chapter, the various accident data sources are also discussed with the methods used to report vehicles fires, for each data source, described.

Chapter 3 contains statistics and analyses which describe the nature, frequency, and trends of fires in motor vehicle crashes. Comparisons are made, for various accident parameters, between crashes involving fire and all motor vehicle crashes. Chapter 4 estimates the safety benefits attributable to FMVSS 301, in terms of vehicle fires and associated occupant casualties avoided. In this chapter the overall consumer costs (including both hardware and fuel penalty costs) of the Standard are also developed, for each of the three vehicle classes, together with descriptions of vehicle modifications made for each class of vehicles.

Appendix A contains a copy of the requirements of FMVSS 301 as taken from the applicable Code of Federal Regulations. Appendix B contains copies of the State and FARS accident report forms - the data sources used in the study. Appendix C contains tables of frequency counts of fires and vehicles from the State sources. Copies of letters to motor vehicle manufacturers requesting information on FMVSS 301 modifications are shown in Appendix D. Appendix E discusses the results of certain analyses conducted to examine the effect of vehicle age on fire rates.

CHAPTER 2

EFFECTIVENESS ANALYSIS OF FMVSS 301: FUEL SYSTEM INTEGRITY

2.0 INTRODUCTION

This chapter describes the analyses which were conducted to estimate the effectiveness of FMVSS 301. The primary measure of effectiveness of the Standard, as chosen in this study, is defined as the magnitude of the reduction in vehicle fires, as reported by police, per accident involved vehicle.[1] Both State accident files and NHTSA's fatal accident files (Fatal Accident Reporting System) have been analyzed. Separate analyses have been conducted for each of the three classes of vehicles to which the Standard applies - passenger cars, light trucks, and school buses.

In order to estimate the effectiveness of Standard 301, accident experience for vehicles manufactured prior to the Standard (Pre-standard vehicles) will be compared with the accident experience of vehicles produced subsequent to the Standard (Post-standard vehicles). For passenger cars, Pre-standard vehicles are those produced in Model Year 1975 or earlier, while Post-standard vehicles are those manufactured in

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[1] The stated purpose of FMVSS 301 (Title 49, CFR, Section 571.301) is to "reduce fatalities and injuries resulting from fires which occur from fuel spillage during and after motor vehicle crashes." The potential effect of reduced fires on injuries and fatalities is addressed later in this chapter and in Chapter 4.

1976 and later years. Pre-standard vehicles for both light trucks and for school buses correspond to Model Years 1976 and earlier while Post-standard vehicles are represented by Model years 1977 and later.

2.1 DATA SOURCES USED

The sources of data for this study consist of motor vehicle crash files as compiled by five States (Michigan, Ohio, Maryland, Illinois, and Indiana) and the Fatal Accident Reporting System files (FARS) which are maintained by NHTSA. In recent years, several States have made their accident data bases available to NHTSA as a source of assistance in various highway safety research and other analytical studies. These State data have been particularly useful to the agency in its evaluation studies of the effectiveness of its motor vehicle standards. The Fatal Accident Reporting System has been in operation by the agency since 1975. Compiled and maintained with the assistance of the States, FARS produces, annually, computerized records of every fatal motor vehicle crash which occurs within the United States.

The occurrence of fire in motor vehicle accidents is recorded by only a few States in their annual compilation of motor vehicle accident files. Those States that do record fire data typically use different reporting formats. The FARS system, which augments the data collected in a typical police accident report, has contained information on vehicle fires since the system's inception in 1975.

Table 2-1 summarizes the data sources used in this study, showing the number of calendar years of accident data from each source, the time period represented by the data, and the total number of accident involved vehicles of the three types (passenger cars, light trucks, school buses) subject to analysis.

Table 2-1
Sources of Accident Data Analyzed

Source	Number of Accident Years	Time Period of Data	Total Number of Accident Vehicles
State Data: [All accident severities]			
Michigan	6	1982 through 1987	3,158,237
Ohio	6	1982 through 1987	3,407,259
Maryland	6	1982 through 1987	1,185,915
Illinois	6	1982 through 1987	4,772,105
Indiana	6	1982 through 1987	2,037,231
Fatal Accident Data:			
FARS	14	1975 through 1988	687,530

The above data set represents over 14.5 million individual crashes and almost 700,000 fatal crashes involving a passenger car, a light truck (i.e., pickups, vans, multipurpose passenger vehicles, and small buses), or a school bus, where the presence of fire is a recordable item. These sources represent the best accident data available to NHTSA on the occurrence of vehicle fires in accidents.

2.1.1 Reporting of Vehicle Fires

The mechanism for reporting vehicle fires differs among the five States used in this study. Appendix B contains a copy of the State Accident Report Form for each of the States, Michigan, Ohio, Maryland, Illinois, and Indiana, and a copy of the FARS report form with the data element(s) for recording vehicle fires highlighted.

Fire Data From Michigan

The State of Michigan uses a four-part code to record the occurrence of fire for each vehicle in the accident. The coding is as follows:

Code "1" - fuel leaked from vehicle
Code "2" - vehicle/cargo caught fire
Code "3" - fuel leaked from vehicle <u>and</u> there was a fire
Code "4" - no vehicle fuel leak or fire occurred

Note that in order to capture all vehicle fires, both codes 2 and 3 must be retrieved from the computer records. Also note that fuel leakage is recorded as part of the reporting mechanism to capture vehicle fires. This variable could be analyzed along with the fire variable since the purpose of FMVSS 301 is to prevent fires by reducing the chances of fuel leakage in a vehicle crash. It was decided not to analyze the fuel leakage data since Michigan was the only State, among the States chosen for analysis, to record this item. Furthermore, it is believed that fuel leakage is more likely to escape detection, in a vehicle crash, compared to the occurrence of fire which should leave more distinct evidence. Also, for fuel-fed fires, the presence of fuel, as the ignition material, might often be difficult to judge by the investigating officer, particularly in more severe fires which do major damage to the vehicle.

Fire Data from Ohio

The State of Ohio uses a different convention to record the presence of fire in its accident files. As per Michigan, a separate block for each involved vehicle is contained on the Ohio Traffic Accident Report Form (see Appendix B) for the recording of fire. However, the reporting convention covers only fire (not fuel leakage), and the coding possibilities are:

code "1" - no fire
code "2" - fire due to crash
code "3" - other fire

Ohio attempts to distinguish between fires which result from crash forces (i.e., crash fires) and "other" fires. Presumably, these other fires are pre-crash fires. Fires which do not result from crash forces (and are also fuel-fed) would not be fires that are reducible by FMVSS 301. Here again, however, it might be difficult for the investigating police officer to discern between fires which are pre-crash versus post-crash in origin.

Fire Data From Maryland

Still a third reporting convention is used by the State of Maryland to record vehicle fires. Instead of a direct "box" on the Motor Vehicle Accident Report Form (see Appendix B), a more indirect method is employed by Maryland. Under a variable for "Areas Damaged" is a general damage category of "fire damage". Typically, areas damaged refers to specific areas of the vehicle (front, top, rear, etc.) which sustain physical damage due to crash or impact force. Under the areas damaged variable, up to three areas may be recorded for each involved vehicle. Fire damage may be recorded in one of these three areas and is a general damage code which does not refer to any specific part, or area of the vehicle. The State of Maryland has yet a second way in which fire can be reported. "Primary Contributing Factor" and "Secondary Contributing Factor" are variables for reporting factors which contributed to, or caused (in the opinion of the reporting officer) the accident to happen. Under these contributing factors is an exhaustive list of possibilities, one of which is fire. The reporting instructions here for the police officer are that "fire is not to be listed as a causative factor (either primary or secondary), if the fire resulted from the accident. Fire reported under primary or secondary cause is an accident level variable (not tied to a specific vehicle), whereas fire reported under vehicle damage is a vehicle specific variable. Once again, it may be difficult for the officer to distinguish between these possibilities, and attempting to separate vehicle fires on this basis in the accident data analysis may be somewhat tenuous.

Fire Data From Illinois

The State of Illinois provides for the reporting of vehicle fires in a block titled "Miscellaneous Information". This block also provides for three other items labeled "traffic control/sign visible?", "tested for drugs?" and "controls functioning?" The fire categories are as follows:

Did Fire Occur? 1 Yes - No 2 Yes - No

While the Illinois convention does provide for reporting fire on a (two) vehicle level, the placement of the information block is away from the basic vehicle ID data at the beginning of the report form, in contrast to some of the report forms cited earlier, such as Michigan and Ohio (see Appendix B). Also placing the fire items under "miscellaneous," near the end of the accident report, and along with other miscellaneous data may result in less reliable reporting of vehicle fires. This may be one reason why the unreported rate for fire in the Illinois files is so high, running up to 40 percent unreported.

Fire Data From Indiana

The fifth State, Indiana, whose data are used in this study, provides for the reporting of fire on a vehicle level. A separate coding block called "Fire" is located in each of the "Vehicle 1," "Vehicle 2" sections near the top of the "Indiana Officer's Standard Accident Report" (see Appendix B). The fire block is set up as follows:

Fire? ___ Yes
___ No

Fire Data in FARS

The Fatal Accident Reporting System, which is a compilation of (fatal) accident data from all 50 States, augmented by special reporting procedures, has a simple, two element code for reporting fires:

code "1" - fire occurred in vehicle during accident

code "0" - no fire

The fire variable is on a per vehicle level. However, it is understood that in multi-vehicle fatal crashes where two or more vehicles catch fire, FARS reporting cannot distinguish whether the fire originated in one vehicle and subsequently spread to another vehicle. It is entirely likely that this restriction applies as well to all State reported accident data. However, such accidents should be very rare events, and the inability to distinguish the "fire starter" vehicle in such cases should have no bearing on the analysis of fire data from accident files to estimate the effect of FMVSS 301.

Pre-crash Versus Post-crash Fires

To conclude this section on the reporting of vehicles fires, a few comments are offered on the subject of pre-crash fires as opposed to post-crash fires.

Since FMVSS 301 is intended to increase the crashworthiness of motor vehicle fuel systems against rupturing or leakage, it follows that data on post-crash fires is the preferred choice for analysis as to the Standard's effectiveness. One might suppose that most, if not, all fire data reported in motor vehicle crash, or accident files would be of the post-crash variety. However, such is not the case. Pre-crash fires do occur. Pre-crash fires could result from a variety of sources such as electrical shorts; oil or transmission fluid leaks that come into contact with sufficently hot surfaces, such as exhaust manifolds; or gasoline from a flooded carburetor, loose line fitting, or deteriorated/cracked fuel hose. Also pre-crash fires could start from flammable cargo being transported in the vehicle, or from personal items such as cigarettes, matches, or other flammable/explosive items.

After working with the accident data from a number of States, it is concluded that while some States make an attempt to do so, in general, post-crash fires cannot reliably be distinguished from pre-crash fires. More will be said about this later as it is germane to the interpretation of the analyses performed in this study.

2.2 EFFECTIVENESS ANALYSIS FOR PASSENGER CARS

The analysis of the effectiveness of FMVSS 301, Fuel System Integrity, for passenger cars is presented in two sections. First, State data are analyzed to estimate the effect of the Standard on all accidents (i.e., all accident severities - those that result in injury as well as those that result in property damage only). This is followed by analyses of State data on injury crashes and of the FARS data to estimate the effect of the Standard on injury crashes and on fatal crashes (i.e., accidents which result in one or more fatalities).

Table 2-2
Fire Rates* in Passenger Car Crashes by State and Vehicle Model Year

	STATE				
Model Year	Michigan	Ohio	Maryland	Illinois	Indiana
1987	1.451	1.641	1.026	0.382	0.489
1986	1.375	2.553	0.853	0.689	0.664
1985	1.365	1.863	0.821	0.636	0.570
1984	1.377	2.415	1.180	0.697	0.702
1983	1.557	2.092	1.227	0.715	0.542
1982	1.582	2.416	1.493	0.814	0.591
1981	1.697	2.511	1.763	0.837	0.808
1980	1.915	2.954	2.085	0.891	0.731
1979	1.882	3.200	2.435	0.896	0.870
1978	2.247	3.442	2.542	0.934	0.967
1977	2.232	3.760	3.007	1.032	0.900
1976	2.429	4.092	3.559	0.922	0.906
1975	2.660	5.024	5.012	1.027	1.165
1974	3.160	5.329	5.526	1.171	1.201
1973	3.343	5.169	4.539	1.352	1.300
1972	3.594	5.602	4.636	0.966	1.650
1971	3.917	5.463	4.781	1.300	1.719
1970	3.380	5.173	5.130	1.249	2.189
1969	3.299	5.305	6.800	1.352	1.567
1968	2.894	6.206	4.952	1.437	1.283
1967	3.265	4.431	5.746	1.532	1.030
1966	2.932	4.103	3.338	1.315	2.000

---

* Fire rates are police reported fires per 1,000 passenger cars in accidents. Appendix C contains the actual counts of fires and passenger cars for each Model Year and State.

The data are for calendar years 1982-87.

2.2.1 Analysis of State Accident Data

Fire data from five States are analyzed - Michigan, Ohio, Maryland, Illinois, and Indiana. As a first step in the analysis process, an array of the data has been constructed in Table 2-2, showing the fire rate (i.e., number of fires per 1,000 accident-involved vehicles) by Vehicle Model Year and State. The actual frequencies of fires and accident-involved passenger cars are contained in Appendix C. For each State, six calendar years of data, 1982-1987, are represented. Model Year 1966, 10 years prior to the implementation date of FMVSS 301 has been chosen as a convenient truncation point. The resulting range, Model Year 1966 through Model Year 1987, spans a 22-year period and accounts for the vast majority of the accident-involved passenger cars (well over 90 percent even including unknown Model Year vehicles) for the six year period in each State.

The incidence of fire is based on the individual reporting methods for the five States, as described in the preceding section (2.1). For Michigan, the fire rates include both code 2, "vehicle/cargo caught fire and," and code 3, "fuel leaked from vehicle and there was a fire". For Ohio, codes 2 and 3, "fire due to crash", and "other fire" are included. In the Maryland files, fire occurrence is based on the AREA DAMAGE variable. Three AREA DAMAGE variables per vehicle are permissible, and the fire rates in Table 2-2 for Maryland include all such cases where the AREA DAMAGE variable is coded as fire (i.e., area damage 1 = fire, area damage 2 = fire, and area damage 3 = fire).

Fire rate data for the State of Illinois include all such cases where the MISCELLANEOUS INFORMATION variable, "Did Fire Occur?" is coded "YES". For the fifth State, Indiana, the incidence of fire is based on all cases where the designated vehicle coding block for "FIRE?" is coded "YES".

Based on the above definitions for recording the incidence of vehicle fire, it is evident that pre-crash fires, as well as post-crash fires (i.e., fires due to the crash event) could be included in the fire rate data. In general, it is not possible to separate fires which result from crash forces from fires which were initiated prior to the crash.

Returning to Table 2-2, a brief perusal of the data reveals several preliminary observations. First, a Model Year, or age trend is noted in the fire rates - older vehicles tend to have higher rates than newer vehicles. This observation is generally consistent throughout the entire model year range of 22 years, and the trend is evident among all five State data bases. The rate of fire varies from about 0.4 per 1,000 vehicle crashes (Illinois, Model Year 1987) to as hight as 6.8 per 1,000 vehicle crashes (Maryland, Model Year 1969). The actual frequencies on which the individual fire rates are based range from 9 to 935 for fire counts and from 5,393 to 368,30 for vehicle counts (See Appendix C).

Another observation from Table 2-2 is that fire rates vary among the States, particularly between Michigan, Ohio, and Maryland, which have consistently higher rates, and Illinois and Indiana, which have similar rates, but considerably below those for the first three States. Reasons for these differences are not readily apparent, but the most likely candidate is believed to be reporting differences among the States.

Finally, with respect to fire rates before and after FMVS 301 - the primary focus of this study - it is noted that the rates for Model Year 1976, the first year of the Standard, are in all instances lower than the rates for Model Year 1975, the year immediately preceding the Standard. While rather large rate decreases are observed for Ohio and Maryland (changes consistent with a beneficial effect of FMVSS 301), it is not possible to ascertain the extent to which these decreases may be attributed to the Standard without further statistical analyses of the data.

2.2.1.1 Analysis of Data From Michigan, Ohio, and Maryland

Since the fire rates from Michigan, Ohio, and Indiana are considerably higher than the rates for Illinois and Indiana, data from these three States will be analyzed first.

Data From Michigan

As a first step in analyzing the Michigan data, plots were made of the fire rate as a function of vehicle age and as a function of vehicle model year. The plots appear in Figures 2-1 and 2-2, respectively. The data points

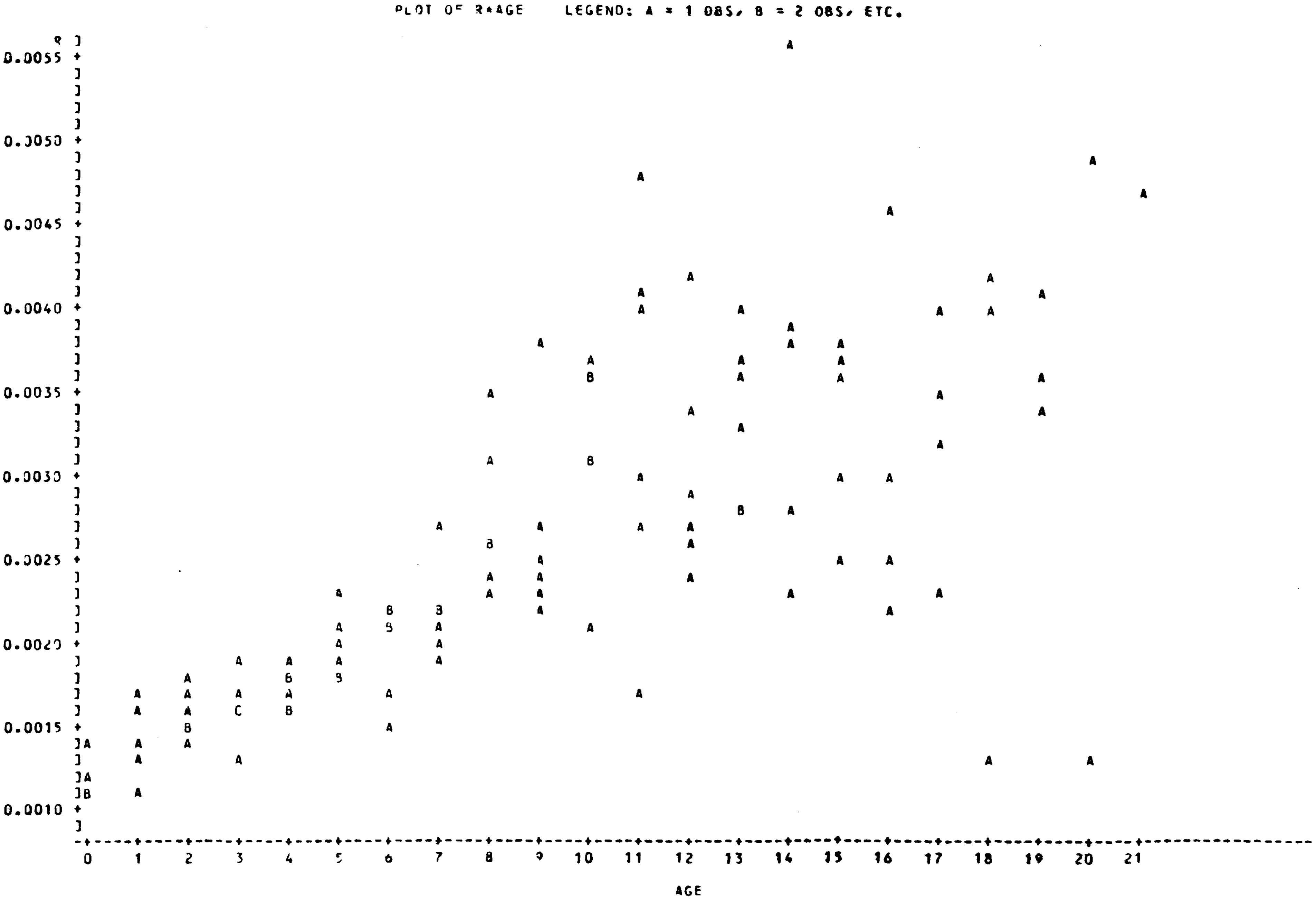

Figure 2-1
Michigan, Passenger Cars

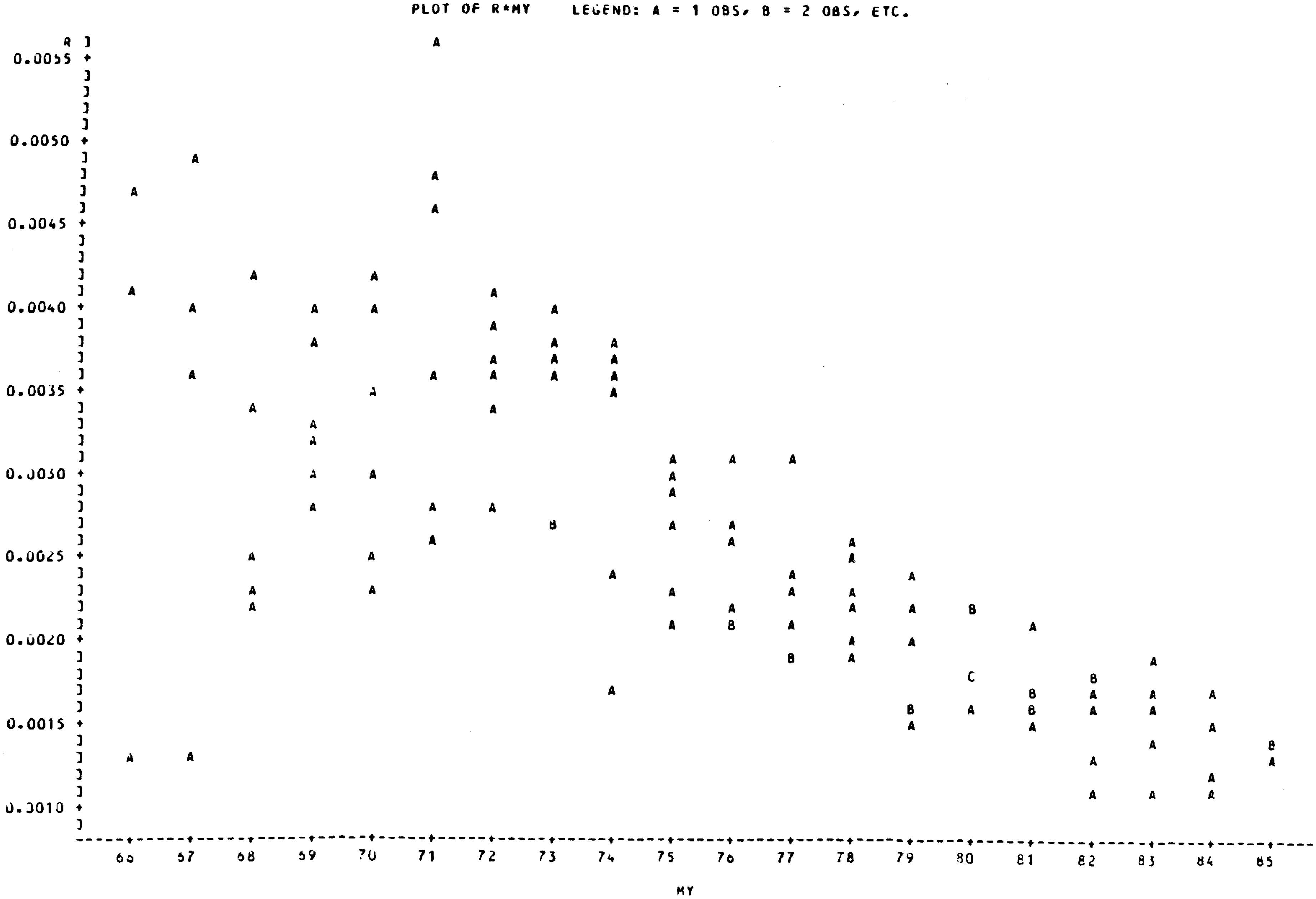

Figure 2-2
Michigan, Passenger Cars

represent fire rates for each model year by calendar year combination (or cell) in the six years of Michigan data. These plots clearly illustrate the age trend in the data. The age plot and the model year plot are virtual "mirror images" of each other.

Simple linear models (regression) were fitted to the data in the two plots. The following functions were fitted:

Age Model: $R_{ij} = a + bx_{ij}$

where R_{ij} = fire rate (fires per accident involved vehicle) for model year i and calendar year j

and x_{ij} = vehicle age at time of crash (i.e., calendar year minus model year) for model year i and calendar year j.

($i = 66$ to 87; $j = 82$ to 87)

Model Year Model:

Same model as above except x_{ij} = vehicle model year for model year i and calendar year j.

The total number of observations (i.e., number of calendar year - model year combinations) was 117, for each model. The observations were weighted since considerable variation existed among the number of accident involved vehicles per cell.

The resulting equations were:

Age model: $R = 0.001204 + 0.0001593x$

Model Year Model: $R = 0.01348 - 0.0001439x$

In both models, the x-coefficients are highly significant (t age = 16.09; t model year = -15.04), indicating a significant increase in fire rate with vehicle age, or conversely, a significant decrease in fire rate as model year increases (i.e., as vehicles become newer).[2] The fit of the models was reasonably high with R^2s of .69 and .66, respectively, for age and model year, indicating that nearly 70 percent of the variation in fire rate is explained by the single variable, vehicle age, or vehicle model year).

In order to estimate the effect of FMVSS 301 on fire rates, it is obvious that the concomitant effect of vehicle age must also be taken into account. The model must consider age, together with the effect of the standard. A multiple linear model was chosen:

$$R_{ij} = a + b\, x_{1(i,j)} + c\, x_{2(i,j)}$$

where R_{ij}, and $x_{1\,(i,j)}$ = fire rate, and vehicle age, as before
and $x_{2(i,j)}$ = standard effect (= 0 for Pre-standard vehicles,
= 1 for Post-standard vehicles)

---

[2] In this study, statistical significance is assessed at the α = .05 level (5 percent risk, or 95 percent confidence). The probability of greater t-values in each of the above models is 0.0001. Therefore, the age and model year effects are significant at much higher levels - 99.99 percent confidence).

Observations were weighted, as before, and an additional step was taken to "balance" the sample of Pre-standard and Post-standard vehicles. Within each calendar year, the number of Model Years of Pre-standard vehicles was kept equal to the number of model years of Post-standard vehicles. This reduced the total number of observations for the model to 108.

The fitted model, incorporating both age and FMVSS 301 effects was:

$$R = 0.001820 + 0.0001253X_1 - 0.0005285X_2$$

Both the age effect (t= 8.98) and standard effect (t = -3.95) are significant.[3] Since the analysis shows a significant effect for the standard, the effectiveness, in terms of percent reduction in vehicle fires will be estimated.

The average (weighted) age of the Pre-standard sample of passenger cars is 11.171 years. Therefore, the effectiveness estimate of FMVSS 301 is:

---

[3] Probability of greater t = .0001 for both age and standard effects. Hence, both effects are highly significant.

$$\text{Effectiveness} = \frac{-0.0005285}{0.001820 + 11.171\ (0.0001253)}$$

$$= \frac{-0.0005285}{0.0032195}$$

$$= -0.1641 \quad = \quad -16.41 \text{ percent}$$

Hence, there is a 16.4 percent reduction in fire rate for cars produced after the Standard became effective. The 95 percent confidence limits on this reduction are ± 8.14 percent giving a 95 percent confidence band of 8.27 percent to 24.55 percent. The Pre-standard fire rate is 3.2195 fires per 1,000 cars (from the denominator of the above equation); the Post-standard fire rate is 2.691 fires per 1,000 cars (i.e., 3.2195 - 0.5285). These rates take into account the age effect on fire rates which is a very strong effect. The R^2 value for the multiple variable model was .73, indicating 73 percent of the variation in fire rates explained, somewhat more than the single variable models of age and model year.

Similar to the plots for Michigan, Figures 2-3 and 2-4 contain plots of fire rate versus vehicle age and vehicle model year for the State of Ohio. Again, the distinct relationship of fire rate and age is seen, although the Ohio data exhibits somewhat less variation in fire rates than did the data from Michigan.

Simple linear (weighted) models of fire rate as functions of age, and model year produced the following equations:

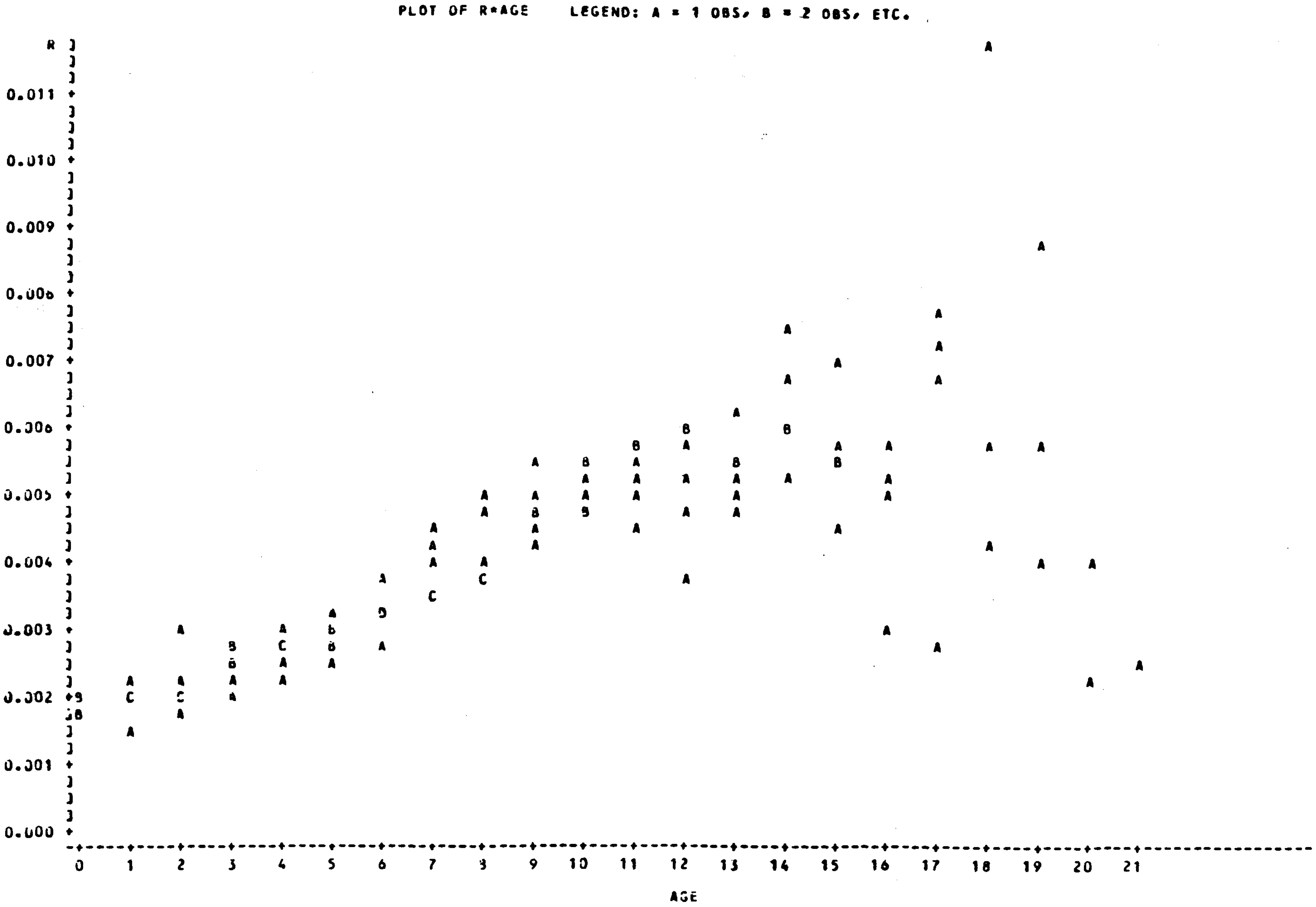

Figure 2-3

Ohio, Passenger Cars

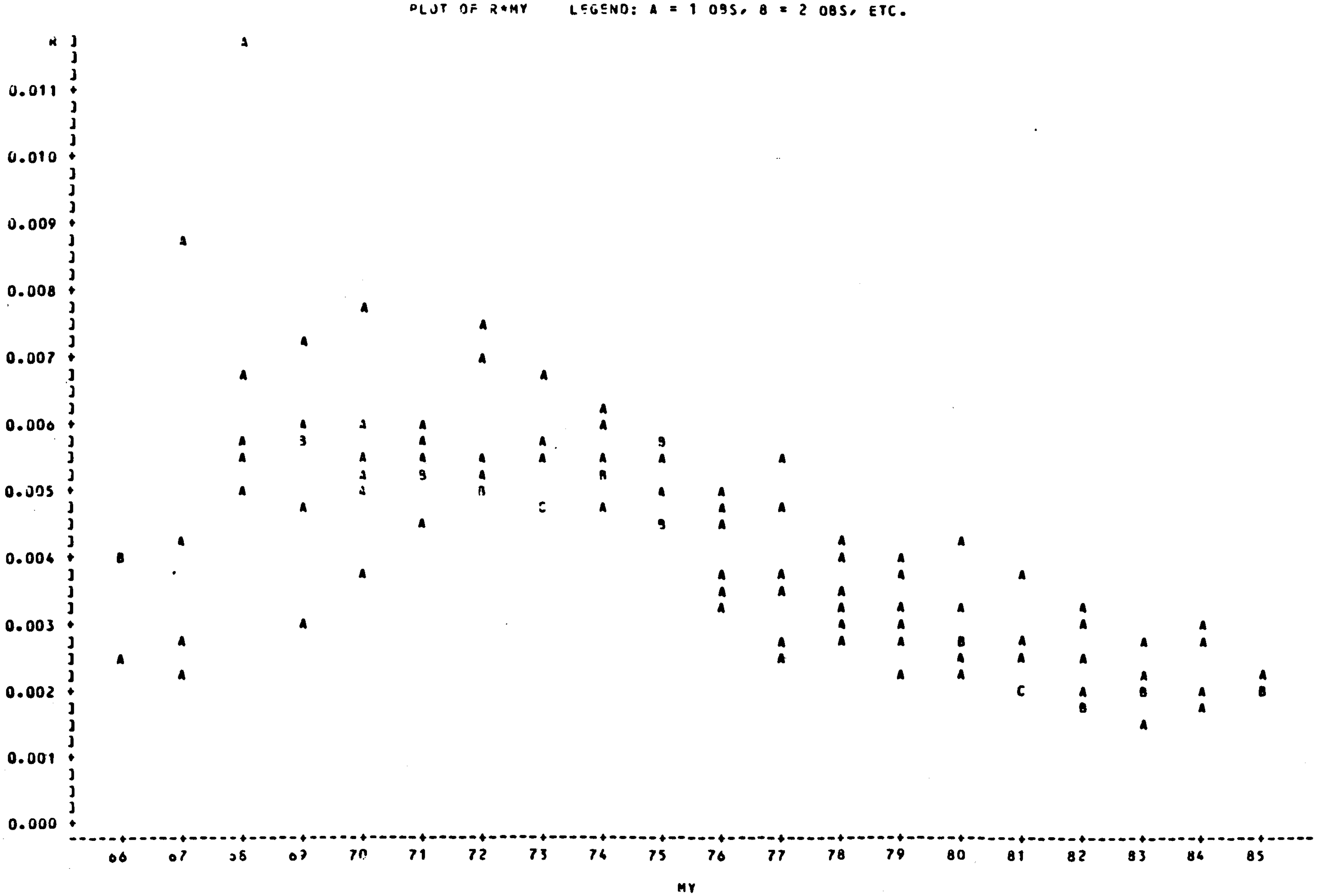

Figure 2-4
Ohio, Passenger Cars

Age model: $R = 0.001746 + 0.0002876X_1$ (age)

Model Year Model: $R = 0.02246 - 0.00024135X_2$ (model year)

As with the Michigan data, the age and model year effects are significant having very large t-values of 21.78 and -14.63, respectively.[4] For the Ohio data, the fit of the age model was even better than for the Michigan data, with an R^2 value of .81 versus .69 for Michigan. The model year equation for Ohio gave a fit very close to that for Michigan, with an R^2 of .65, compared to .66 for Michigan. Once again, the single variable, age, is seen to be very closely associated with fire rate, the correlation being 0.9, and this single variable produces a model which accounts for the major portion of the variation in fire rate.

The next step is to add a second variable to the model to determine the effect of FMVSS 301 on fire rates in the Ohio data, given the effect of the age factor. The same model as before will be used, i.e.,

$$R = a + bX_1 \text{ (age)} + cX_2 \text{ (Std)}$$

The model was weighted, as with Michigan, and balanced for equal number of Pre-standard and Post-standard model year cells within each of the six

---

[4] Probability of great $t = 0.0001$ for both effects; hence, they are highly significant.

calendar years. Again, the total number of observations was 108 (model year by calendar year combinations).

The resulting equation was:

$$R = 0.002361 \ + \ 0.0002574\ X_1\ \text{(age)}\ -0.0005736\ X_2 \text{(Std)}$$

Both effects are highly significant with $t = 13.64$ for age and $t = -3.33$ for the Standard.[5] R^2 for the fitted model was .84, indicating about 4 percent more explained variation over the simple model with age only.

The average (weighted) age of the Pre-standard cars in the Ohio data is 11.356 years. The estimated effect of Standard 301 on fire rate is thus:

$$\begin{aligned} \text{Effectiveness} &= \frac{-0.0005736}{0.002361 + 11.356\ (.0002574)} \\ &= \frac{-0.0005736}{0.005284} \\ &= -.1086 \ = -10.86 \text{ percent} \end{aligned}$$

After accounting for vehicle age, the Standard is estimated to have reduced the fire rate by 10.86 percent over the fire rate for passenger cars built prior to the Standard. Ninety-five percent confidence limits on the estimate are:

± 6.39% or 4.47% to 17.25%

---

[5] Probability of greater t=.0001 for age; probability of greater t for Standard = .0012.

In the data, the fire rate for Pre-standard vehicles is estimated at 5.284 fires per 1,000 vehicles and the fire rate for Post-standard vehicles at 4.710 fires per 1,000 vehicles.

Overall, the analyses of the Ohio data give results which closely parallel the results from the Michigan data, with the single exception that the overall fire rates are higher for Ohio.

Data from Maryland

The last State to be analyzed in the first group is Maryland. Following the procedure used for Michigan and Ohio, the data are first plotted in Figures 2-5 and 2-6 to provide a visual picture of the relationship of fire rate with vehicle age and with model year. Trends very similar to those noted before are seen - fire rates distinctly increase with vehicle age.

Simple linear functions for age and for model year give:

Age model: $R = 0.0006493 + 0.0003550 X_1$ (age)

Model Year Model: $R = 0.02677 - 0.0003076 X_2$ (model year)

As with the first two States, the age and model year coefficients are highly significant, with t-values of 19.93 and -15.24, respectively.[6] R^2 for the age model is .78 and .69 for the model year function, again showing good fits, as with the previous States.

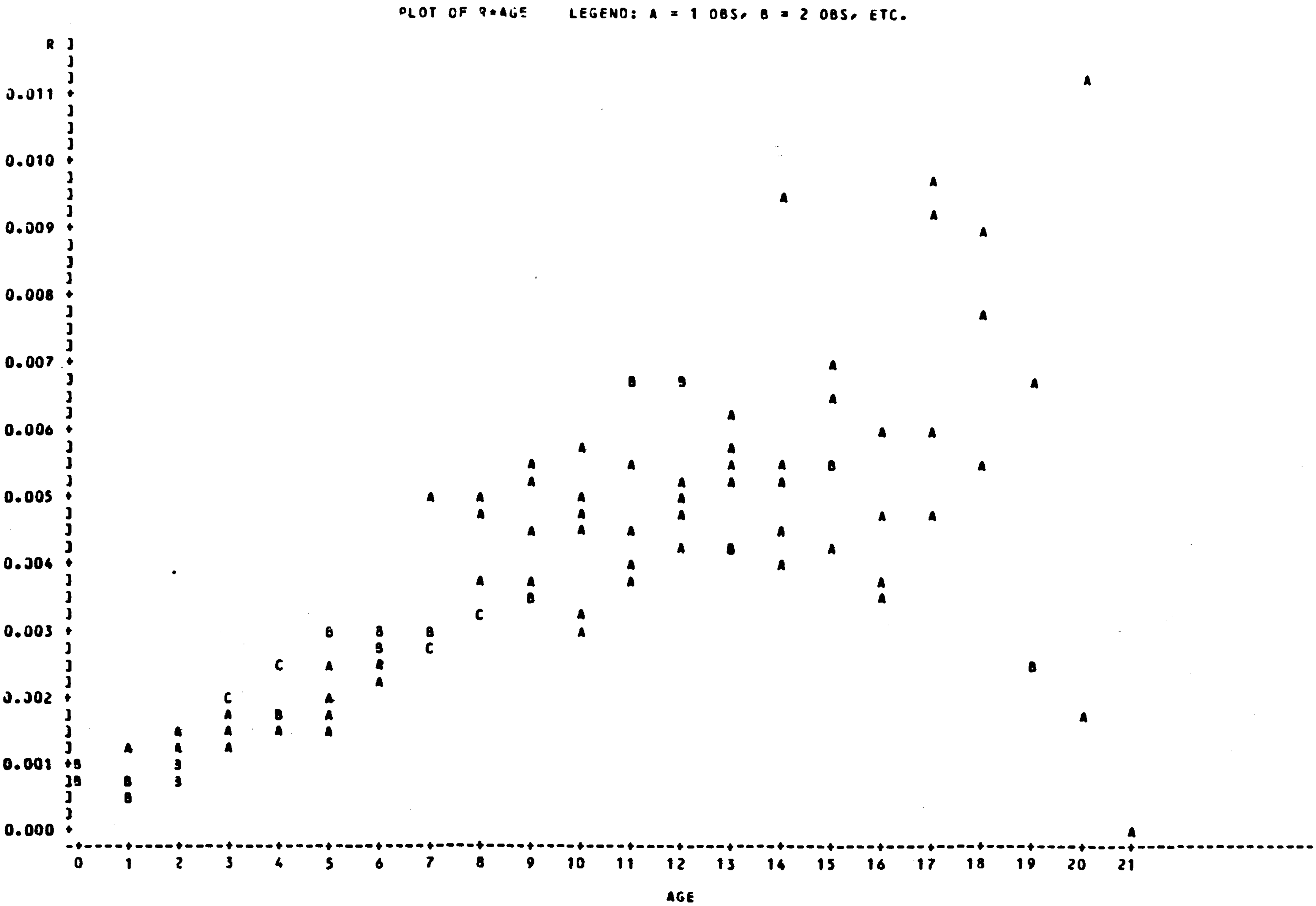

Figure 2-5
Maryland, Passenger Cars

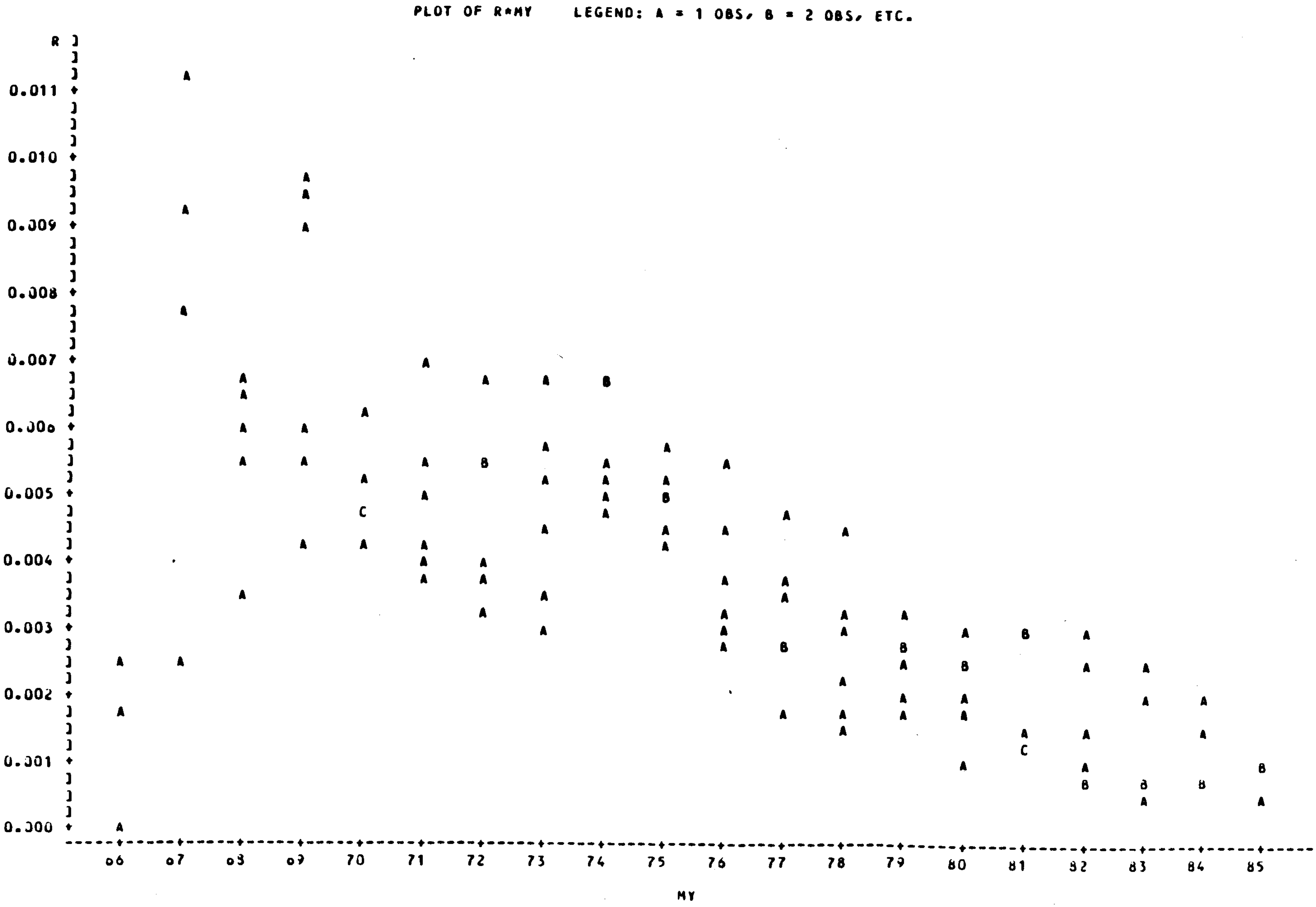

Figure 2-6

Maryland, Passenger Cars

Converting to the 2-variable model to estimate the effect of the Standard resulted in the following equation:

$$R = 0.001511 + 0.0003104\ X_1\ (\text{age}) - 0.0007670\ X_2\ (\text{Std})$$

T-values for the age and Standard effects are 11.01 and -2.84, respectively, indicating, once again, high significance.[7] R^2 was .80 - a good fit but only slightly better than the age model.

Turning to the effectiveness estimate for FMVSS 301, given the average age of the Maryland cars to be 11.484 years:

$$\text{Effectiveness} = \frac{-0.0007670}{.001511 + 11.484\ (.0003104)}$$

$$= \frac{-0.0007670}{.005075}$$

$$= -.1511 = -15.11 \text{ percent}$$

After accounting for the effect of vehicle age, passenger cars produced after FMVSS 301 took effect show a 15.11 percent lower fire rate in the Maryland data, than cars made prior to the Standard.

---

[6] Probability of greater t = .001 for both effects.

[7] Probability of great t for age coefficient =.0001; probability of greater t for Standard coefficient = .0054.

Attaching 95 percent confidence limits to the estimate of effectiveness gives:

15.11 ± 10.43% = 4.68% to 25.54%

The fire rate for Pre-standard vehicles in Maryland is estimated at 5.075 fires per 1,000 crash involved cars compared to the Post-standard rate of 4.308 fires per 1,000 crash involved cars.

Overall, the results from the Maryland data are quite similar to the results from Michigan and Ohio. With respect to the overall fire rate, Maryland data are quite close to the Ohio data, with both States showing higher fire rates than the State of Michigan.

Overall Results from Michigan, Ohio, and Maryland

Since the analyses results from Michigan, Ohio, and Maryland were so similar, the data were combined and and analyses performed on the composite data set. The modeling procedures were the same as for the individual State analysis. Plots of the data appear in Figures 2-7 and 2-8.

At this juncture, the primary interest is in obtaining a "best" estimate for the effect of FMVSS 301. In the preceding analyses, generally similar relationships were noted for fire rate as a function of vehicle age and fire rate as a function of vehicle model year. Furthermore, this similarity was noted among all three States, Michigan, Ohio, and Maryland. The most reasonable explanations for these findings is believed to be that vehicles

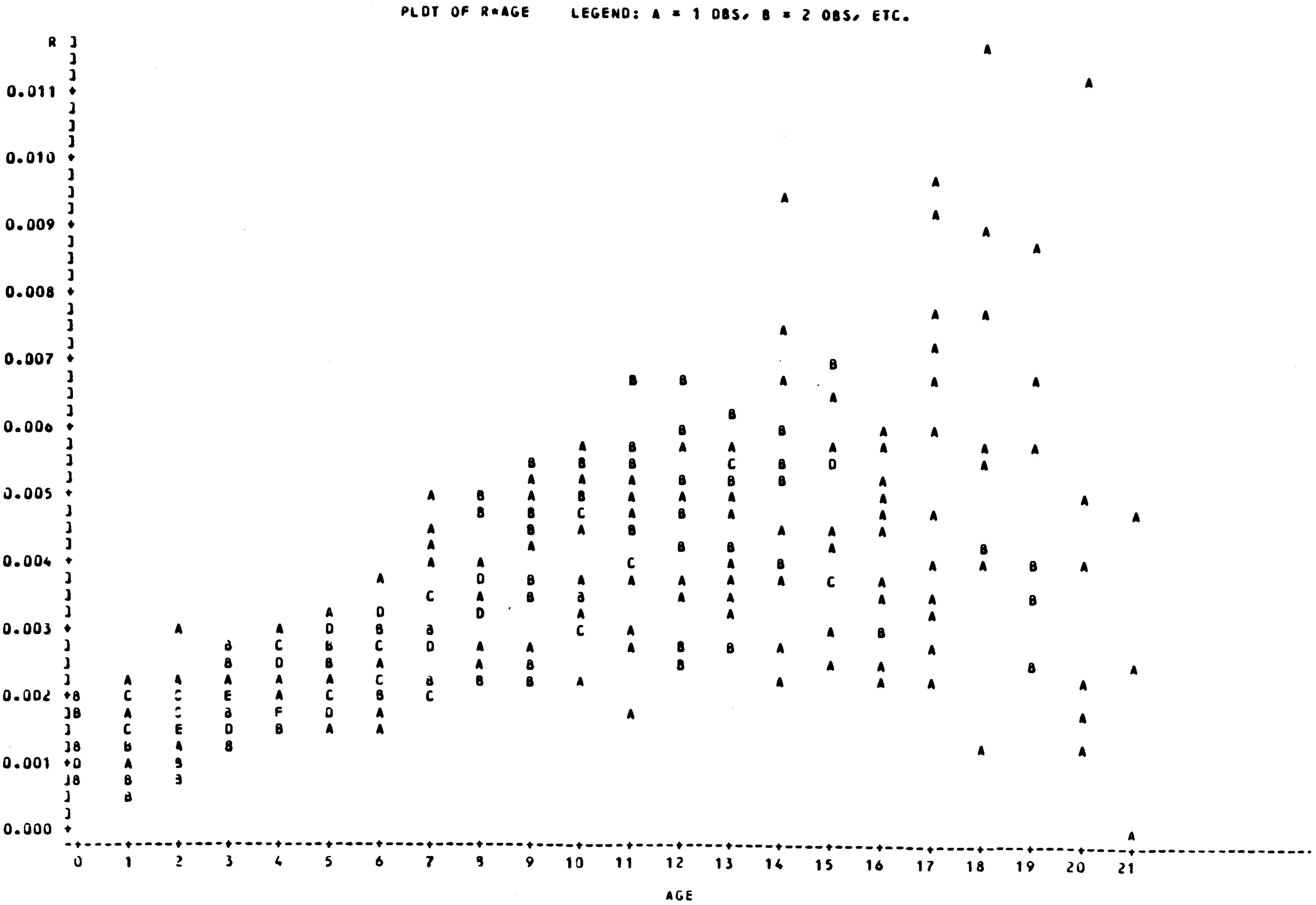

Figure 2-7

Michigan, Ohio, Maryland; Passenger Cars

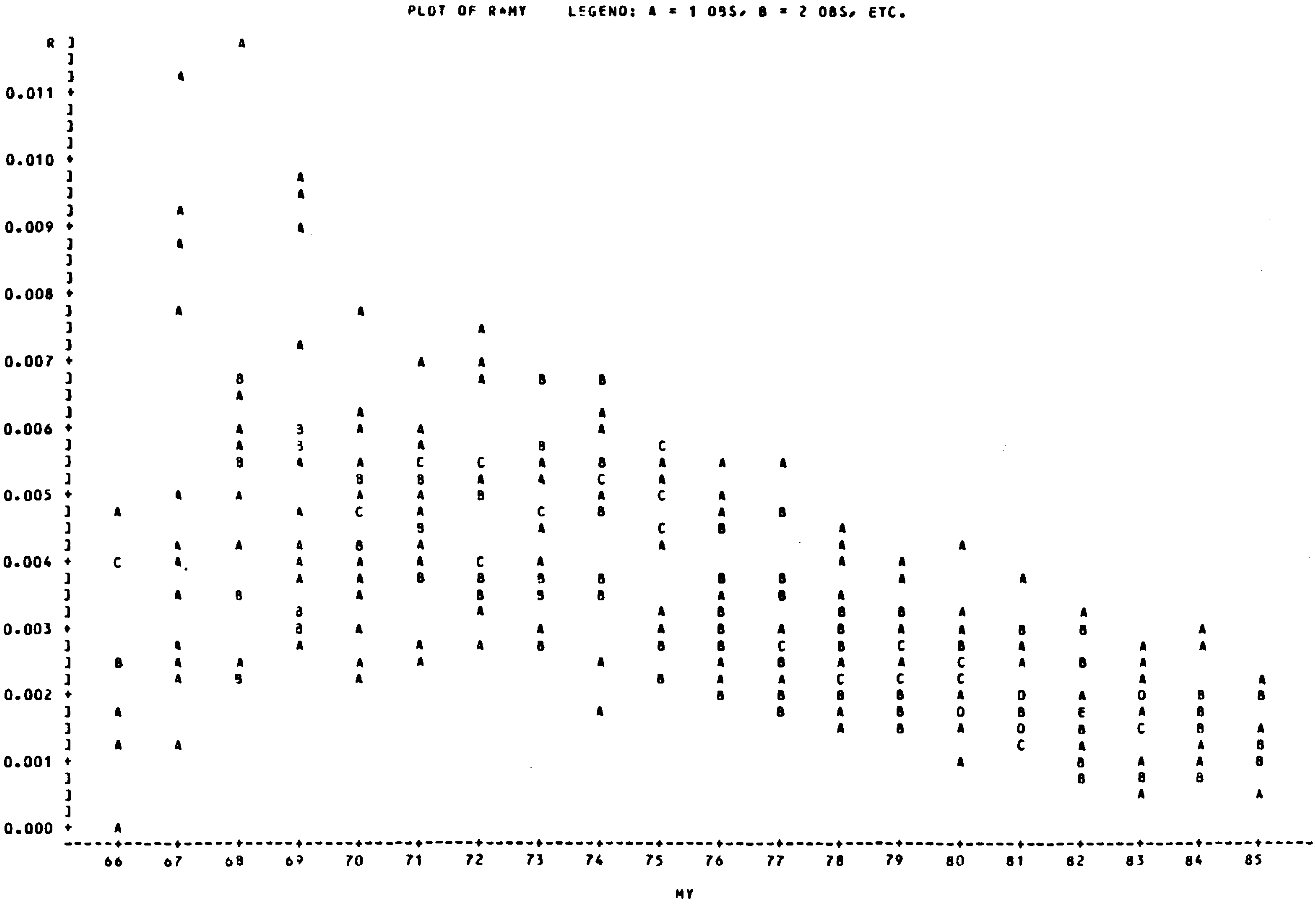

Figure 2-8

Michigan, Ohio, Maryland; Passenger Cars are more susceptible to fire as the vehicles become older. The "mirror" trend of decreasing fire note with newer model years is interpreted as evidence of this same age trend, rather than a consistent structural improvement, model year by model year, that decreases the chances of fire.

Therefore, only the model with age and the Standard as independent variables is fitted in the overall analysis. The combined data produced 324 observations (after balancing for model years). The average age of the Pre-standard sample of passenger cars was 11.314 years.

The fitted model for the three States, combined, was:

$$R = 0.002005 + 0.0002237\ X_1\ \text{(age)} - 0.0006435\ X_2\ \text{(Std)}$$

Both coefficients were significant, having t-values of 12.88 and -3.95, respectively, for age and the Standard.[8] R^2 was somewhat less than for the individual State runs at .62.

The estimated effect for the Standard is:

$$\begin{aligned}\text{Effectiveness} &= \frac{-0.0006435}{.002005 + 11.314\ (.0002237)}\\ &= -\frac{.0006435}{.004536}\\ &= .1418 = -\ 14.18\ \text{percent}\end{aligned}$$

---

[8] Probability of greater t=.0001 for both X_1 and X_2 coefficients.

The fire rate for Post-standard cars, after adjusting for the effect of vehicle age, is 14.18 percent less than the rate for Pre-standard cars. Ninety-five percent confidence limits on the effectiveness estimate are:

$$14.18 \pm 7.04\% = 7.14\% \text{ to } 21.22\%$$

As would be expected, the 14.18% reduction is within the range of the three individual State estimates of 16.41%, 10.86%, and 15.12%, respectively, for Michigan, Ohio, and Maryland. It is also interesting to note that the regression estimate of effectiveness is very close to that obtained by merely taking a simple average of the three individual estimates, i.e.,

$$\frac{.1086 + .1512 + .1641}{3} = .1413 = 14.13\%$$

2.2.1.2 Analysis of Data from Illinois and Indiana

This section discusses the analyses of data from the States of Illinois and Indiana. Recall that the fire rates from these two States (Table 2-2) were considerably less than the fire rates from Michigan, Ohio, and Maryland, ranging from 0.4 fires per 1,000 vehicles to slightly above 2.0 fires per 1,000 vehicles.

Recalling also the accident reporting instructions for the two States, Indiana fires are to be defined by "vehicle caught fire as a result of the crash", while Illinois fires are to be positive answers to the question, "Did fire occur?" From these definitions alone, Indiana fires could be said to be post-crash fires, whereas Illinois fires would appear to cover pre-crash, as well as post-crash fires. Given these conditions, it is interesting to note that the overall fire rates in the two States are surprisingly similar in magnitude (refer again to Table 2-2).

Figures 2-9 and 2-11 display the fire rate by age plots for Illinois and Indiana, respectively. Figures 2-10 and 2-12 contain the fire rate by model year plots.

Employing the same analysis procedures as used for the first three States, regression runs were made on the data from Illinois and Indiana, with the following results:

Data from Illinois

For the fire rate by age model, the age effect was significant with a t-value of 4.76,[9] the fitted equation being:

$$R = 0.0007455 + 0.0000291 X_1 \text{ (age)}$$

The R^2 was .18, indicating significantly less of the variation in fire rate being explained by age than in the cases for Michigan, Ohio, and Maryland.

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[9] Probability of greater t = .0001.

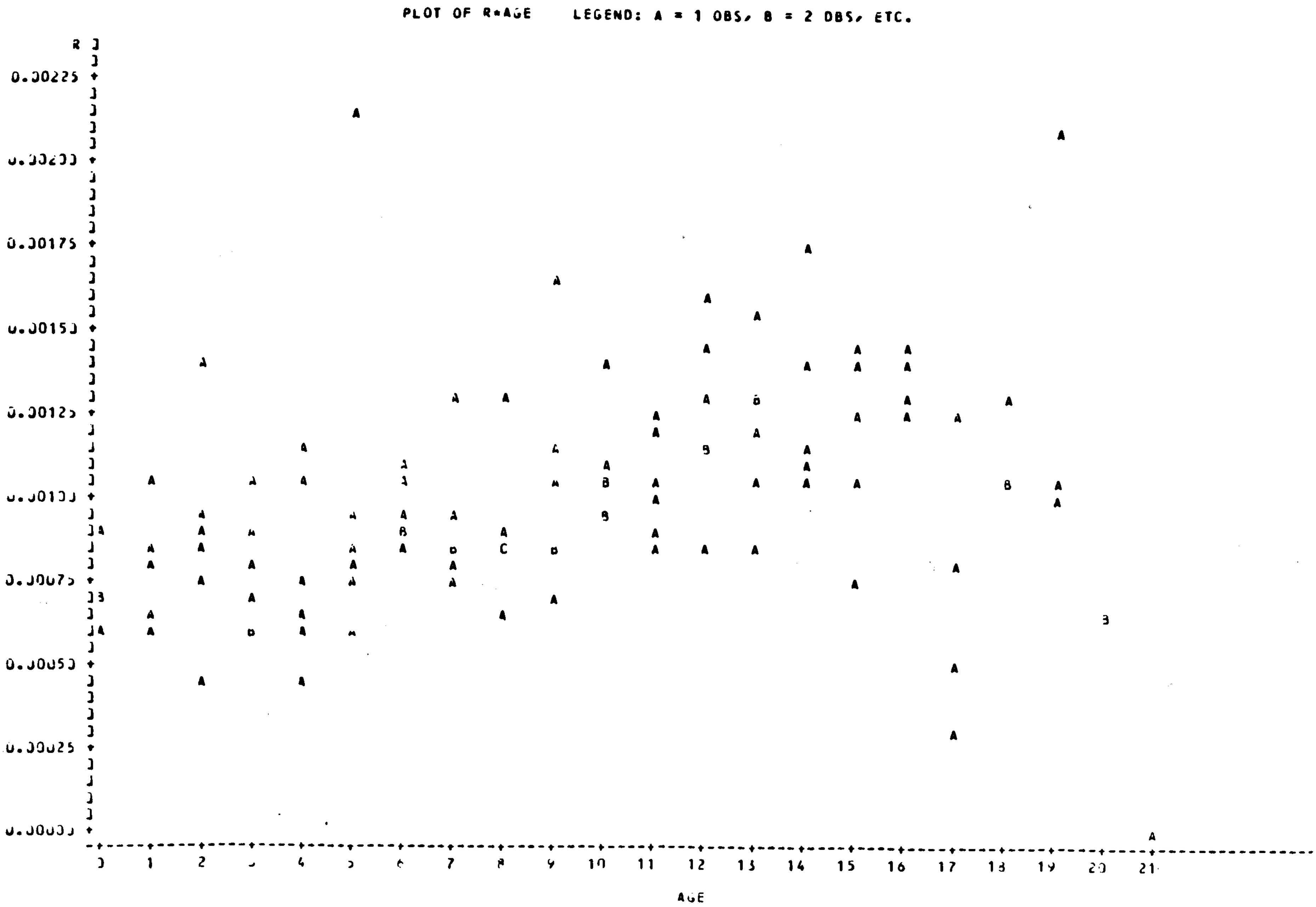

Figure 2-9

Illinois, Passenger Cars

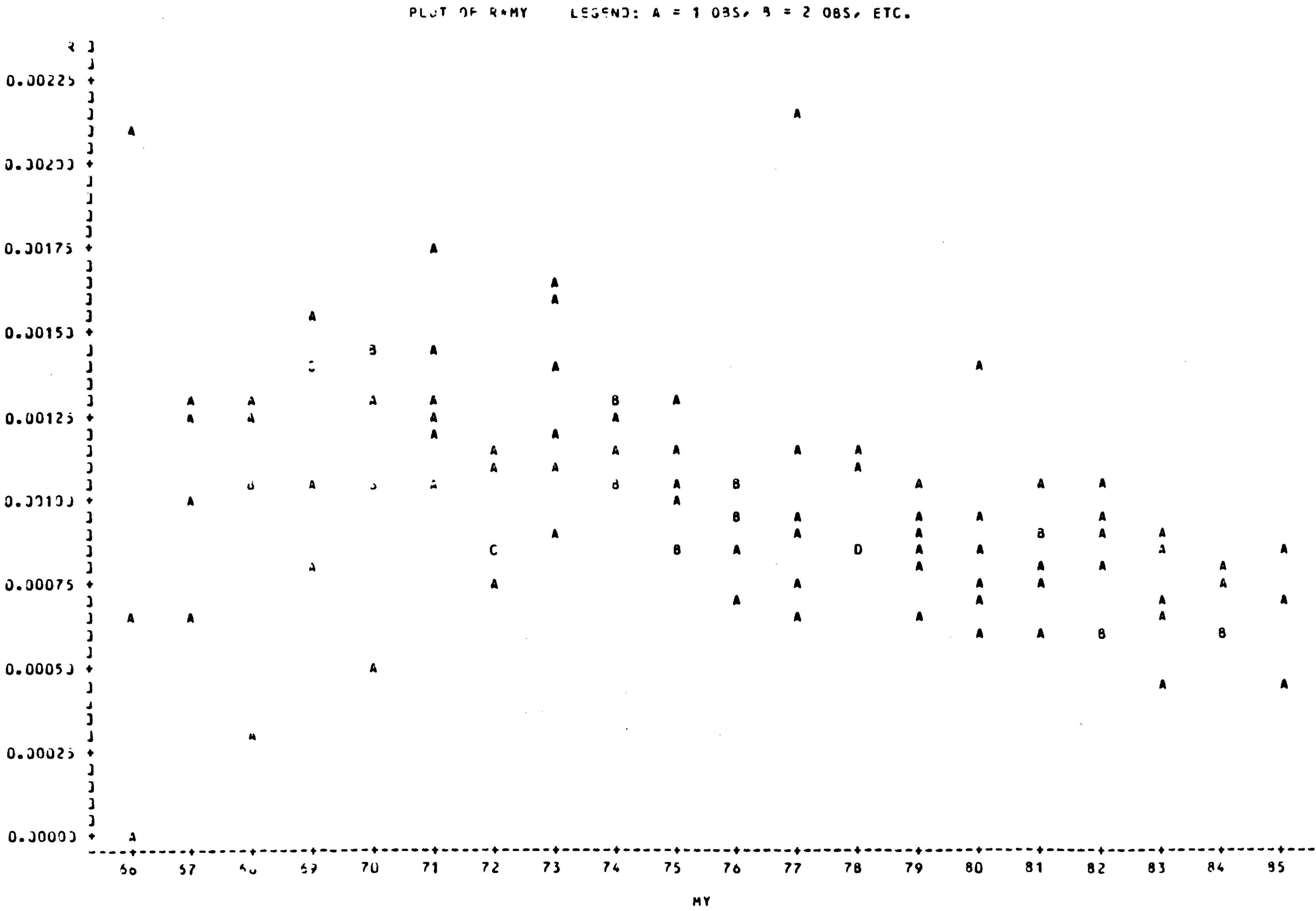

Figure 2-10
Illinois, Passenger Cars

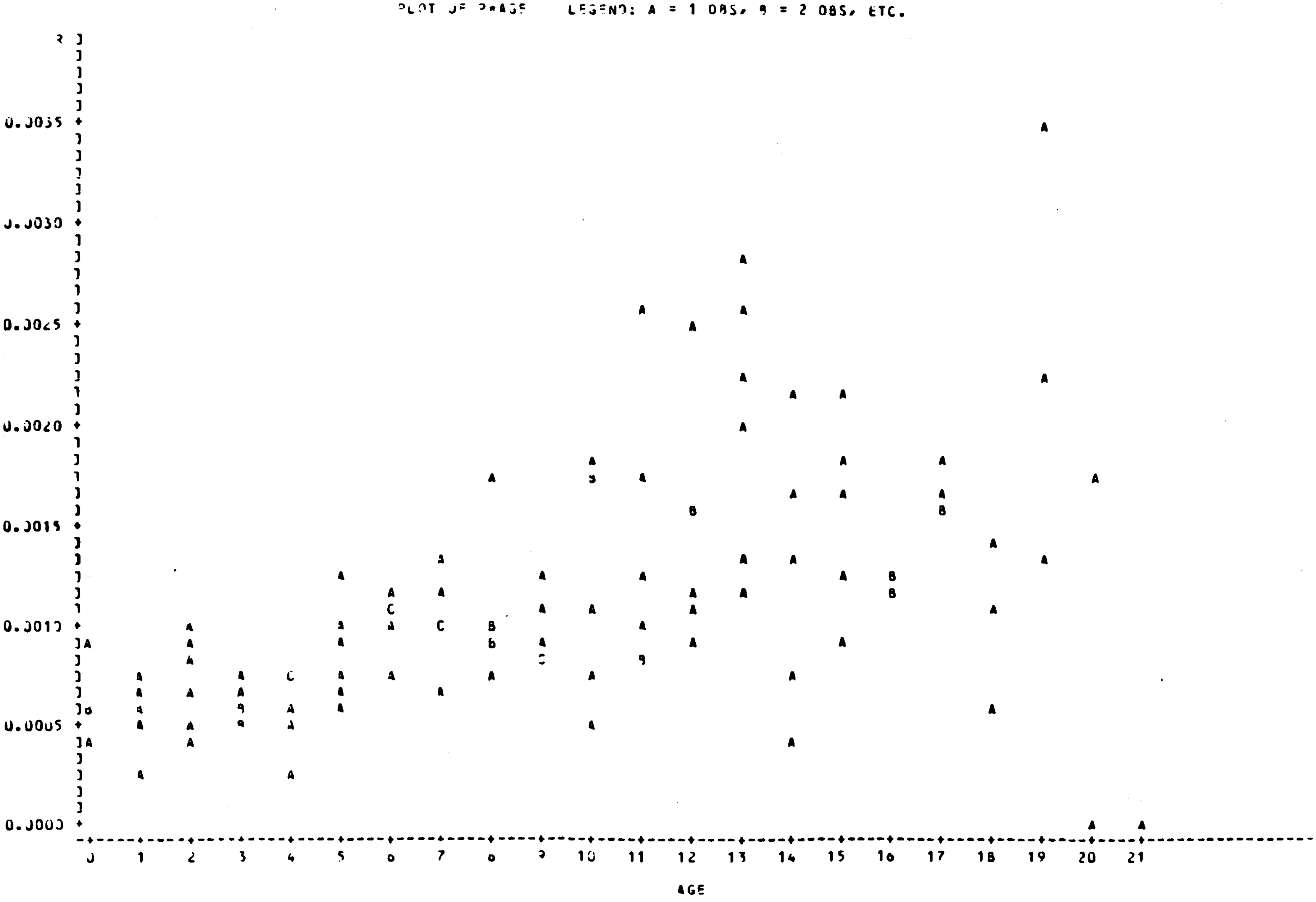

Figure 2-11
Indiana, Passenger Cars

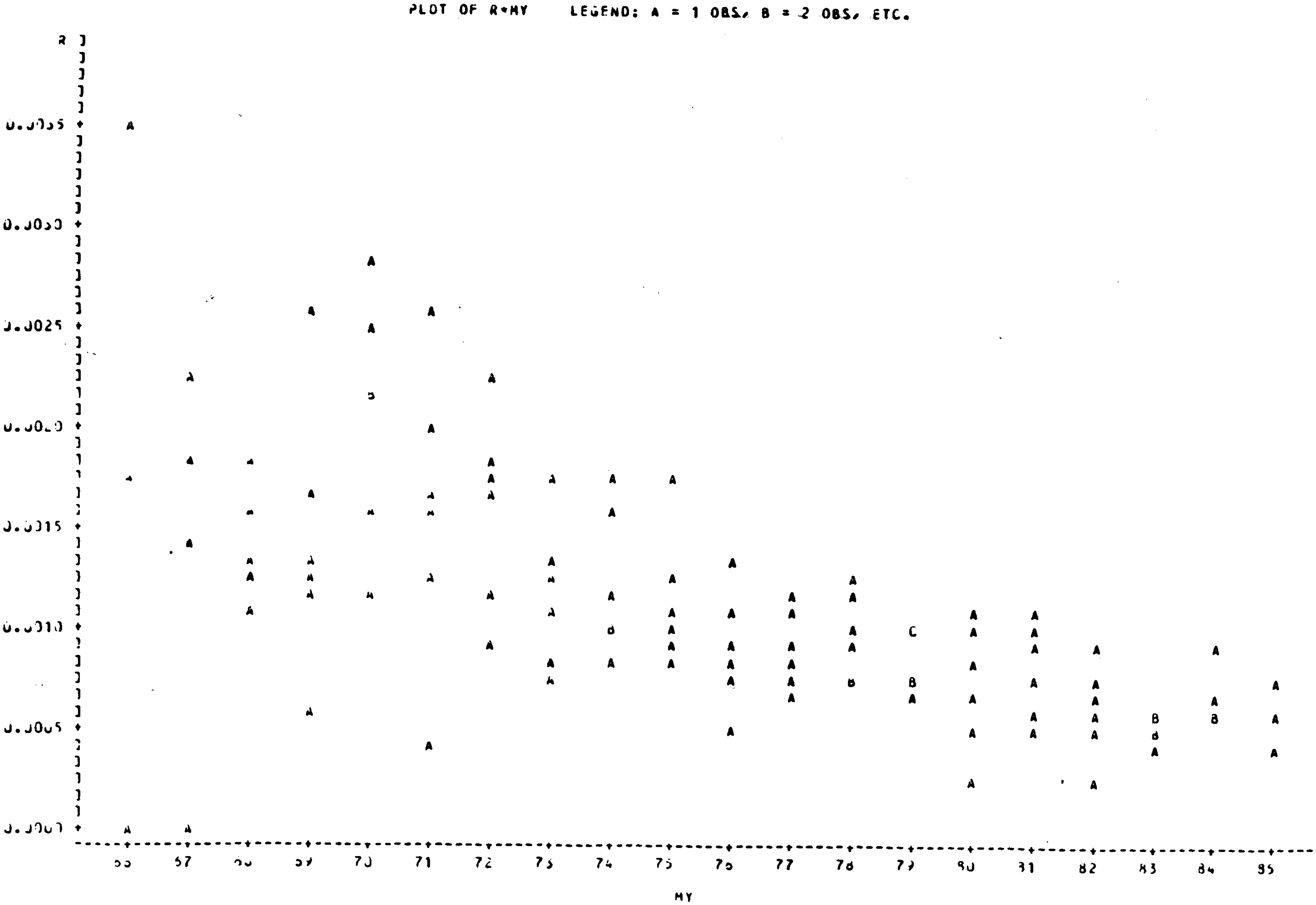

Figure 2-12
Indiana, Passenger Cars

Turning to the two-variable model to include the Standard effect, the fitted equation was:

$$R = 0.001022 + 0.0000120\ X_1\ (\text{age}) - 0.0002240\ X_2\ (\text{Std})$$

In this model, the Standard effect was significant, but the age factor was not significant. The t-value for the Standard effect was -2.84, while the t-value for the age effect was 1.41.[10] The R^2 of 0.23 showed some improvement over the single variable (age) model, but still much below the model fits obtained for the States of Michigan, Ohio, and Maryland.

The next step is to estimate the effectiveness of the Standard from the fitted model. Given the age of the Pre-standard vehicles at 11.217 years, the effectiveness estimate is:

$$\begin{aligned}\text{Effectiveness} &= \frac{-.0002240}{.001022 + 11.217\ (.0000120)} \\ &= \frac{-.0002240}{.001157} \\ &= -.1937 = -19.37\%\end{aligned}$$

The fire rate for the Post-standard of vehicles was significantly below the fire rate for Pre-standard vehicles, the magnitude of the difference being 19.37 percent.

---

[10] For Standard effect, probability of greater t = .0054; for age effect, probability of greater t = .1601.

Attaching 95 percent confidence limits gives:

$$19.37 \pm 13.36\% = 6.01\% \text{ to } 32.73\%$$

Data from Indiana

The fire rates from Indiana are plotted in Figures 2-11 and 2-12. The regression equation for the single variable, age, was:

$$R = 0.0005085 + 0.0000669 X_1 \text{ (age)}$$

The fit was considerably better than those for the Illinois data, with an R^2 of .38. Age was significant with a t-value of 8.08.[11]

Adding the second variable to estimate the effect of the Standard gave the following equation:

$$R = 0.0009783 + 0.0000374 X_1 \text{ (age)} - 0.0003724 X_2 \text{ (Std)}$$

In this model, both the age and the Standard effects are significant with t (age) = 3.24 and t (Std) = -3.50.[12] The fit was somewhat improved over the single variable (age) model with the R^2 rising to .45, from .38. The average age of the Pre-standard vehicles is 11.65 years.

---

[11] Probability of a greater t=.0001.

[12] Probability of greater t = .0016, and .0007, for age and Standard coefficients, respectively.

Estimating the Standard effectiveness from the Indiana data gives:

$$\text{Effectiveness} = \frac{-0.0003724}{.0009783 + 11.65\ (.0000374)}$$

$$= \frac{-0.0003724}{0.001414}$$

$$= -.2634 = -26.34 \text{ percent}$$

The 95 percent confidence limits on the estimate are:

26.34 ± 14.74% = 11.60% to 41.08%

Discussion of Results from Illinois and Indiana

Both the Illinois and the Indiana data produce effectiveness estimates that are higher, and at the same time, more variable, than the results from the three States, Michigan, Ohio, and Indiana. Illinois was the only State among the five where age was not a significant effect in the effectiveness model (i.e., 2-variable model). The five rates were generally of the same order of magnitude for Illinois and Indiana, even though one State apparently records only post-crash fires (i.e., Indiana) while the other State (Illinois) appears to record both pre-crash and post-crash fires. One other item of some concern for the Illinois data is the unusually high rate of "unknowns" for the fire variable. For the six years of Illinois data, the rate of unknowns ranged from 35 percent to 43 percent. The unknown rate for Indiana ranged from 3 percent to about 7 percent.

2.2.2 Analysis of State Injury Accident Data

In the preceeding section (2.2.1), analyses of data for passenger car crashes from the States of Michigan, Ohio, and Maryland found a 14 percent reduction in fires for cars manufactured after Standard 301 took effect. That analysis and estimated reduction pertained to fires in all police reported accidents most of which are non-injury. A logical follow-on question is: "what effect has the Standard had in reducing injuries -- i.e., burn injuries resulting from vehicle crash fires?"

In order to explore this question, the analysis will focus on the rate of fire in injury crashes involving passenger cars and whether or not fires have been significantly reduced for vehicles produced after the Standard took effect.

Table 2-2a shows the fire rates for passenger cars in injury crashes for the three States, Michigan, Ohio, and Maryland, which have been shown to have the most complete data on fires. The table entries are the number of police reported fires per 100 crashes in which the driver sustains injury at severity level A (serious) or at severity level B (moderate). The data are overall, or aggregate values for the six calendar years, 1982 through 1987. It will be noted that the fire rates given here, for injury crashes, are 2 to 3 times higher than the fire rates for all reported crashes (i.e., both injury and noninjury) as shown in Table 2-2. This is true for Michigan and Ohio, but not for Maryland where the fire rates for injury crashes and all

Table 2-2a
Fire Rates* in Passenger Car Injury Crashes by State and Vehicle Model Year

Model Year	STATE		
	Michigan	Ohio	Maryland
1987	0.44	0.54	0.40
1986	0.53	0.80	0.09
1985	0.43	0.52	0.22
1984	0.50	0.53	0.15
1983	0.39	0.55	0.10
1982	0.36	0.54	0.10
1981	0.43	0.48	0.16
1980	0.55	0.61	0.29
1979	0.64	0.76	0.27
1978	0.66	0.84	0.20
1977	0.68	0.80	0.35
1976	0.90	0.88	0.42
1975	0.82	1.08	0.44
1974	0.82	1.21	0.38
1973	0.97	1.11	0.44
1972	1.08	1.33	0.56
1971	1.30	1.06	0.34
1970	0.91	1.08	0.34
1969	1.19	1.45	0.56
1968	0.68	1.51	0.55
1967	1.53	1.45	0.36
1966	0.90	0.98	0.16
1965	1.39	1.25	0.99

---

* Fire rates are police reported fires per 100 passenger car crashes where the driver is injured at severity level A (serious) or severity level B (moderate). Appendix C contains the actual counts of fires and injury crashes (vehicles) for each Model Year and State.

The data are overall aggregates for calendar years 1982 through 1987.

crashes lie approximately within the same range. Intuitively, fires would be expected to occur more frequently in injury crashes than in all crashes, because of their typically higher crash forces. Why the data from Maryland display a departure from this pattern is not apparent at this juncture.

The reasons for combining injury levels A and B is that the cell counts (i.e., number of fires for separate injury levels within some model year by calendar year combinations) are too small to support reliable analysis. Of course, all statistical inferences resulting from the analysis will apply to the rate of fires in the population of injury crashes where injury is defined as either A or B severity (to the driver). Separate inferences, with respect to A-injury crashes, or with respect to B-injury crashes will not be appropriate.

The individual counts of vehicle fires in A + B injury crashes and of all vehicles in A + B injury crashes are given in Appendix C, Table C-2a, where the counts are the 6-year totals for each of the three States. A quick review of Table C-2a reveals that the fire counts for Maryland are relatively small. Recalling that the data to be submitted to the model for analysis, following the convention in the preceeding section for all accidents, are the individual model year x calendar year counts, this means that the Maryland data will be too sparse and must therefore be dropped from further analysis. The unusually low rate of fires in injury crashes for Maryland, as noted earlier, constitutes a second reason for excluding Maryland and restricting the effectiveness analyses to the data from the States of Michigan and Ohio.

The Michigan data will be analyzed first. The analysis approach is similar to that used in Section 2.2.1 for the analysis of fire rates in all police reported crashes.

Figures 2-12a and 2-12b are plots of the fire rates in A + B injury crashes by vehicle age and by vehicle model year, respectively. Each data point represents the fire rate for vehicle model year i, and calendar year j. As with the plots of fire rates in all crashes, the fire rates in injury crashes are also shown to have a distinct relationship with age (or model year), with the rate increasing with age.

Simple and multiple linear models were fitted to the data as follows:

Age Model: $R_{ij} = a + b\, X_{ij}$

Model Year Model: $R_{ij} = a + b\, X_{ij}$

Age, Standard Model: $R_{ij} = a + b\, X_{1(ij)} + c\, X_{2\,(ij)}$

In these equations, the dependent and independent variables have the same interpretation as those used in the analysis of fire rates in Section 2.2.1, with the exception that here the fire rates are those for injury crashes. The subscripts i,j, refer to vehicle model year and the calendar year in which the crashes occurred, respectively.

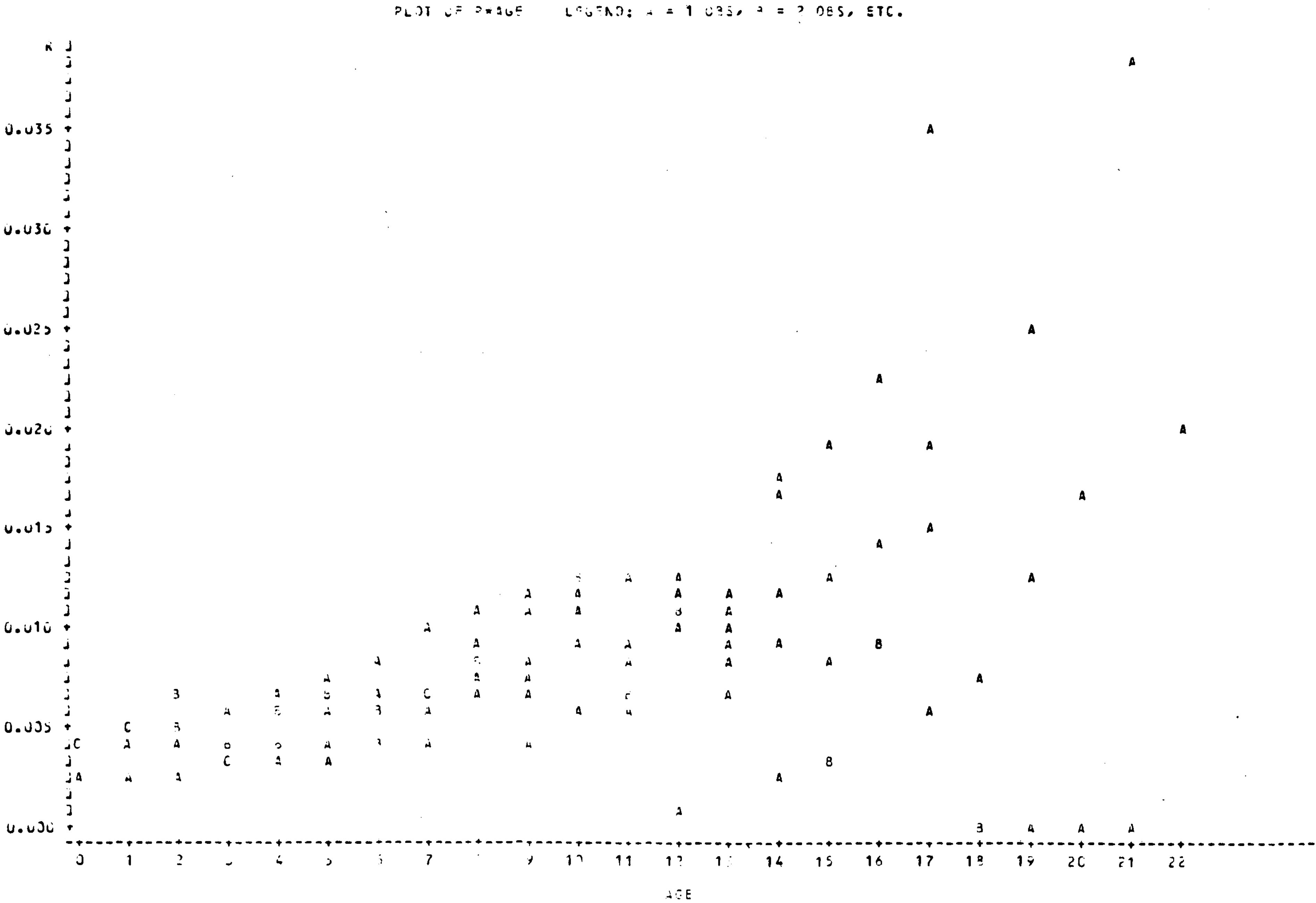

Figure 2-12a
Michigan, Passenger Cars

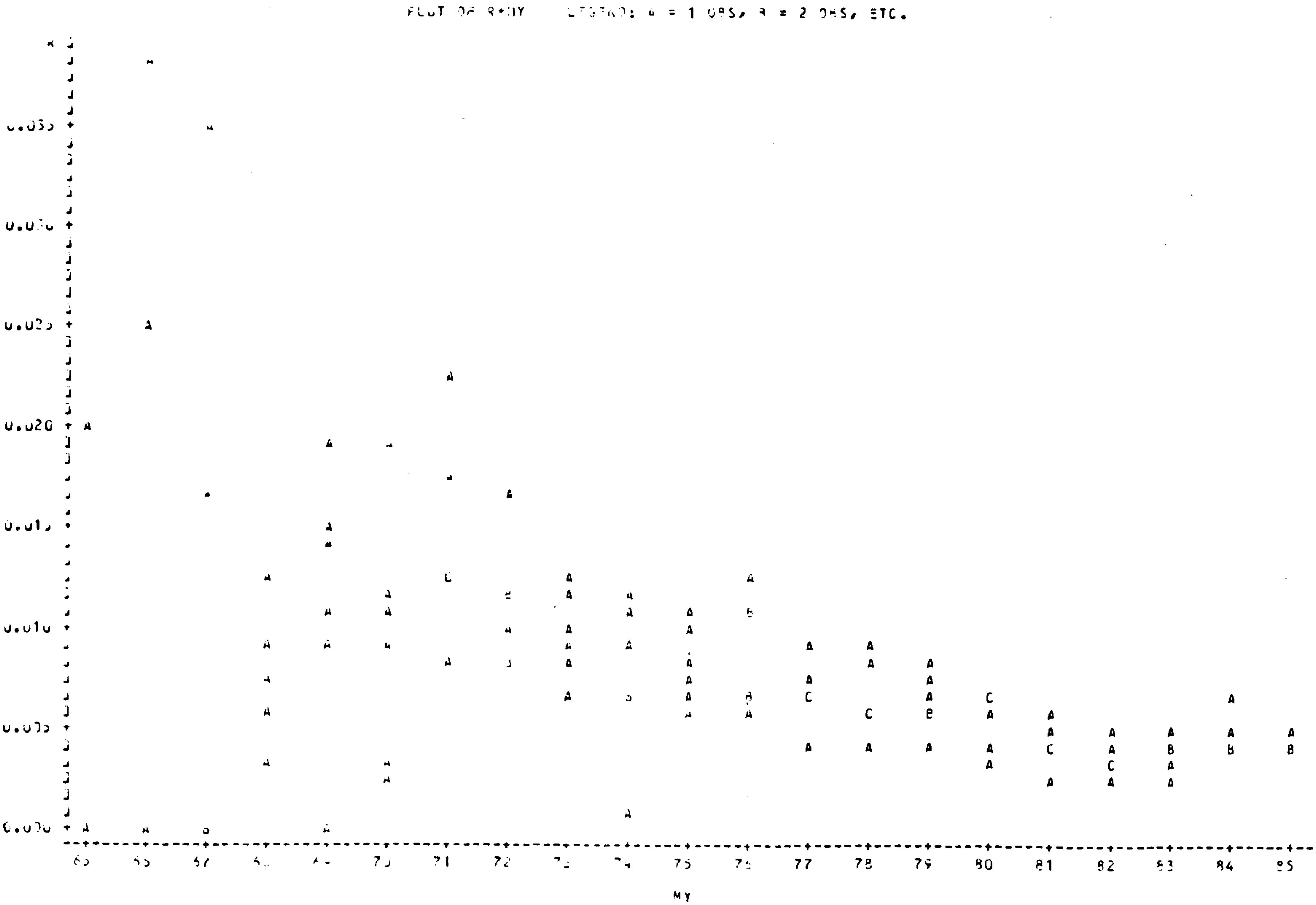

Figure 2-12b
Michigan, Passenger Cars

Fitting the data to the models produced the following results:

Age Model: $R = 0.00344053 + 0.00051505\ X_1(\text{age})\quad R^2 = .44$

Model Year Model: $R = 0.04692532 - 0.00051447\ X_1(\text{mod. yr.})\quad R^2 = .46$

Age, Standard Model:

$$\begin{aligned} R = {} & 0.00464540 + 0.00044165\ X_1(\text{age}) \\ & - 0.00098141\ X_2(\text{Std})\quad R^2 = .45 \end{aligned}$$

In all three cases, the age (or model year) coefficients are highly significant (P>t= .0001) while the coefficient for the effect of Standard 301 is non-significant (P>t = .20). Even though not significant, the effect of the Standard will be estimated. Given the average age of Pre-standard vehicles is 11.2 years, the estimate is:

$$\text{Effectiveness} = \frac{-0.00098141}{.0046454 + 11.2\ (.00044165)}$$

$$= -.102$$

$$= -10.2\%$$

Thus, the results of analyzing the Michigan fire rate in injury crashes for passenger cars finds the effect of the Standard to be not significant at a numerical reduction in fires of 10.2 percent.

Turning next to the data from Ohio, the fire rates in injury crashes as a function of age and model year are graphed in Figures 2-12c and 2-12d, respectively. Once again the relationship of fire rate and vehicle age is readily evident.

Fitting the Ohio data to the same 3 models produced the following equations:

$$\text{Age Model:} \quad R = 0.00401897 + 0.00063687X_1(\text{age}) \qquad R^2=.57$$

$$\text{Model Year Model:} \quad R = 0.05526704 - 0.00060391\ X_1(\text{mod.year}) \qquad R^2=.54$$

$$\text{Age, Standard Model:} \quad R = 0.00612149 + 0.00050309X_1(\text{age}) -0.00167810X_2(\text{std.}) \qquad R^2=.59$$

Similar to the results from Michigan, the coefficients for the age variable are highly significant (P>t=.0001) in all three equations, and the coefficients of determination indicate that age explains a substantial portion of the total variation in fire rates. Moving to the coefficient measuring the effect of Standard 301, however, a different result is noted from that obtained with the Michigan data. Here, the coefficient is statistically significant (P>t=.0170) indicating that fire rates in injury crashes are lower for Post-standard vehicles than they are for Pre-standard vehicles. Estimating the effect of the standard using the estimates from the last equation, above, and the average age of the Pre-standard vehicles at 11.41 years, yields;

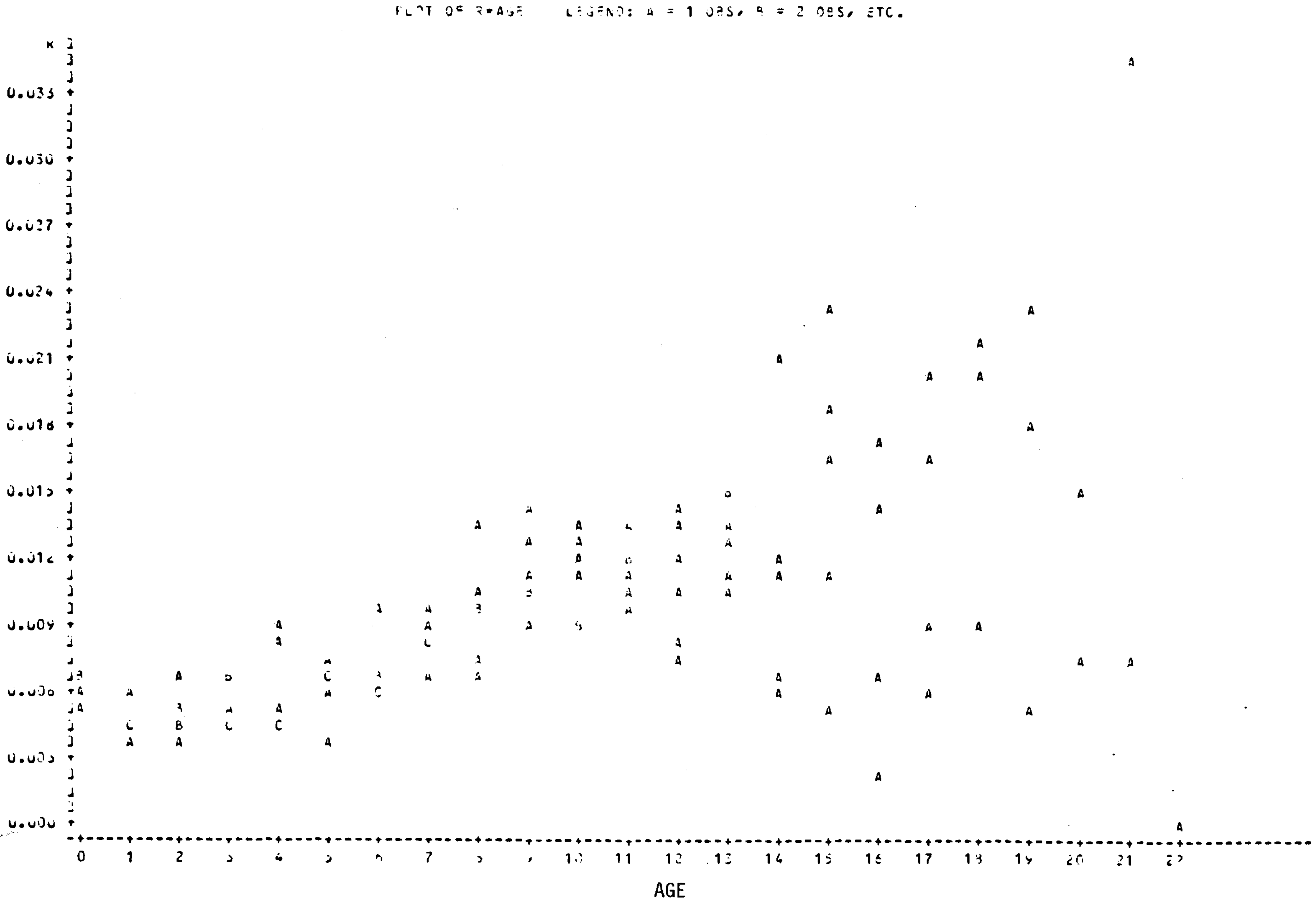

Figure 2-12c
Ohio, Passenger Cars

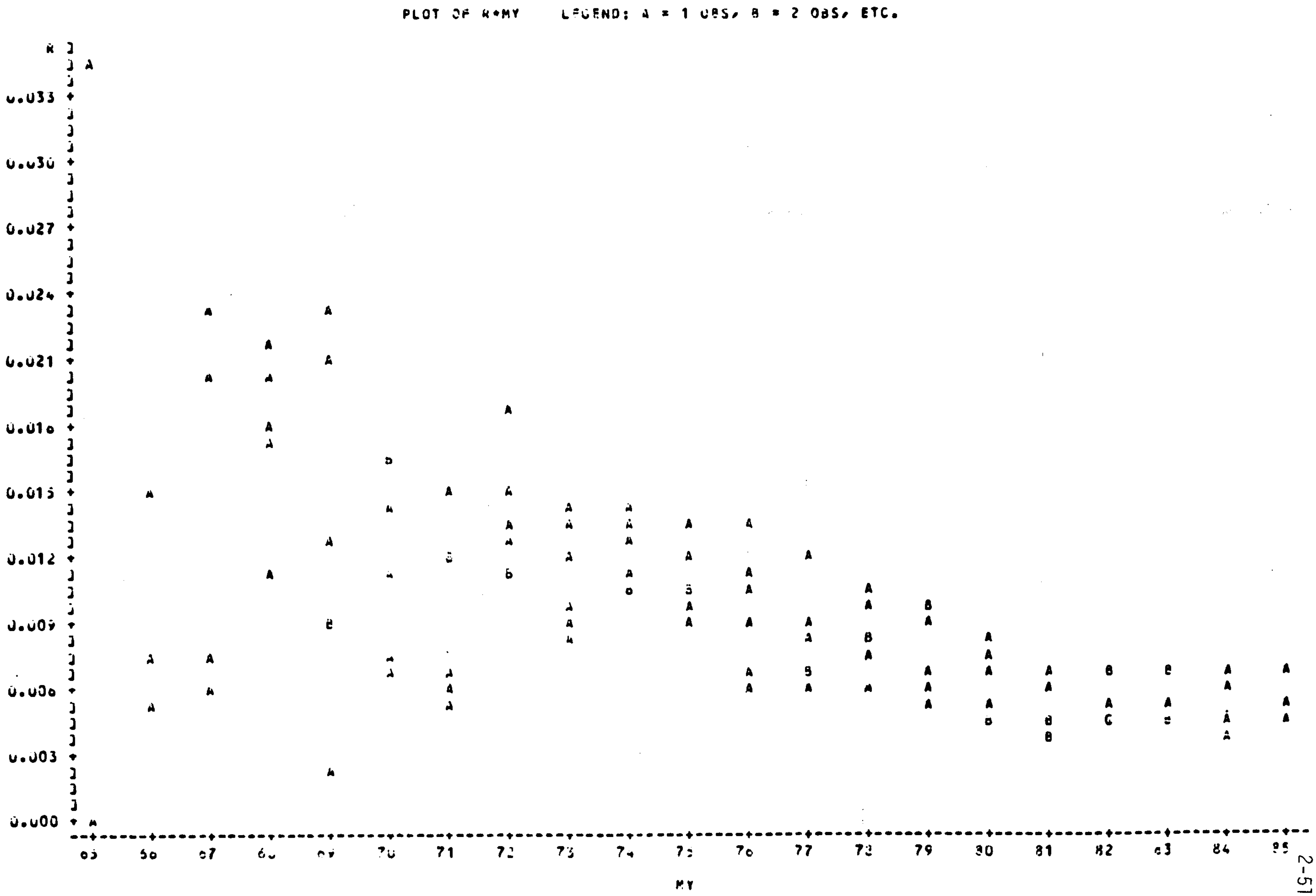

Figure 2-12d
Ohio, Passenger Cars

$$\text{Effectiveness} = \frac{-\ 0.00167810}{0.00612149 + 11.41\ (0.00050309)}$$

$$= -.141$$

$$= -14.1\%$$

Therefore, using data from Ohio, a statistically significant reduction of 14 percent in fires in injury crashes is found for cars produced after FMVSS 301 took effect.

2.2.3 Analysis of Fatal Accident Data

In the previous sections, analysis of State data from five States was discussed. Analysis of State data can provide insight into the effect of FMVSS 301 on property damage and injury accidents. However, for the effect of the Standard on fatal accidents, the numbers in the State files are too small. Therefore, the data from the Fatal Accident Reporting System (FARS) are used.

To recall, FARS records, for each vehicle in the accident, the presence of fire according to the following convention:

NO - No fire

YES - Fire occurred in vehicle during accident

As with the State files, fires in the FARS files may contain fires which resulted from the crash as well as fires which occurred prior to the crash. The FARS data contain an additional variable, "FIRST HARMFUL EVENT," which can provide information on the origin of the fire. One of the codes for First Harmful Event (an accident-level variable) is "fire/explosion." Fires which are coded as "first harmful event" would presumably be pre-crash, rather than post-crash events. A sample check of the FARS data for six calendar years revealed that less than one percent of passenger car fires were coded in the "first harmful event" category.

Thus, it could be said that in excess of 99 percent of passenger car fires associated with fatal crashes are a result of the crash itself. However, while post-crash fires are expected to represent a much larger proportion of "fatal crash fires" than they are among "all accident fires" - owing to the much more severe forces involved in fatal accidents - it must still be recognized that to discern, reliably, the origin of the fire could still be a tenous task for police investigating officers. It seems reasonable to assume that the very large majority of fires in fatal crashes would indeed be of the post-crash variety. However, to state that such proportion is over 99 percent of all fires associated with fatal car crashes may be a more precise statement than is warranted based on the overall data reporting mechanisms.

Given the above conditions, Table 2-3 lists the fatal crash fire rates for passenger cars as recorded in FARS from calendar years 1975 through 1988. Fire rates are given by vehicle model year, along with the actual frequencies of vehicle fires and frequencies of all passenger cars involved in fatal accidents. One item to note is that fire rates for passenger cars in fatal crashes is much higher (up to 10 times as high) as fire rates for cars in all (severity) accidents. This is no doubt a reflection of the much higher crash forces involved in fatal accidents.

Analyses similar to those performed on the State data were performed on the FARS data. Regression models, with weighting of individual observations, and balancing of Pre and Post model years within calendar years were run. For the FARS years 1975 through 1988, this produced a total number of 182 observations, each observation being the fire rate (i.e., number of passenger

Table 2-3
Fire Rates* in Fatal Passenger Car Accidents by Vehicle Model Year

Model Year	No. Passenger Car Fires	No. Passenger Cars in Fatal Accidents	Fire Rate*
1989	3	133	2.256
1988	56	2,798	2.001
1987	150	6,015	2.494
1986	218	8,969	2.431
1985	256	11,428	2.240
1984	339	14,289	2.373
1983	278	12,538	2.217
1982	319	14,645	2.178
1981	382	18,544	2.060
1980	538	23,578	2.282
1979	808	30,569	2.643
1978	800	33,308	2.402
1977	870	34,249	2.540
1976	857	33,121	2.587
1975	771	27,191	2.835
1974	864	34,996	2.469
1973	879	37,211	2.362
1972	813	31,948	2.545
1971	637	25,371	2.511
1970	561	23,804	2.357
1969	505	21,558	2.343
1968	419	17,769	2.358
1967	320	13,701	2.336
1966	241	12,129	1.987
1965	189	9,587	1.975
1964	109	6,117	1.782
1963	76	3,803	1.998
1962	46	2,332	1.973
≤1961	88	3,792	2.321
UNK	67	3,420	1.959

SOURCE: Fatal Accident Reporting System files for calendar years 1975 through 1988.

* Fire rates are reported fires per 100 passenger cars in fatal accidents.

cars with fire divided by total involved passenger cars) for a given calendar year - model year combination.

The data are plotted in Figures 2-13 and 2-14 as a function of vehicle age and vehicle model year.

Fitting a simple function of fire rate versus age gave the following equation:

$$R = 0.02174 + 0.0006329 \ X_1 \ (\text{age})$$

The age coefficient was significant at a t-value of 9.21.[13] This simple model of age explained approximately 32 percent of the variation in fire rate ($R^2 = .32$), somewhat less than was typically noted in the earlier age models of the State accident data.

Adding a second variable to account for the effect of FMVSS 302 resulted in the following model:

$$R = 0.02192 + 0.0006218 \ X_1 \ (\text{age}) -0.0001739 \ X_2 \ (\text{Std})$$

---

[13] Probability of greater t = 0.0001).

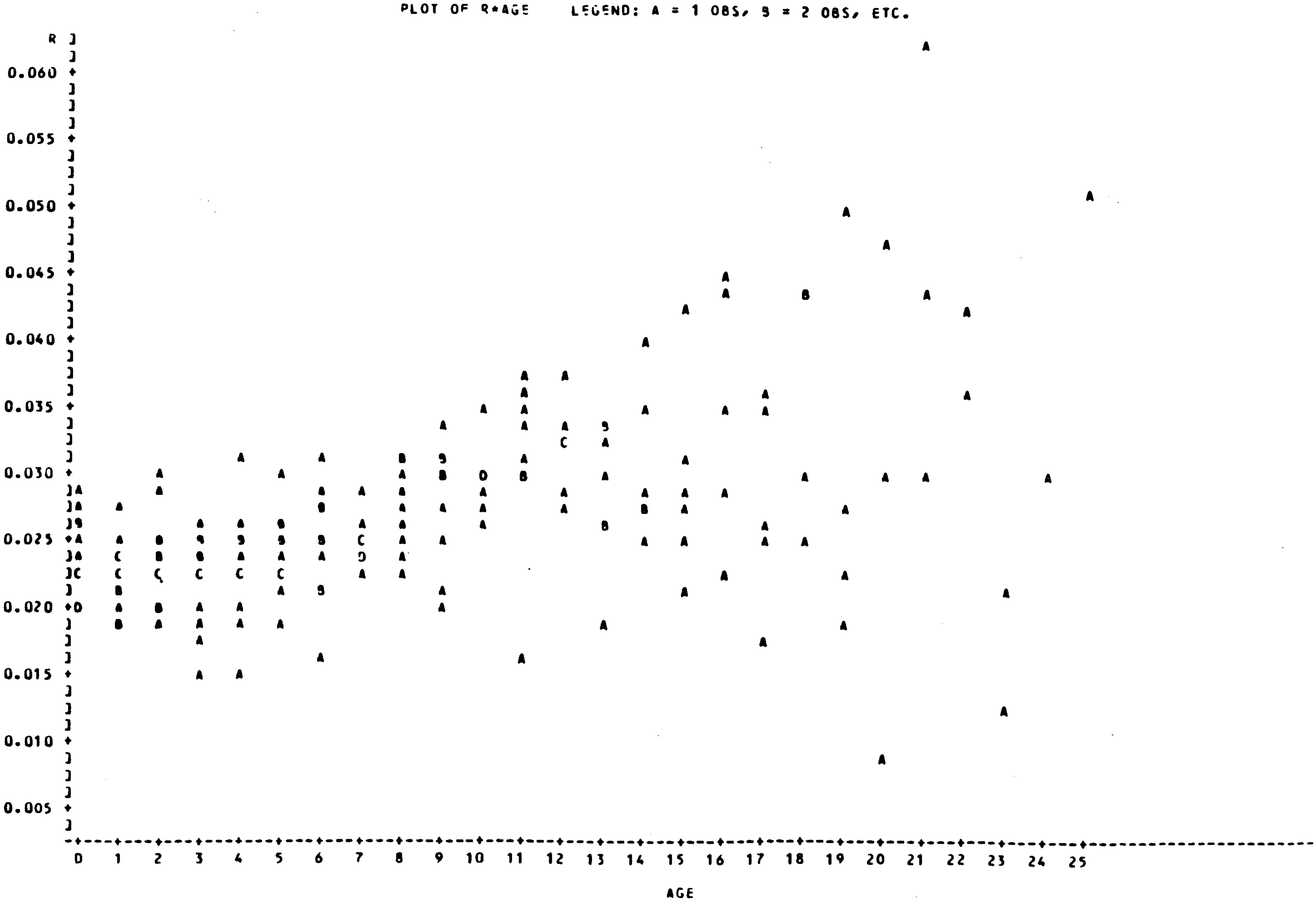

Figure 2-13
FARS, Passenger Cars

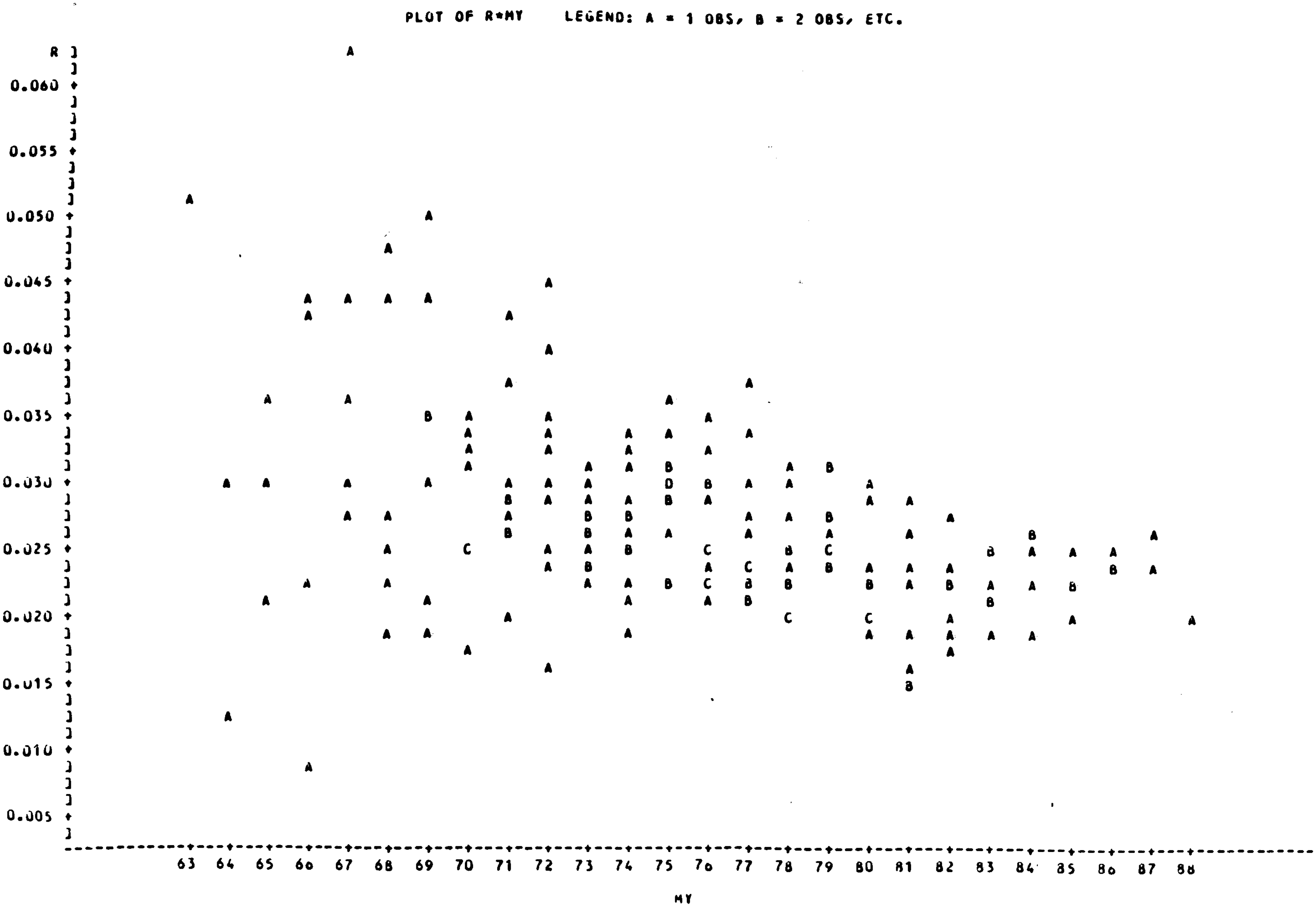

Figure 2-14

FARS, Passenger Cars

While the sign of the X_2 coefficient is in the right direction, it's magnitude is far from being sufficient for statistical significance, the t-value being only -0.22.[14] Therefore, the Standard effect is not significantly different from zero. The age factor, on the other hand, maintains significance with a t-value of 7.32.[15] The R^2 value remained unchanged (from the age only model) at .32, indicating further than the addition of the variable for the Standard had no effect in further explaining the variation in fire rate.

The average age of the Pre-standard cars was 9.066 years. Although not significantly different from zero, the estimate of the effect of the Standard is:

$$\text{Effectiveness} = \frac{-0.0001739}{.02192 + 9.066\ (.0006218)}$$

$$= \frac{-0.0001739}{.02756}$$

$$= -.006310 = -0.63\%$$

Ninety-five percent confidence limits are:

$.63 \pm 5.51\% = -4.88\%$ to 6.14%

---

[14] Probability of greater t = .8226.

[15] Probability of greater t = .001.

Based on this analysis, no effect is found for FMVSS 301 in reducing fires in fatal passenger car crashes, there being no difference in fire rates between Pre and Post-standard cars.

An alternate method of analyzing the fatal accident data for passenger cars is summarized in Table 2-4. Here, Pre-standard and Post-standard fire rates are compared for one, two, ..., six model years before and after FMVSS took effect. For example, ±1 MY in the first column of the table refers to Model Year 1975 for the Pre-standard sample and Model Year 1976 for the Post-standard sample. The comparisons are cumulative, i.e., ± 2 MY includes ±1MY and ±2MY and encompasses Model Years 1974, 1975 in the Pre-standard group, and Model Years 1976, 1977 in the Post-standard group. The fire rates include all eligible FARS data from calendar year 1975 through 1988. The comparisons are balanced in the same manner as was done for the regression analyses - in each calendar year of FARS, the number of model years in the Pre-standard group is kept equal to the number of model years in the Post-standard group.

It should be borne in mind that the comparisons in Table 2-4 do not account for the effect of the vehicle age upon fire rates. This will be considered later.

Columns 4 and 5 in the table give the actual and relative differences in fire rates between the Pre- and Post- groups within each comparison group. The difference is defined as the Pre-standard fire rate minus the Post-standard fire rate. The relative difference is the difference expressed as a percent of the Pre-standard fire rate.

Table 2-4
Selected Comparisons of Pre-standard and Post-standard Fire Rates for Passenger Cars Fatal Accident Data

Comparison (No. of Pre, Post Model Years)	Fire Rate ($x10^{-2}$)		Difference ($x10^{-2}$)	
	Pre-Standard	Post-Standard	(Pre-Post)	Percent Difference
± 1 MY	$\frac{722}{25175}=2.868$	$\frac{855}{32995}=2.591$	0.277	9.65%
± 2 MY	$\frac{1429}{52878}=2.702$	$\frac{1724}{66158}=2.606$	0.096	3.55%
± 3 MY	$\frac{2084}{78354}=2.660$	$\frac{2520}{99321}=2.537$	0.123	4.62%
± 4 MY	$\frac{2598}{96139}=2.702$	$\frac{3324}{129712}=2.563$	0.139	5.14%
± 5 MY	$\frac{2895}{106580}=2.716$	$\frac{3858}{153122}=2.520$	0.196	7.22%
± 6 MY	$\frac{3095}{113365}=2.730$	$\frac{4240}{171572}=2.471$	0.259	9.49%

For each of the six comparisons, it is seen that there is a small, but consistent difference between the Pre-standard and Post-standard groups, with the fire rate being lower for the Post-standard vehicles. On a relative basis, this difference ranges from about 3.5 percent to 9.5 percent. The direction of these differences is in line with a favorable effect of FMVSS 301 in reducing fatal crash fires.

However, recall that the comparison in Table 2-4 are confounded with the effect of vehicle age, which has been shown in prior analyses to have a significant impact on fire rates. In the two prior regression analyses, age was seen to increase the fire rate by 2.91 percent per year (.0006329/.02174 = .0291 = 2.91%) in the age only model, and by 2.84 percent (.0006218/.02192 = .0284 =2.84%) in the age by Standard model. The average of these is approximately 2.9 percent per year - increase in fire rate due to age.

If the effect of age is introduced, the differences in Table 2-4 essentially disappear. Table 2-5 contains estimates of the adjustment effects for vehicle age. Columns 2 and 3 of the table list the average age of the Pre-standard and Post-standard samples within each of the six comparison groups. The average age is the weighted age, based on the total number of vehicles involved in fatal crashes within each group. Column 4 is the difference in age (in years) between Pre- and Post-standard samples. The last column contains the age adjustment factors for each of the six comparison groups. This is merely the product of the average age difference, in years, between Pre- and Post- samples times the average effect of age on fire rates (i.e., = + 2.9%/year, from the above calculation).

Table 2-5
Adjustment for Vehicle Age on the Selected Comparisons of Pre-standard and Post-standard Passenger Cars (see Table 2-4)

Comparison Group	Vehicle Age (Years)		Difference (Pre-Post)	Age Adjustment (%) (Difference x 2.9%/Yr)
	Pre-standard	Post-standard		
± 1 MY	5.88	5.26	0.62	1.8%
± 2 MY	6.38	5.14	1.24	3.6%
± 3 MY	7.08	4.96	2.12	6.1%
± 4 MY	7.63	4.78	2.85	8.3%
± 5 MY	8.05	4.63	3.42	9.9%
± 6 MY	8.37	4.50	3.87	11.2%

Comparing the last two columns in Tables 2-4 and 2-5, it is seen than the lower rates for Post-standard vehicles are negated by the effect of vehicle age. While an advantage still remains for Post-standard vehicles in the ± 1 MY comparison, this is considered the result of statistical fluctuation, with the successively higher sample sizes in the subsequent fire comparisons (± 2 MY through ± 6 MY) producing more stable results: In all 5 of these comparisons, the age effect exceeds the magnitude of the lower rates for Post-standard vehicles from Table 2-4.

The result of this alternate analysis of fire rates in fatal passenger car crashes is similar to the results of the prior regression analyses. No difference is found between Pre-standard and Post-standard vehicles.

2.3 EFFECTIVENESS ANALYSIS FOR LIGHT TRUCKS

This section discusses the analysis of State and FARS data to estimate the effect of FMVSS 301 in reducing fires in light truck crashes. The analysis proceeds along similar lines as employed in Section 2.2 on the analysis of passenger car data.

The procedures for recording light truck fires in the State accident data and in the fatal accident data are the same as described in Section 2.2 for passenger cars.

2.3.1 Analysis of State Accident Data

Table 2-6 lists the fire rates in light truck accidents for each of the five States. The individual counts of fires and accident involved vehicles are included in Appendix C. The data covers the same 1982 through 1987 time period as was the case for passenger cars. It is noted that the fire rates for trucks display essentially the same patterns found for passenger cars. In general, older vehicles have higher fire rates, and the data from Michigan, Ohio, and Maryland show considerably higher incidence of fire than do the data from Illinois and Indiana. In terms of overall magnitude, the fire rates for trucks are generally similar to those noted for passenger cars.

As was done for passenger cars, the analysis of the light truck data will be discussed in two separate groupings, owing to the overall difference in fire rates for the States of Michigan, Ohio, and Maryland, as compared to the fire rates from Illinois and Indiana. Data from the former three States will be analyzed first.

2.3.1.1 Data from Michigan, Ohio, and Maryland

Regression analysis of the data from these three States was performed in a manner similar to that for passenger cars. First a simple linear model was fit to evaluate the effect of vehicle age on fire rate. Secondly, a multiple linear model was fit, adding a second variable for FMVSS 301, along with the

Table 2-6

Fire Rate* in Light Truck Crashes by State and Vehicle Model Year

Model	STATES				
Year	Michigan	Ohio	Maryland	Illinois	Indiana
1987	1.984	2.345	1.013	0.844	0.196
1986	1.200	2.150	1.895	0.917	0.497
1985	1.245	2.623	1.313	0.875	0.383
1984	1.739	2.686	1.838	0.942	0.694
1983	1.785	3.360	2.100	0.603	1.469
1982	1.630	2.519	2.267	1.079	0.944
1981	1.669	3.268	2.155	1.112	0.779
1980	1.500	3.086	3.350	1.060	0.433
1979	2.320	3.662	4.525	1.110	1.061
1978	2.057	4.485	4.235	1.409	0.855
1977	2.118	4.010	4.832	1.109	1.349
1976	2.349	4.395	3.816	1.404	1.295
1975	3.068	5.737	5.031	1.805	1.329
1974	2.951	4.995	4.853	1.619	0.808
1973	2.655	4.789	5.670	1.247	0.727
1972	4.059	4.286	4.381	1.760	2.370
1971	3.941	4.853	8.368	1.683	1.978
1970	2.270	6.922	5.287	1.393	1.362
1969	2.870	5.778	5.123	0.931	1.882
1968	3.345	6.347	9.582	2.185	0.918
1967	1.607	5.958	4.237	0.679	1.421
1966	1.884	4.865	6.593	0.962	0.956

---

* Fire rates are police reported fires per 1,000 light trucks involved in accidents. In order to obtain the actual fire rate, table entries should be multiplied by 10^{-3}

Appendix C contains the actual counts of fires and light trucks for each model year and State. The data are for calendar years 1982-1987.

variable for age. As with the analysis for passenger cars. The data were balanced to give an equal number of vehicle model years, within each calendar year, for the Pre-standard sample and the Post-standard sample. This produced 102 individual observations for each model, with each observation being the fire rate for a given model year, i, and a given calendar year, j. In carrying out the model runs, the variable for the FMVSS 301 was coded one for Post-standard vehicles (i.e., $\geq$ model year 1977) and zero for Pre-standard vehicles (i.e,, $\leq$ model year 1976). As with passenger cars, the regression runs were weighted. The following paragraphs summarize the analyses results for each of the three States.

Data from Michigan

The fire rates for light trucks from the Michigan accident files are shown in Figures 2-15 and 2-16, as a function of vehicle age and model year, respectively.

The simple model of fire rate as a function of age produced the following equation:

$$R = 0.001279 + 0.0001495\ X_1\ (\text{age})$$

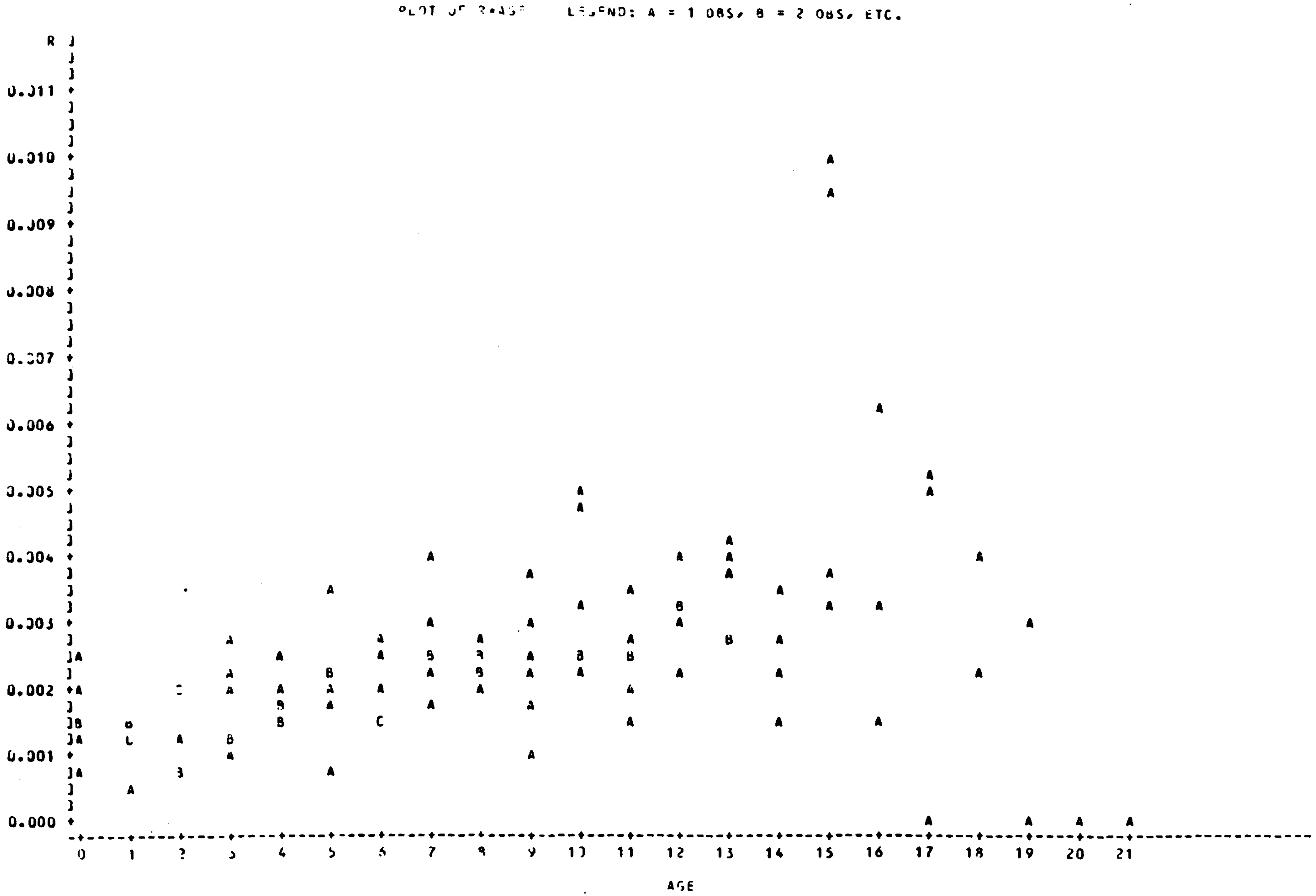

Figure 2-15
Michigan, Light Trucks

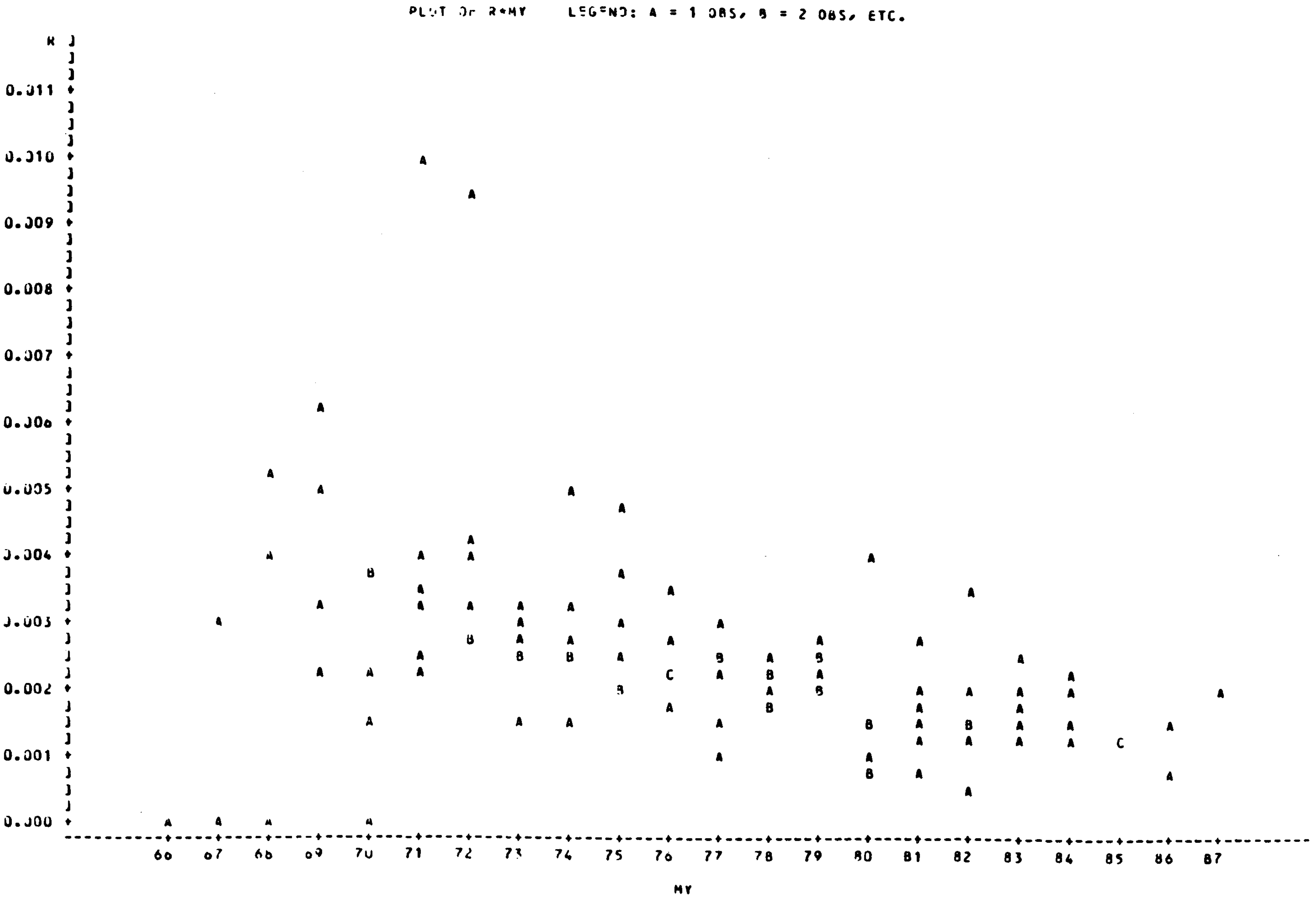

Figure 2-16
Michigan, Light Trucks

The age effect was significant with a t-value of 7.60.[16] R^2 was .37, indicating a fit only about half as good as that obtained for passenger cars.

The 2-variable model assessing the effect of the Standard gave the following fit:

$$R = 0.001625 + 0.0001270\ X_1\ (\text{age}) - 0.0002965\ X_2\ (\text{Std})$$

Here, age was again significant, the t-value being 4.48,[17] but the Standard effect was not, the t-value being -1.10.[18] The fit of the model, as indicated by R^2, remained unchanged at a value of .37.

While the Standard effect was not significantly different from zero, its magnitude will be estimated. Given the average age of Pre-standard trucks at 10.403 years, the estimate is:

$$\begin{aligned}\text{Effectiveness} &= \frac{-0.0002965}{.001625 + 10.403\ (0.0001270)}\\ &= \frac{-0.0002965}{.002946}\\ &= -.1006 = -10.06 \text{ percent}\end{aligned}$$

---

[16] Probability of greater t = 0.0001.

[17] Probability of greater t = 0.0001.

[18] Probability of greater t = 0.2757.

The fire rate for Post-standard trucks is 10 percent below that for Pre-standard trucks, after accounting for vehicle age, but this is not sufficient for statistical significance. The 95 percent confidence based is rather wide at:

$$-10.06 \pm 18.0\% = - 7.94 \% \text{ to } 28.06\%.$$

Data from Ohio

Plots of fire rate for trucks versus age and model year, for Ohio, are contained in Figures 2-17 and 2-18, respectively.

Fitting a simple linear function for vehicle age gave:

$$R = 0.002424 + 0.0002337 X_1 \text{ (age)}$$

Once again, age was significant (t=10.27).[19] The fit was considerably better than for Michigan, with a R^2 of .51.

Adding the second variable, for the effect of the Standard, resulted in the following fit:

$$R = 0.002506 + 0.0002283 X_1 \text{ (age)} - 0.00006924 X_2 \text{ (Std)}$$

---

[19] Probability of greater t = 0.0001.

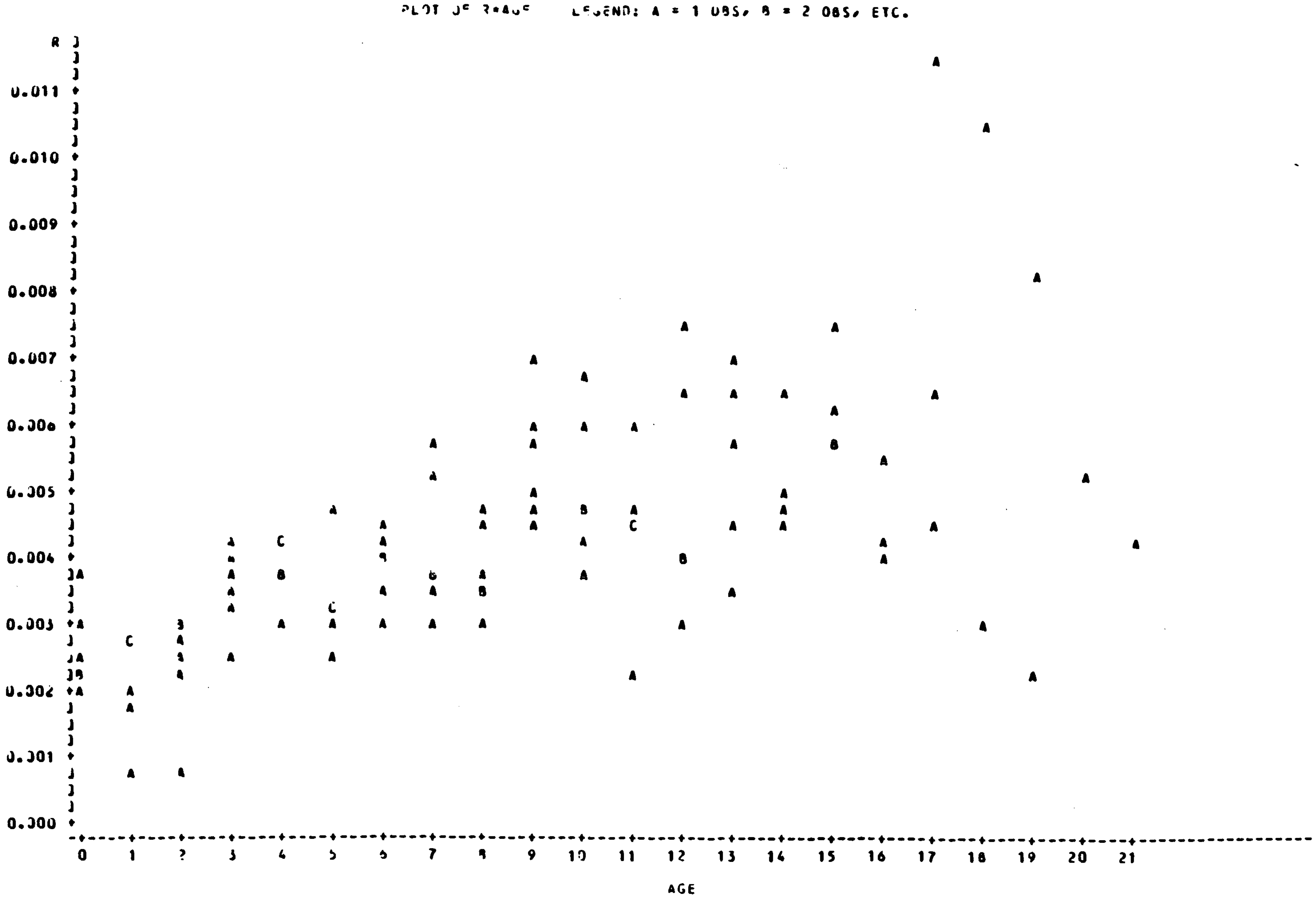

Figure 2-17
Ohio, Light Trucks

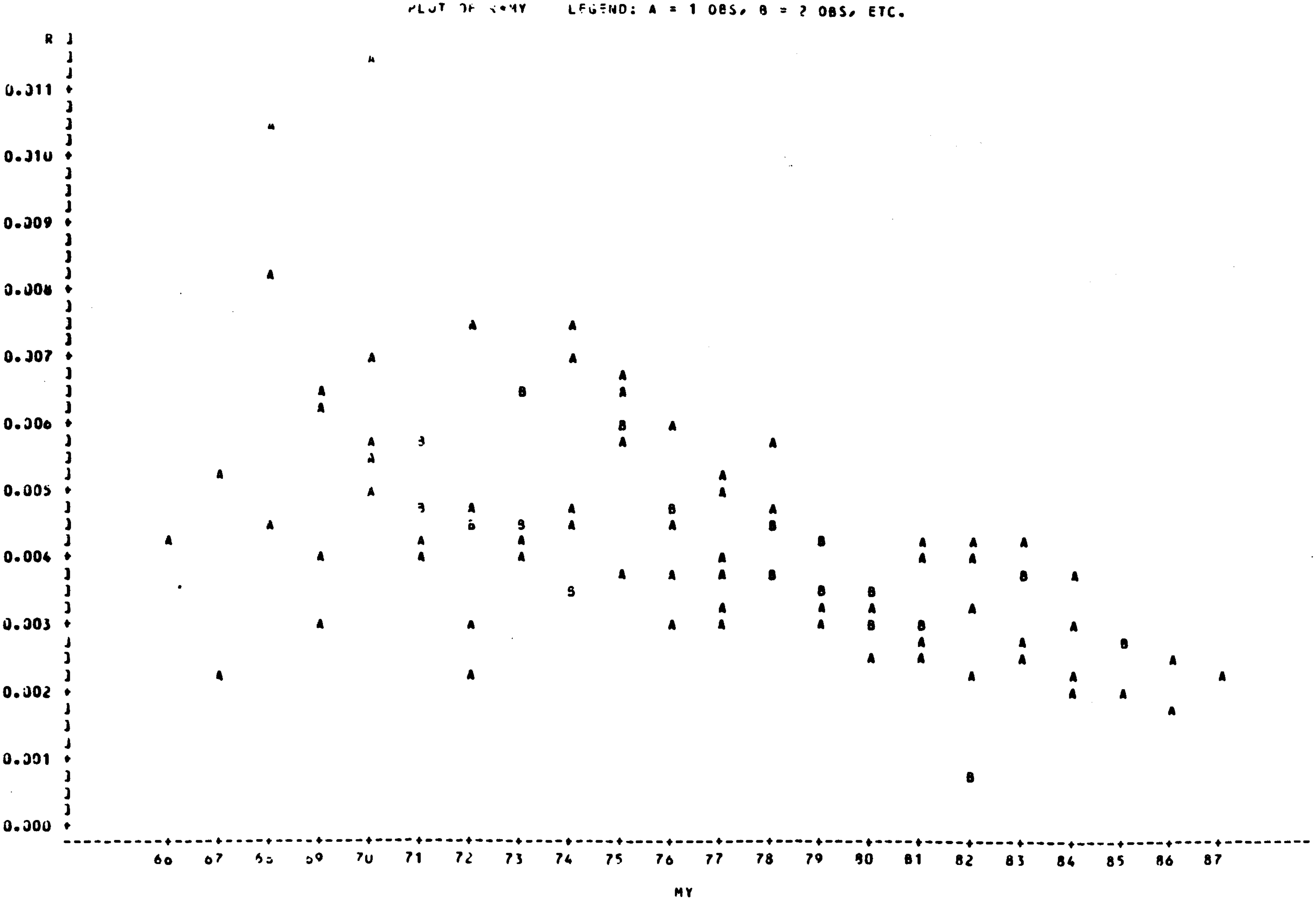

Figure 2-18
Ohio, Light Trucks

Age remained significant at a t = 6.76,[20] but, as with Michigan, the effect for the Standard was not significant, the t-value being only -0.22.[21]

The effectiveness of the Standard, while not significantly different from zero, is estimated as:

$$\text{Effectiveness} = \frac{-0.0000692}{.002506 + 10.495\ (.0002283)}$$

$$= -\frac{0.0000692}{.004902}$$

$$= -\ .01412 = -\ 1.41\%$$

Adding 95 percent confidence limits gives:

$$-\ 1.41 \pm 12.73\% = -\ 11.32\% \text{ to } 14.14\%$$

Data from Maryland

Fire rate versus age and model year plots for Maryland are shown in Figures 2-19 and 2-20. As with almost all data previously analyzed, the age relationship with fire rate is again apparent.

Fitting the simple linear model, fire rate as a function of age, gave the following result:

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[20] Probability of greater t = 0.0001.

[21] Probability of greater t=0.8285.

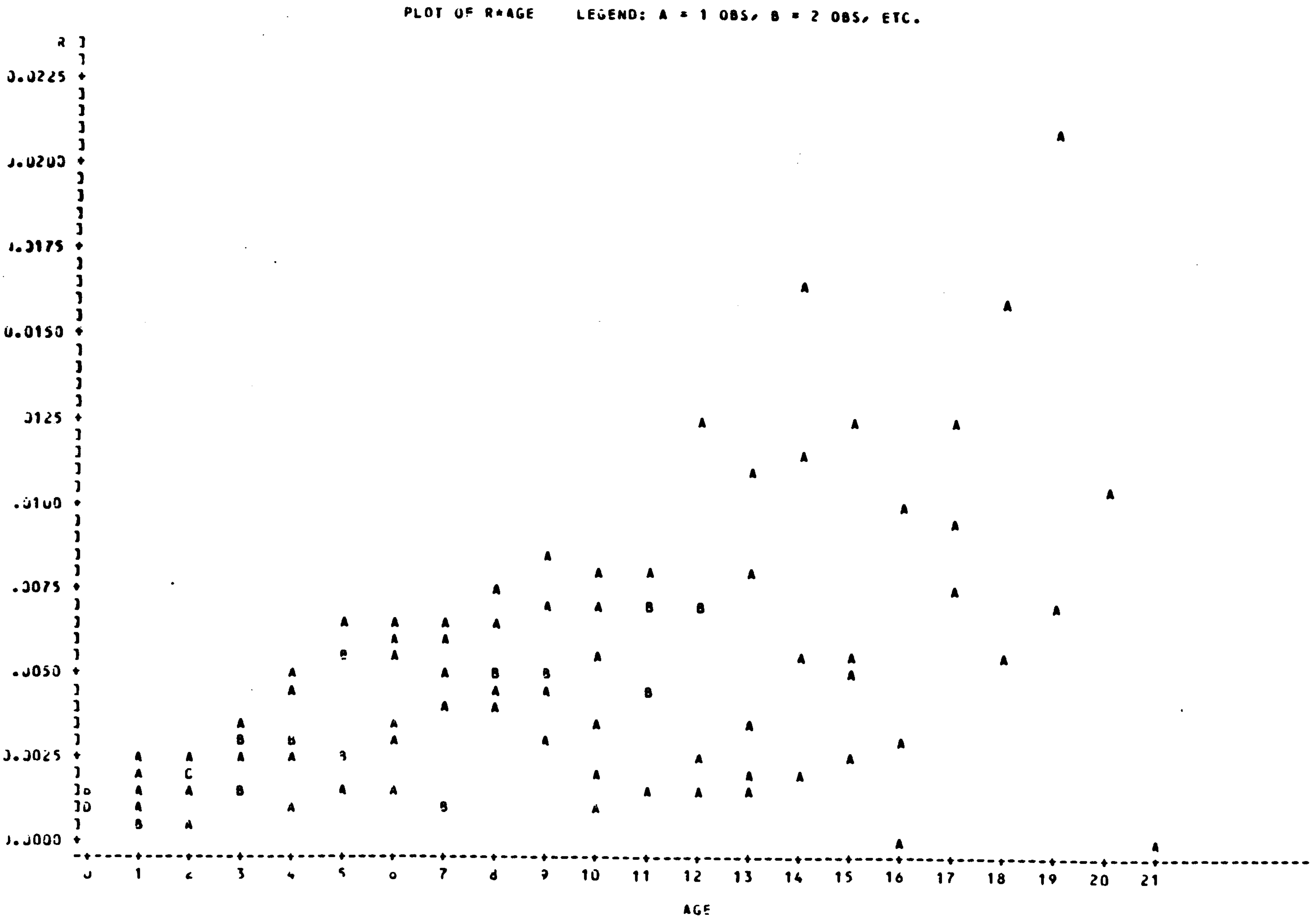

Figure 2-19
Maryland, Light Trucks

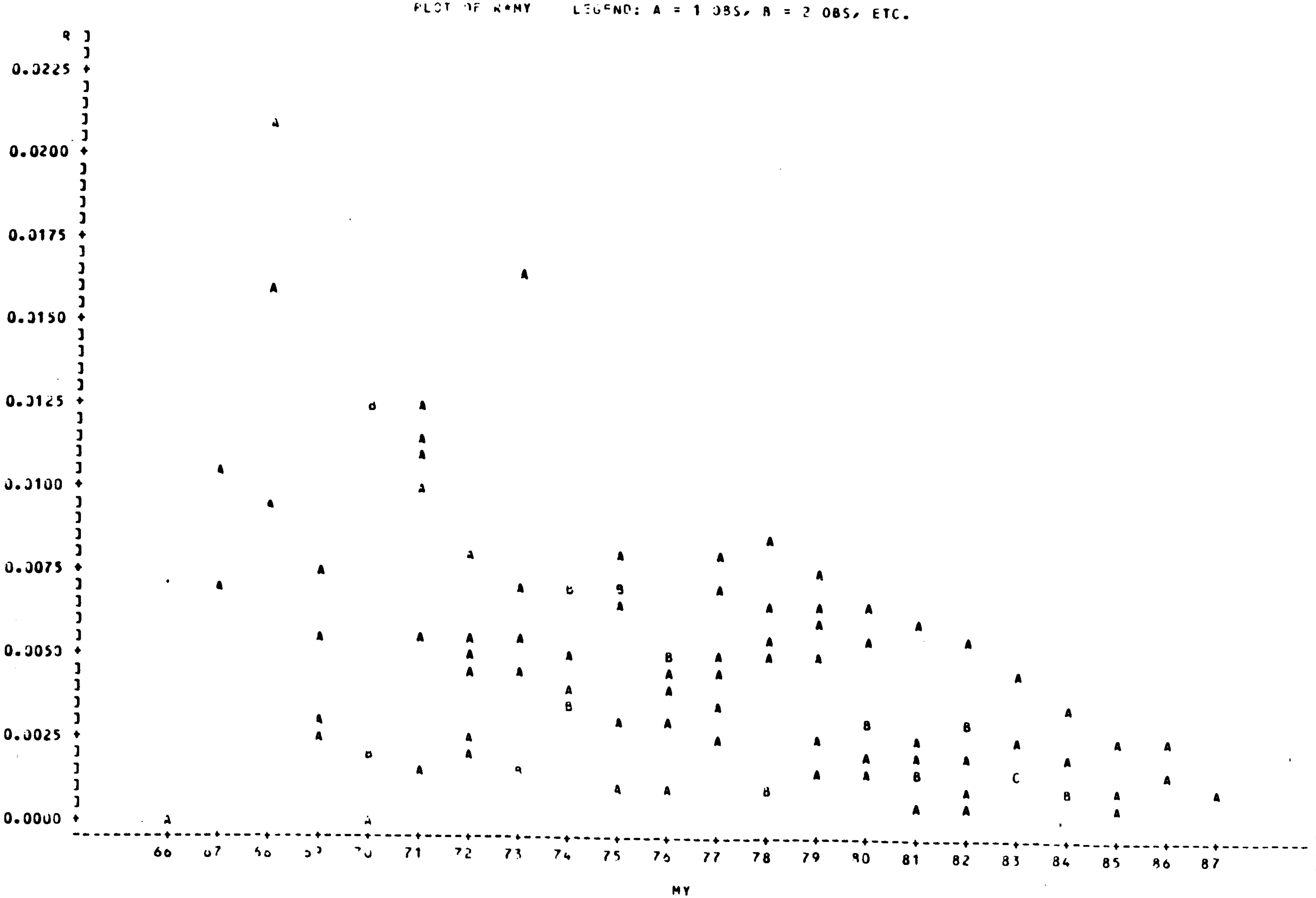

Figure 2-20
Maryland, Light Trucks

$$R = 0.001247 + 0.0004227 X_1 \text{ (age)}$$

Age is again significant (t=9.24),[22] and the amount of variation in fire rate that is explained by age is 46 percent ($R^2 = .46$), about the same as noted for Ohio, and slightly more than was found for Michigan.

Turning to the multiple linear model to evaluate the effect of FMVSS 301 in the Maryland data produced the following fit:

$$R = -0.001151 + 0.0005842 X_1 \text{ (age)} + 0.0020754 x_2 \text{ (Std)}$$

Age remains significant in the 2-variable model at a t-value of 8.52.[23] However, the effect of the Standard is not in the favorable direction in this model, but rather it has a positive sign, indicating that fire rates for Post-standard vehicles are higher, rather than below, the fire rates of Pre-standard vehicles. Furthermore, the estimated effect of the Standard here is significantly positive, having a t-value of 3.07.[24]

---

[22] Probability of greater t = 0.0001.

[23] Probability of greater t = 0.0001

[24] Probability of greater t=0.0028

These results seem unusual at first. However, a review of the Maryland fire rates in Table 2-6 and in Figure 2-20 shows that Model Year 1977, the first year following FMVSS 301 for trucks, had a considerably higher fire rate than 1976, the year immediately preceding the Standard. In interpreting these results, the most reasonable explanation is the variation inherent in the data for Maryland rather than an indication that the Standard acted to actually increase the fire rate. Both the fire frequencies and the number of accident involved trucks in Maryland are small, compared to the data from Ohio and Michigan (see Appendix C). A final observation is that the estimate of the intercept indicates a negative fire rate when the vehicle age is zero. The estimate is not significantly different from zero, however, with a t-value of -1.38, [25] and is again believed to be the result of the smaller numbers in the data from Maryland. The R^2 value for the model was .51.

The conclusion from analysis of the Maryland data is that there is no effect of FMVSS 301 in reducing vehicle fires in light truck accidents.

Overall Results from Michigan, Ohio, and Maryland

Since the overall magnitude of the fire rates from Michigan, Ohio, and Maryland, as well as the preceding individual analysis, were generally

---

[25] Probability of greater t = .1699.

similar, the data were combined and analyzed. The number of observations for the combined data set was 306. Plots of the combined data showing fire rate by age and model year are contained in Figures 2-21 and 2-22, respectively.

The single variable model of fire rate as a function of age produced the following fit:

$$R = 0.001686 + 0.0002339\ X_1\ \text{(age)}$$

The t-value for age was 12.12, again denoting age was a significant effect.[26] The R^2 value was .33.

The 2-variable model, incorporating the effect of the Standard gave the following result:

$$R = 0.0001597 + 0.0002397\ X_1\ \text{(age)} + 0.0000760\ X_2\ \text{(Std)}$$

The age effect remained significant at a t = value of 8.42.[27] The standard effect gave a positive value, indicating negative effectiveness. However, the standard coefficient of 0.0000760 was not significantly different from zero.[28] R^2 remained at .33, the same as for the simple model of age.

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[26] Probability of great t = 0.0001.

[27] Probability of greater t = 0.0001.

[28] Probability of great t = .7799

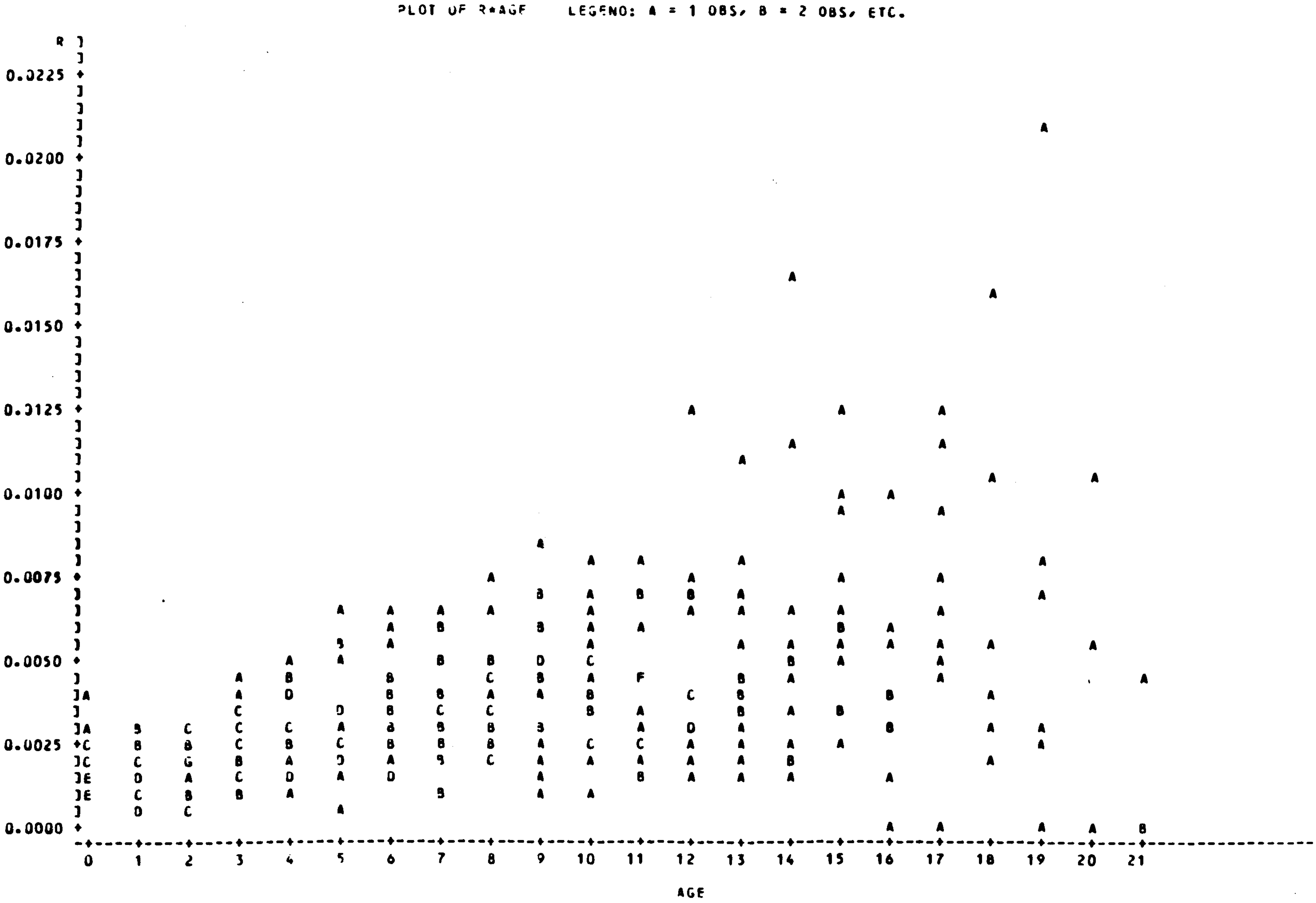

Figure 2-21
Michigan, Ohio, Maryland; Light Trucks

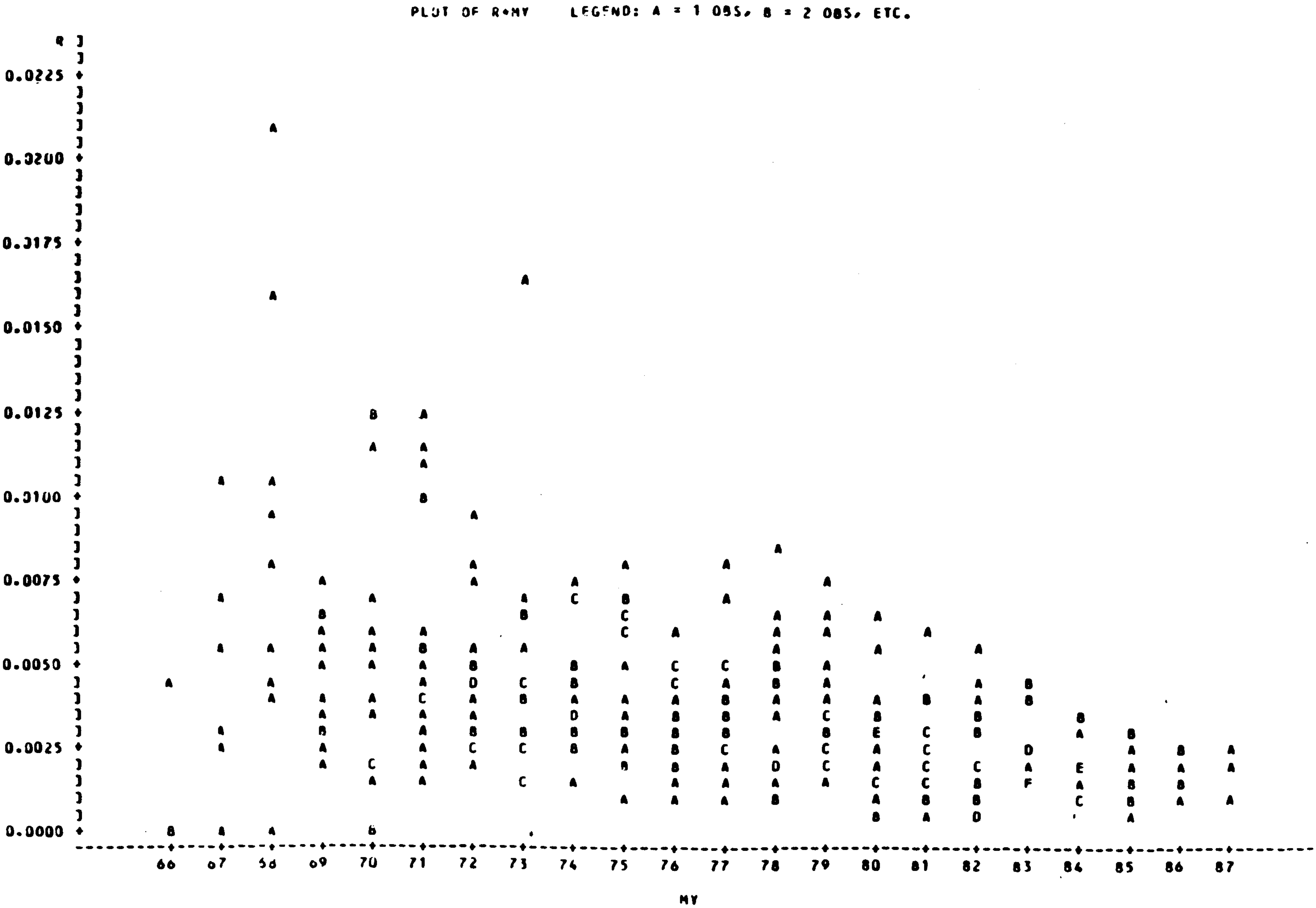

Figure 2-22
Michigan, Ohio, Maryland; Light Trucks

The average age of the trucks in the combined 3-State model is 10.431 years. Therefore, the effectiveness estimate from the overall data set is:

$$\text{Effectiveness} = \frac{0.0000760}{.0001597 + 10.431\ (.0002397)}$$

$$= \frac{0.0000760}{.00266}$$

$$= .02857 = 2.86 \text{ percent}$$

While the estimate of 1.86 percent is positive, this is not to be interpreted as an indication that Post-standard fire rates are higher than Pre-standard fire rates. This "negative" difference is considered to lie within the range of normal statistical, or "chance variation, and the proper inference to be drawn is that the difference between Pre and Post-standard fire rates is zero.

This concludes the analysis of data from Michigan, Ohio, and Maryland for light trucks. Fires in light truck crashes involving occupant injury were too sparse for reliable analysis.

2.3.1.2 Data From Illinois and Indiana

As was the case for passenger cars, the fire rates for light trucks from the States of Illinois and Indiana were considerably below the rates found in the three States of Michigan, Ohio, and Indiana. Therefore, data from Illinois and Indiana are analyzed separately.

Data from Illinois

Figures 2-23 and 2-24 show the fire rates for light trucks from Illinois, respectively, as functions of age, and model year. For this State, the age effect is not so apparent as has been the case with most all data, including that for passenger cars, analyzed to this point.

The simple model fitted with age was:

$$R = 0.0008965 + 0.0000480\ X_1\ \text{(age)}$$

The age coefficient was significant at a t-value of 3.83.[29] The fit was rather low, at an R^2 of .13, and this is considerably below the R^2 values obtained for all preceding analyses of State data.

Turning to the 2-variable model with age and the Standard effect, the result was:

$$R = 0.001296 + 0.0000219\ X_1\ \text{(age)} - 0.0003403\ X_2\ \text{(Std)}$$

In this case, the Standard effect is significant at a t-value of -2.03, while the age effect, with a t-value of 1.23, is non-significant.[30] R^2 was

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[29] Probability of greater t = 0.0002.

[30] Probability of greater t for Standard coefficient = 0.0452; probability of greater t for age coefficient = 0.2227.

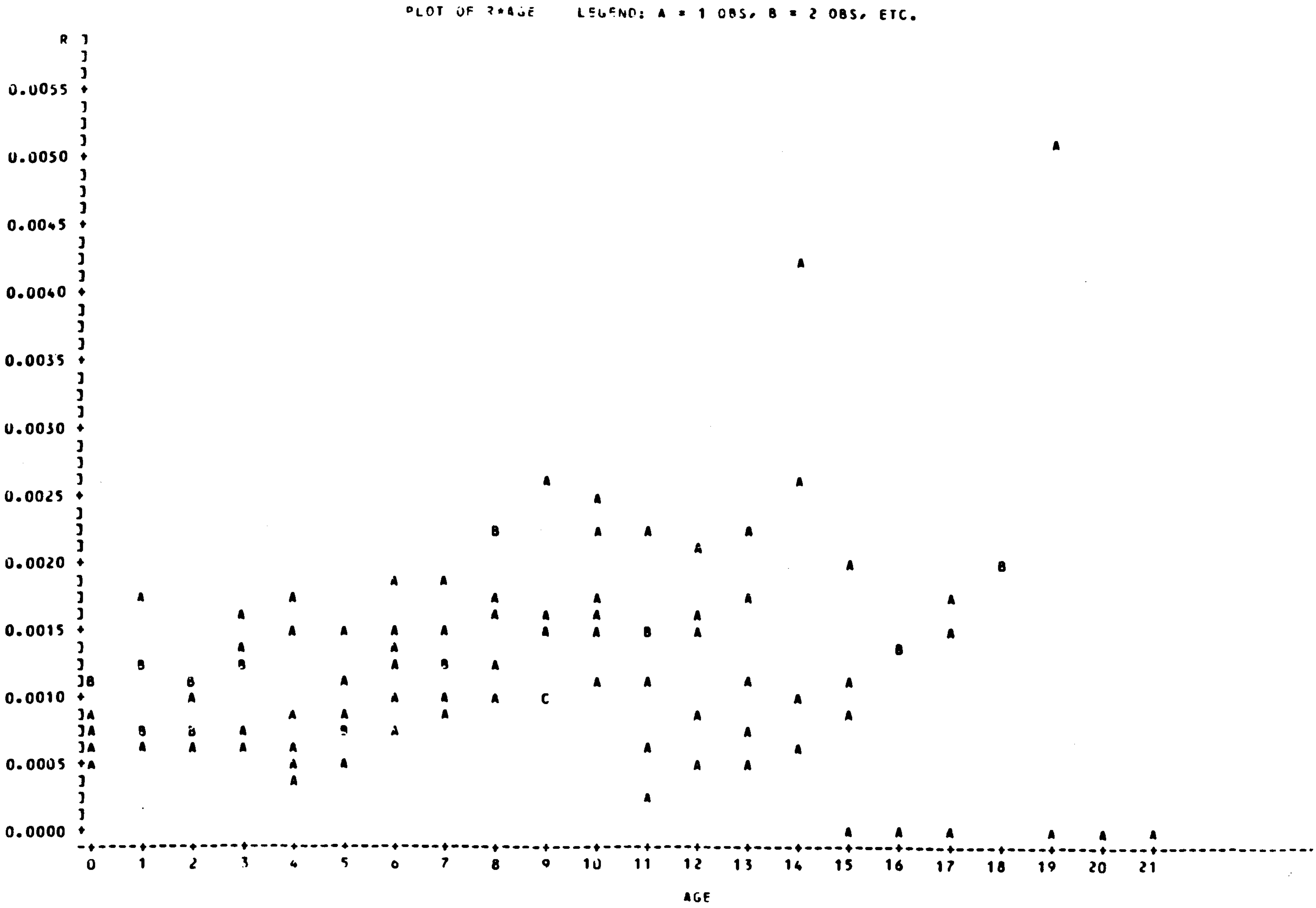

Figure 2-23
Illinois, Light Trucks

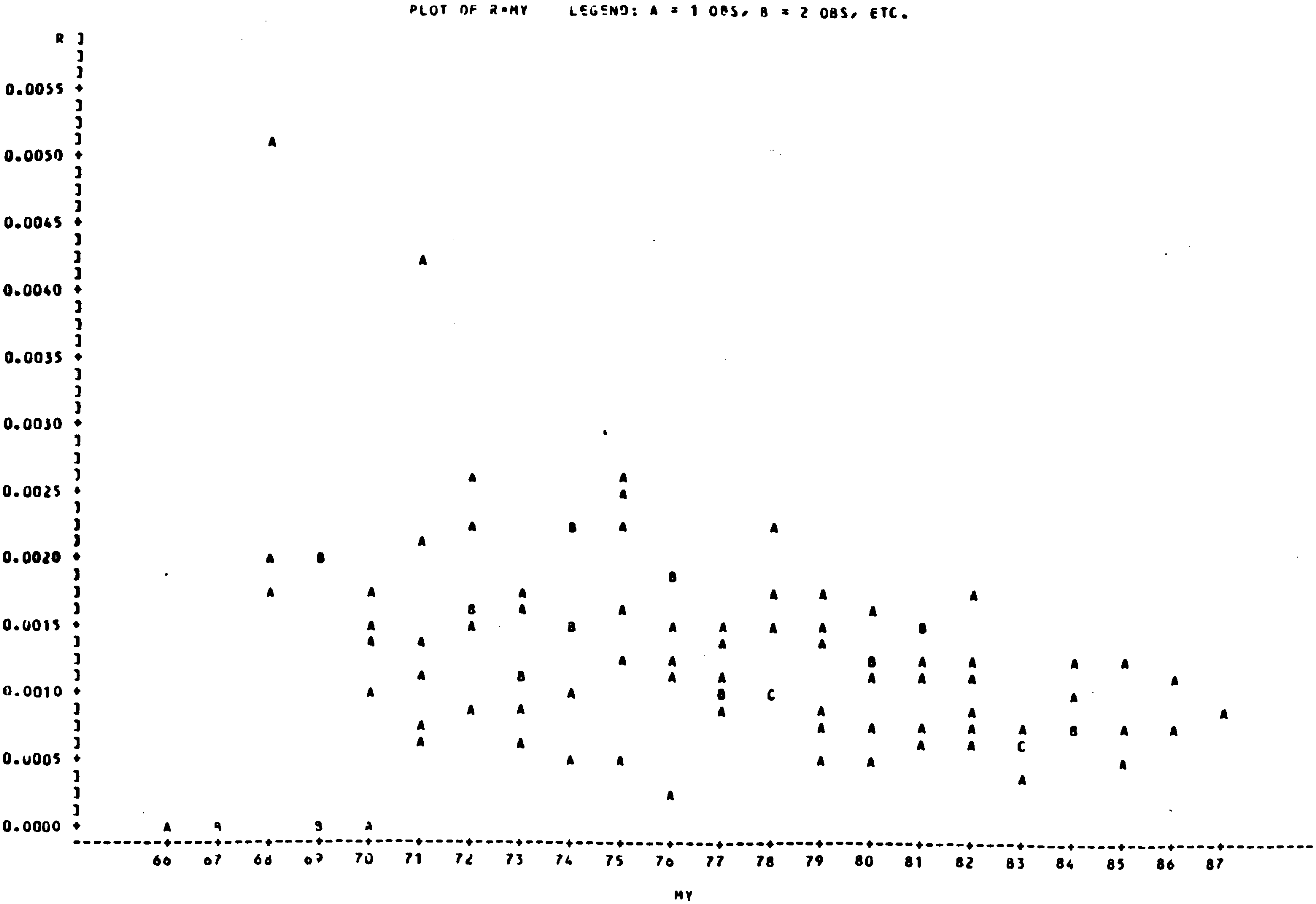

Figure 2-24
Illinois, Light Trucks

again quite low at .16, only a .03 increase from the simple age model.

Estimating effectiveness for the Standard from the Illinois data, given the average age of Pre-standard trucks to be 10.387 years, gives:

$$\text{Effectiveness} = \frac{-0.0003403}{0.001296 + 10.387\ (.0000219)}$$

$$= -\frac{.0003403}{.001523}$$

$$= -\ .2234 = -\ 22.34 \text{ percent}$$

The Post-standard trucks are estimated to have fire rates 22 percent below the fire rates for Pre-standard trucks. Adding 95 percent confidence limits gives:

22.34% ± 21.60% = 1.74% to 43.94%

The wide band on the effectiveness estimate (which nearly encompasses the zero, or non-signficant point), the relatively poor fit of the model, the lack of significance of the age effect, and the generally higher variability in the Illinois data make this State suspect in terms of providing a good basis for estimating the effect of FMVSS 301.

Data From Indiana

The fire rate by age and model year, from the Indiana data, are depicted in Figures 2-25 and 2-26 respectively. As with Illinois, the generally more sparse data from Indiana do not evidence as distinct an age relationship as found for the other States.

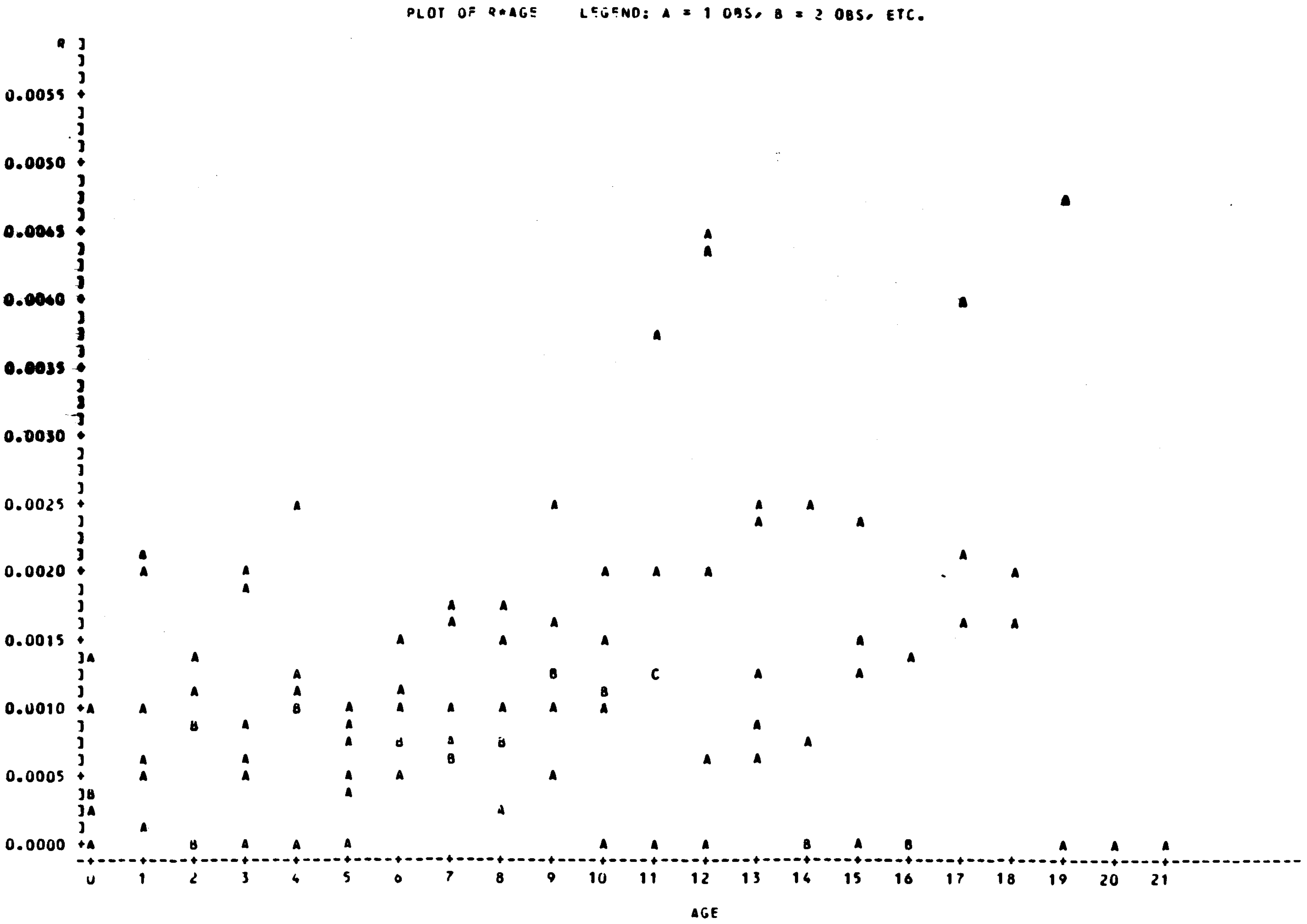

Figure 2-25
Indiana, Light Trucks

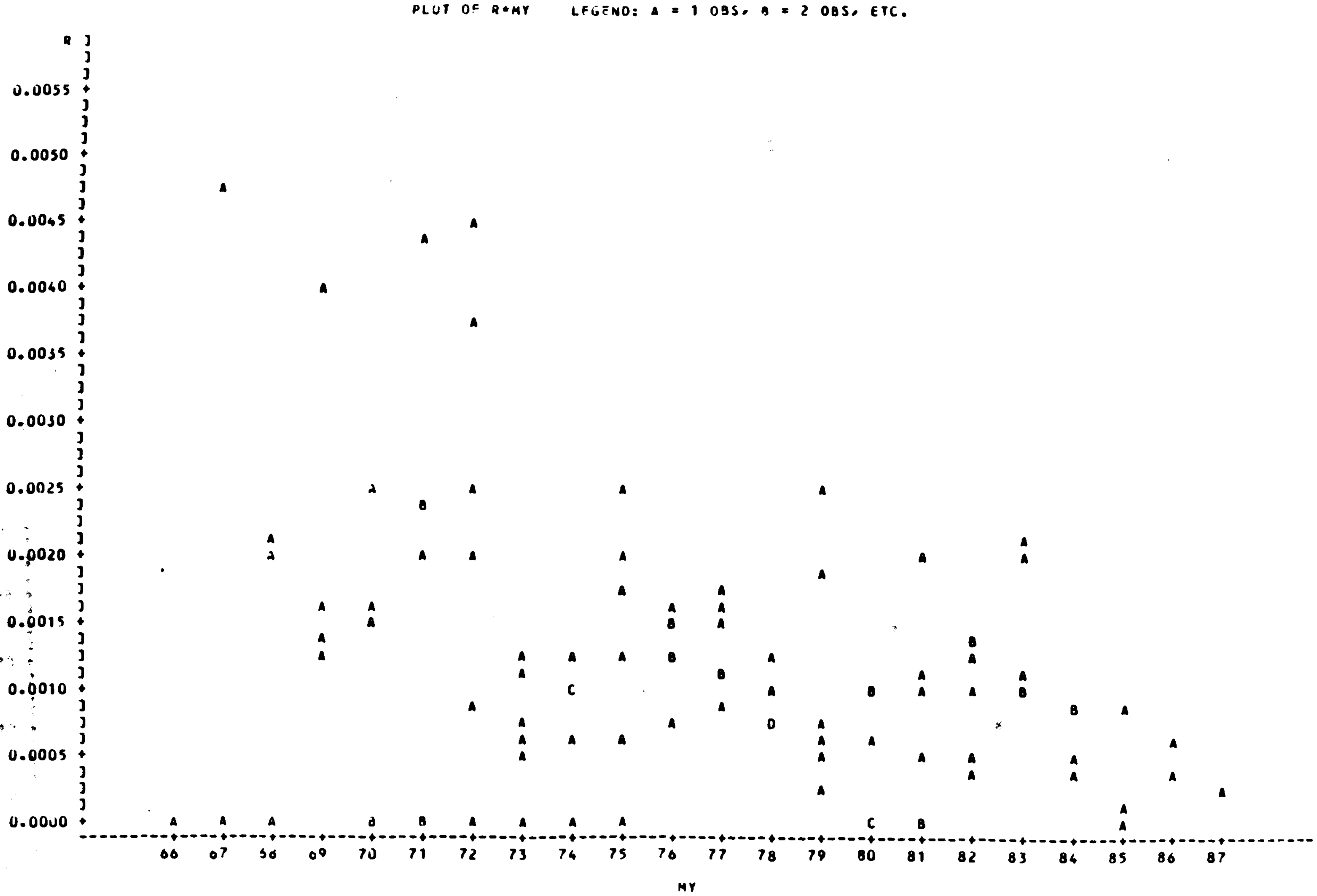

Figure 2-26
Indiana, Light Trucks

Fitting the simple linear model by age produced the following equation:

$$R = 0.0006756 + 0.0000543 X_1 \text{ (age)}$$

Here, age was significant at a t=3.22,[31] but the fit was even poorer than for Illinois with an R^2 of only .09.

Adding the second variable for the Standard effect gave:

$$R = 0.009118 + 0.0000388 X_1 \text{ (age)} - 0.0002002 X_2 \text{ (Std)}$$

In the model, neither the age, nor the Standard effect was significant, although the age effect came closer.[32] R^2 was .10, quite low and essentially the same as for the single model with age.

Discussion of Results from Illinois and Indiana

The analysis results from Illinois and Indiana were inconsistent. While age was significant in the simple models for both States, it was not significant for either State in the 2-variable model. The effect of the standard was

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[31] Probability of greater t=0.0017

[32] T-value for age coefficient = 1.52 (probability of greater t=0.1307); t-value for Standard coefficient =-0.81 (probability of greater t=0.4180).

significant in the Illinois data, but was far from being significant in the Indiana data. The fit of the models was not good in either States, with R^2 values ranging from only .09 to .16 - much lower than found in the prior analyses of the Michigan, Ohio, and Maryland data. Small cell frequencies of fires were also more numerous in the Illinois and Indiana data.

2.3.2 Analysis of Fatal Accident Data

This section discusses the analyses of fire data for light trucks involved in fatal crashes. The data files used are those from NHTSA's Fatal Accident Reporting System for calendar years 1975 through 1988, the same as used in the analysis of fatal accident fire rates for passenger cars.

Table 2-7 summarizes the fire rates by truck model year. The data are aggregated over the 14 available years of FARS data, i.e., from 1975 through 1988. The fatal accident fire rates for trucks are seen to be reasonably close to those for passenger cars shown previously. Again, the fire rates for fatal crashes are seen to be an order of magnitude higher than the fire rates in all police reported accidents (i.e., State data).

Regression analyses were performed on the rates as in the prior analyses for passenger cars. The data were balanced so that the number of Pre-standard model years was equal to the number of Post-standard model years within each of the 14 FARS calendar years. Also the data were weighted as in prior runs. The number of observations for each of the two models fitted was 156, each observation being the fire rate for an individual model year - calendar year

Table 2-7

Fire Rates* in Fatal Light Truck Accidents by Vehicle Model Year

Model Year	No. Light Truck Fires	No. Light Trucks in Fatal Accidents	Fire Rate*
1989	2	57	3.509
1988	32	1,361	2.351
1987	79	2,937	2.690
1986	127	4,786	2.654
1985	146	5,505	2.652
1984	139	6,179	2.250
1983	117	4,873	2.401
1982	124	5,163	2.402
1981	146	5,586	2.614
1980	141	6,380	2.210
1979	332	12,386	2.680
1978	330	12,840	2.570
1977	350	12,593	2.779
1976	322	11,584	2.780
1975	256	8,920	2.870
1974	307	11,172	2.748
1973	273	10,171	2.684
1972	284	8,017	3.542
1971	176	5,604	3.141
1970	174	5,049	3.446
1969	194	5,227	3.711
1968	104	3,303	3.149
1967	72	3,196	2.253
1966	66	2,670	2.472
1965	76	2,251	3.376
1964	48	1,672	2.871
1963	26	1,255	2.072
1962	15	877	1.710
≤1961	151	4,153	3.636
UNK	26	960	2.708

---

* Fire rates are reported fires per 100 light trucks in fatal crashes.

Source: Fatal Accident Reporting System, NHTSA; calendar years 1975 through 1988.

combination. Figures 2-27 and 2-28 show the data plots of fire rate by age and model year.

The first model fit, that of fire rate as a function of vehicle age, produced the following results:

$$R = 0.02376 + 0.0007069\ X_1\ (\text{age})$$

The age effect was significant, the t-value being 5.26.[33] Age, however, did not explain much of the variation in fire rate with the R^2 being only .15. In this model the fire rate is seen to increase about 3 percent (.0007069/.02376 = .0298) per year of vehicle age.

The second model, with age plus the Standard effect resulted in the following equation:

$$R = 0.02559 + 0.0005885\ X_1\ (\text{age}) - 0.001806\ X_2\ (\text{Std})$$

In this 2-variable model, age remained significant (t=3.45), while the Standard effect was not significant (t=-1.12).[34] Adding the Standard effect had negligible effect on explaining more of the variation in fire rate, as the R^2 increased by only .01, from .15 to .16.

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[33] Probability of greater t=0.0001.

[34] Probability of greater t for age coefficient =.0007; probability of greater t for Standard coefficient =.2632.

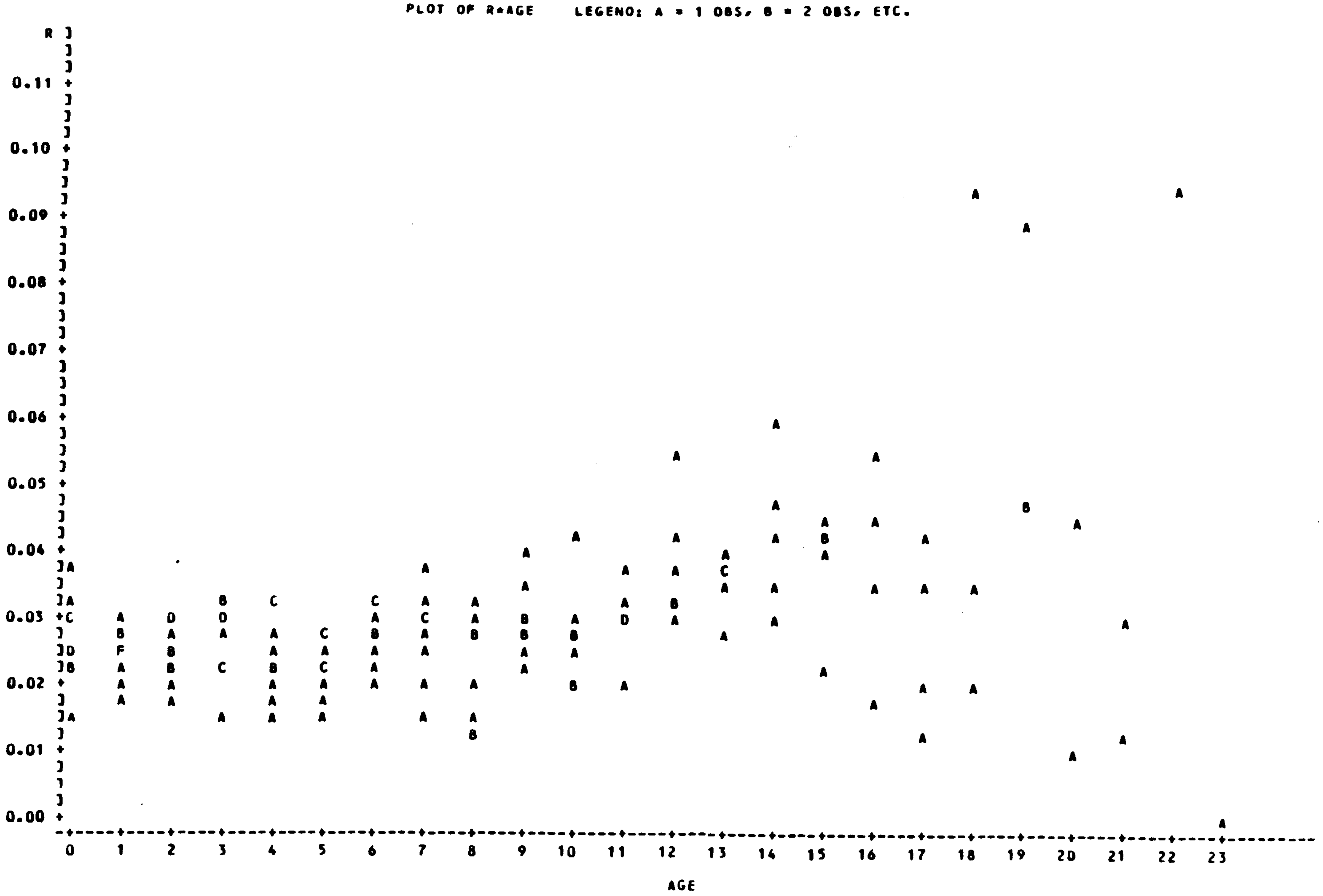

Figure 2-27
FARS. Light Trucks

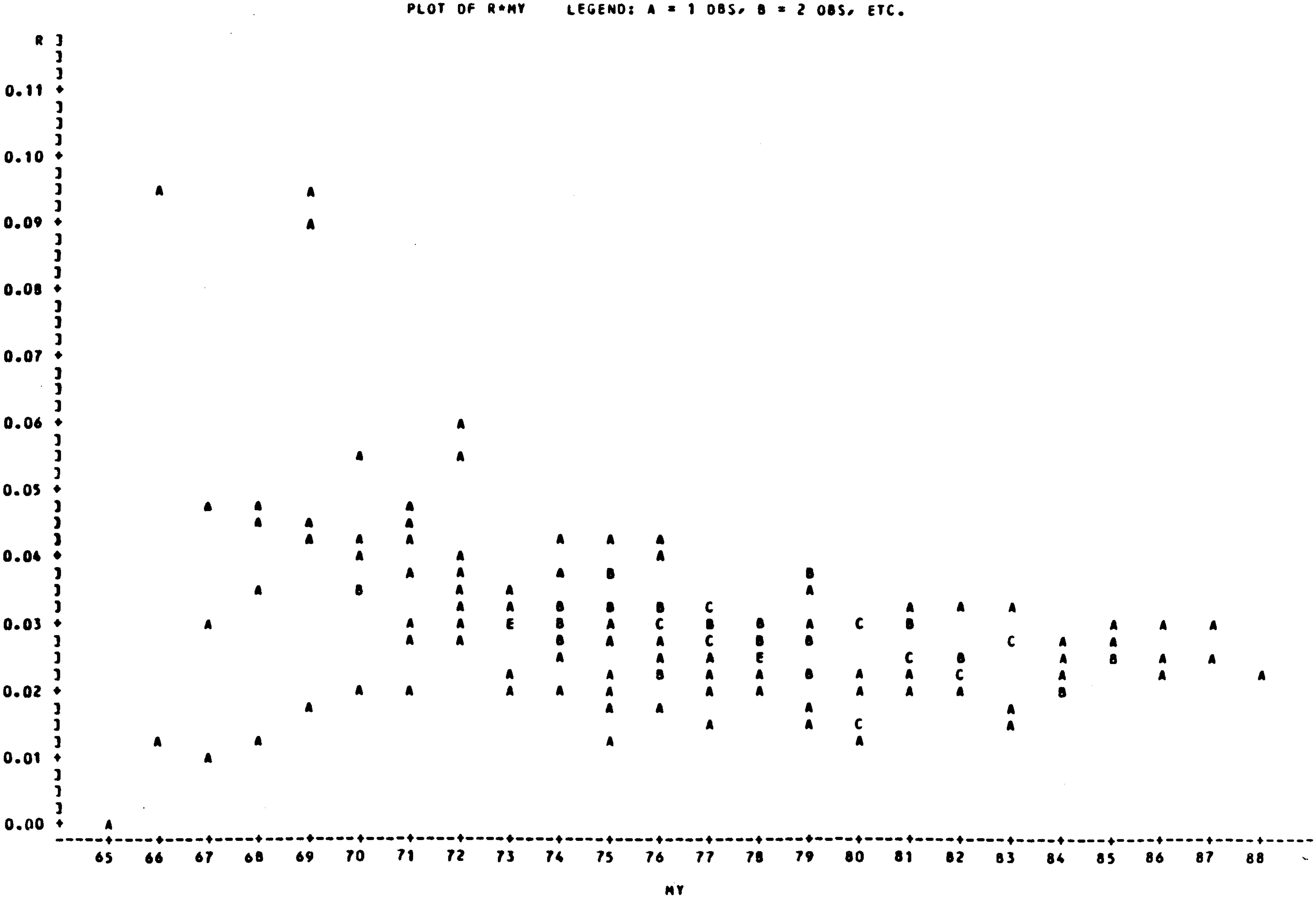

Figure 2-28
FARS, Light Trucks

The fire rate is estimated to increase about 2.3 percent (.0005885/.02559 = .023) per year of vehicle age. Although not significantly different from zero, the effect of the Standard, given the average of Pre-standard trucks to be 9.20 years, is estimated at:

$$\frac{-0.001806}{0.02559 + 9.20\ (0.0005885)}$$

$$= \frac{-.001806}{.03100}$$

$$= -.05826 = -\ 5.83 \text{ percent}$$

Alternate Analysis of Fatal Accident Data for Trucks

As was done for the analysis of fatal crash fire rates for cars, an alternate approach is taken to the analysis of fatal crash fire rates for light trucks. Six comparisons of Pre-standard and Post-standard fire rates are made, each comparison based on an increasing period (i.e., number of years) of time before, and after FMVSS 301 took effect. Pre-standard vehicles are model years 1976 and earlier, and Post-standard vehicles are 1977 and later. The six comparisons are ±1 model year, ±2 model years, ..., ±6 model years. The comparisons are balanced with the Pre-standard and Post-standard samples containing an equal number of model years within each calendar year. Finally, the comparisons are cummulative -- i.e., ±2 MY comparison includes ±1 MY comparison, ±3 MY comparison includes +1 MY, ±2 MY, etc.

The data are shown in Table 2-8. In the first comparison, the Post-standard fire rate is slightly greater than the Pre-standard fire rate, the difference being -0.030 fires per 100 fatal truck crashes, or -1.1 percent. In the remaining five comparisons, the Post-standard rate is less than the Pre-standard rate, the difference generally increasing from 2.8 percent for the ± 2 MY comparison to 11.1 percent for the ± 6 MY comparison. If age were a significant factor, the progression would be expected to follow such a trend.

Since age is included in the comparisons in Table 2-8, a second Table 2-9, has been constructed, which lists adjustment factors for age. The adjustment factors are based on the difference in vehicle age, between Pre-standard and Post-standard samples within each comparison group of Table 2-8, and the average age effect on fire rate. The age effect is taken as the average effect obtained in the two prior regression analyses described above, or 2.7 percent.

Comparing the last column of Table 2-9 with the last column of 2-8, it is seen that the age effect essentially cancels out the difference in Pre- and Post-standard fire rates. This is taken as further evidence that the Standard has had no effect on fires in fatal crashes involving light trucks, and is a finding similar to that for passenger cars discussed in Section 2.2.2.

2.4 EFFECTIVENESS ANALYSIS FOR SCHOOL BUSES

The analysis of fire data on school bus crashes is presented in this section. First, State data on all accident severities are analyzed. This is followed by an analysis of FARS data on fires in fatal school bus crashes. The reporting of fire for school bus crashes in the State and FARS data bases follows the same convention as discussed earlier in the analyses of fire rates for passenger cars and light trucks.

Table 2-8
Selected Comparisons of Pre-Standard Versus Post-Standard Fire Rates in Fatal Light Truck Crashes

Comparison (No. of Pre- Post Model Years)	Fire Rate (x 10^{-2})		Difference (Pre-Post)	Percent Difference
	Pre-Standard	Post-Standard		
± 1 MY	$\frac{292}{10{,}579} = 2.760$	$\frac{350}{12{,}545} = 2.790$	-0.030	-1.1%
± 2 MY	$\frac{463}{16{,}771} = 2.761$	$\frac{680}{25{,}341} = 2.683$	0.078	2.8%
± 3 MY	$\frac{650}{23{,}103} = 2.813$	$\frac{1010}{37{,}661} = 2.682$	0.131	4.7%
± 4 MY	$\frac{793}{29{,}145} = 2.721$	$\frac{1151}{44{,}006} = 2.616$	0.105	3.9%
± 5 MY	$\frac{920}{32{,}438} = 2.836$	$\frac{1297}{49{,}578} = 2.616$	0.220	7.8%
± 6 MY	$\frac{1002}{34{,}320} = 2.920$	$\frac{1421}{54{,}718} = 2.597$	0.323	11.1%

Source: FARS files, NHTSA
Fire rates are based on aggregated frequencies for years 1975 through 1988.

Table 2-9

Age Adjustment Factors for Selected Comparisons of Fire Rates in Pre and Post-Standard Light Truck Fatal Crashes

	Average Age (Years)		Difference	Age Adjustment
Comparison	Pre-Standard	Post-Standard	(Pre-Post)	(Difference x 2.7%)
± 1 MY	5.34	4.60	0.74	2.0%
± 2 MY	5.96	4.47	1.49	4.0%
± 3 MY	6.49	4.28	2.21	6.0%
± 4 MY	6.85	4.16	2.69	7.3%
± 5 MY	7.18	4.06	3.12	8.4%
± 6 MY	7.43	3.95	3.48	9.4%

2.4.1 Analysis of State Accident Data

The fire rates for school buses are shown in Tables 2-10a and 2-10b. Table 2-10a lists the rates for the 3 States of Michigan, Ohio, and Maryland while Table 2-10b contains the rates for Illinois and Indiana.

Overall, it is seen that fire rates are higher in the States of Michigan, Ohio, and Maryland, than they are for Illinois and Indiana. This is consistent with the fire rates for passenger cars and light trucks analyzed in the previous sections.

Since the absolute frequencies of school bus fires and total crashes are very small, in comparison to the corresponding frequencies noted for cars and light trucks, the rates have been summarized in Table 2-11, by State and by Pre-standard (Model year 1976 and earlier) versus Post-standard vehicles (Model Year 1977 and later). Instances where the bus model year was unknown have been excluded from these data. A glance at the table reveals that 2 of the States (Michigan and Ohio) show lower fire rates for Post-standard buses, while for the other three States, fire rates are higher for Post-standard buses.

The data are much too sparse for performing regression analyses as was done for passenger cars and light trucks. Instead a simple test of hypothesis is made to determine whether the overall fire rate for all States is lower for Post-standard school buses than the rate for Pre-standard school buses. Although differences among States are indicated, this approach is considered reasonable in view of the extremely small frequencies involved. Letting p_1

Table 2-10a
Fire Rates* in School Bus Crashes by State and Vehicle Model Year

Model Year	STATES		
	Michigan	Ohio	Maryland
1987	0/47	1/105 (9.524)	1/88 (11.364)
1986	0/270	1/278 (3.597)	0/144
1985	0/509	2/524 (3.817)	0/277
1984	1/593 (1.686)	0/617	0/237
1983	0/386	0/522	0/308
1982	0/492	2/649 (3.082)	0/271
1981	1/626 (1.597)	1/651 (1.536)	1/243 (4.115)
1980	1/938 (1.066)	8/1328 (6/024)	0/487
1979	2/1124 (1.799)	3/875 (3.429)	0/530
1978	2/830 (2.410)	1/716 (1.397)	2/535 (3.738)
1977	1/661 (1.513)	7/662 (10.574)	1/600 (3.333)
1976	1/563 (1.776)	5/637 (7.849)	1/411 (2.433)
1975	2/587 (3.407)	2/616 (3.247)	1/581 (1.721)
1974	0/303	0/445	0/222
1973	1/151 (6.623)	1/361 (2.770)	0/269
1972	0/111	0/330	0/232
1971	1/63 (15.873)	1/201 (4.975)	0/99
1970	0/44	3/147 (20.408)	0/60
1969	1/23 (43.478)	0/101	0/38
1968	0/26	0/108	0/34
1967	0/21	0/78	0/12
1966	0/16	0/47	0/5
1965	0/10	0/11	0/4
1964	0/2	0/3	0/6
1963	0/6	0/6	0/3
1962	--	0/1	0/1
≤ 1961	0/6	0/20	0/5
UNK	1/703 (1.422)	1/1099 (0.910)	0/48

---

* Fire rate is number of police reported fires per 1,000 school buses involved in crashes. Only non-zero rates are given (in parentheses).

Data are aggregated for calendar years 1982 through 1987.

Table 2-10b
Fire Rates* in School Bus Crashes by State and Vehicle Model Year

Model Year	STATE	
	Illinois	Indiana
1987	0/182	0/198
1986	1/533 (1.876)	0/221
1985	2/868 (2.304)	0/318
1984	0/1070	0/341
1983	2/1104 (1.812)	1/460 (2.174)
1982	1/899 (1.112)	0/253
1981	2/1085 (1.843)	0/535
1980	2/1411 (1.417	3/561 (5.348)
1979	0/1501	0/493
1978	1/1280 (0.781)	0/298
1977	1/904 (1.106)	0/322
1976	0/663	0/248
1975	1/833 (1.200)	0/370
1974	0/529	0/452
1973	0/307	0/170
1972	1/203	0/108
1971	0/134	0/182
1970	0/122	0/47
1969	0/50	0/40
1968	0/41	0/15
1967	0/12	0/31
1966	0/23	0/3
1965	0/13	0/2
1964	0/2	0/1
1963	0/1	0/4
1962	0/1	0/1
≤ 1961	0/21	0/6
UNK	2/2092 (0.956)	0/104

* Fire rate is number of police reported fires per 1,000 school buses involved in crashes. To obtain actual fire rate table values should be multiplied by 10^{-3}. Only non-zero rates are given (in parentheses).

Data are aggregated for calendar years 1982 through 1987.

Table 2-11
Fire Rates* in School Bus Crashes by State and Pre-Standard versus Post-Standard Vehicles

	Fire Rates		
State	**Pre-Standard**	**Post-Standard**	**Overall**
Michigan	$\frac{6}{1879}$ (3.1932)	$\frac{8}{6479}$ (1.2348)	$\frac{14}{8358}$ (1.6750)
Ohio	$\frac{12}{3113}$ (3.8548)	$\frac{26}{6931}$ (3.7513)	$\frac{38}{10044}$ (3.7834)
Maryland	$\frac{2}{2072}$ (0.9653)	$\frac{6}{3635}$ (1.6506)	$\frac{8}{5707}$ (1.4018)
Illinois	$\frac{2}{2907}$ (0.6880)	$\frac{12}{10883}$ (1.1026)	$\frac{14}{13790}$ (1.0152)
Indiana	$\frac{0}{1680}$ (0.000)	$\frac{4}{4040}$ (0.9901)	$\frac{4}{5720}$ (0.6993)
Overall	$\frac{22}{11,651}$ (1.8882)	$\frac{56}{31,968}$ (1.7518)	$\frac{78}{43,619}$ (1.7882)

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* Fire rates are x 10^3, or fires per 1,000 bus crashes.

and p_2 represent the fire rates for Pre-standard and Post-standard buses, respectively, the test statistic, Z, is:

$$Z = \frac{p_1 - p_2}{\hat{\sigma}_{p_1 - p_2}}$$

where,

$$\hat{\sigma}_{p_1 - p_2} = \left[\hat{p} \ (1-\hat{p}) \ (\frac{1}{n_1} + \frac{1}{n_2}) \right]^{\frac{1}{2}}$$

and,

$$\hat{p} = \frac{n_1 \ p_2 + n_2 \ p_2}{n_1 + n_2}$$

Substituting the respective values from Table 2-11 gives:

$$\hat{p} = \frac{11651 \ (.001888) + 31968 \ (.001752)}{11651 + 31968}$$

$$= .001788$$

$$\hat{\sigma}_{p_1 - p_2} = \left[.001788(.9982) \ \frac{1}{11651} + \frac{1}{31968} \right]^{\frac{1}{2}}$$

$$= .0004572$$

$$Z = \frac{.001888 \ - \ .001752}{.004572}$$

$$= \frac{.000136}{.0004572} = 0.2975$$

The Z-value is non-significant, being less than the critical value of $Z = 1.645$.[35] Thus, while the fire rate for Post-standard buses is lower than the Pre-standard rate by .000136 or 7.2 percent (.000136/.001888), this difference is not significantly different from zero.

If the comparison of Pre and Post-standard buses is performed using balanced (i.e., equal number of) samples of model years for each period, as was done earlier for cars and trucks, the overall rates become:

$$\text{Pre-standard:} \quad \frac{20}{10855} = .0018425$$

$$\text{Post-standard:} \quad \frac{56}{31914} = .0017547$$

The corresponding test statistic is:

$$Z = .1880$$

which, again is not significant. The difference in rates in this case is .0000878 or 4.7 percent, with the Post-standard group having the lower rate.

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[35] Test performed at $\alpha = .05$, or 95 percent confidence level.

The above comparisons do not consider any effect that vehicle age might have on the fire rates. Data are simply too sparse to attempt to evaluate this factor. However, drawing upon the findings of the prior analyses for passenger cars and light trucks, it is reasonable to postulate that age would have an impact. The impact would be to decrease the magnitude of the difference in Pre and Post-standard fire rates obtained by a strict overall comparison such as done above.

Based on the above analyses, indications are that no difference exists in the fire rate, for all accidents, between Pre-standard and Post-standard school buses. However, due to the small frequencies of fires and total school bus crashes, no reliable inferences may be drawn.

2.4.2 Analysis of Fatal Accident Data

Table 2-12 summarizes the fire data for school buses in fatal crashes, as recorded in the FARS files for the years 1975 through 1988. For each FARS year, the table lists:

- the total number of school buses in fatal crashes (col. 2)
- a breakout of the total number of involved buses by Pre-standard, Post-standard, and unknown model year (cols. 3, 4, and 5, respectively)
- the number and model year of the buses in which fire occurred (col.6).

It can be seen that the absolute frequencies of fires and fatal crashes are quite small for school buses. The overall fire rate for school buses in fatal crashes, including buses of unknown model years is:

overall fire rate= 17/1685 = .01009

This is about 1 fire per 100 fatal school bus crashes.

For Pre-standard and Post-standard buses, the rates are:

Pre-standard: fire rate = 7/948 = .007384

Post-standard: fire rate = 10/712 = .01404

The fire rate for Post-standard buses is higher (by a factor of nearly 2) than the fire rate for Pre-standard buses. However, as was the case for fire rates in the State data, these rates are not based on a balanced sample, in that the number of model years spanned by the Pre-standard group is equal to the number of model years spanned by the Post-standard group. Balancing the samples results in the following rates for Pre and Post buses:

Pre-standard: fire rate = 4/357 = 0.1120

Post-standard: fire rate = 10/681 = 0.1468

The fire rate for the Post-standard buses is still higher, although by much less than in the unbalanced comparison. There is no need to test for significance here, since for either comparison, the Z - statistic will be negative and hence non-significantly different from zero. As with the prior comparisons of fire rates from State data, these comparisons do not account for any effect due to vehicle age.

Because of the small frequencies of fires and fatal school bus crashes, these results are not considered conclusive. Nevertheless, evidence has not been produced that FMVSS 301 has had a positive effect in reducing fires in fatal school bus crashes.

2.5 DISCUSSION OF EFFECTIVENESS ANALYSIS PERFORMED

To close this chapter, a few comments are made to summarize the results of the several analyses performed to estimate the effect that FMVSS 301 has had on reducing fires in motor vehicle crashes.

Passenger Cars

For passenger cars, the analyses indicate that FMVSS 301 has reduced the overall rate of fire in accidents by about 14 percent. This estimate is based on analyses of the data from Michigan, Ohio, and Maryland. Both the methods

Table 2-12
School Buses Involved in Fatal Crashes by Calendar Year, Pre-Standard versus Post-Standard and Fire Occurrence

Calendar Year	No. of Vehicles (School Buses) Involved				No. of Vehicles with Fire/(MY)
	Total Vehicles	Pre-Standard Vehicles	Post-Standard Vehicles	UNK MY	
1988	105	11	91	3	1 (1977)
1987	132	21	111	0	4 (1979,81 83,86)
1986	101	27	73	1	2 (1985, 1986)
1985	126	35	90	1	1 (1976)
1984	119	43	75	1	1 (1977)
1983	99	41	57	1	1 (1970)
1982	104	41	62	1	1 (1979)
1981	110	57	53	0	0
1980	117	77	39	1	2 (1973, 1978)
1979	150	115	33	2	2 (1973, 1976)
1978	143	115	20	8	0
1977	126	117	8	1	1 (1965)
1976	123	120	0	3	0
1975	130	128	0	2	1 (1975)
TOTALS	1685	948	712	25	17 (7 PRE, 10 POST)

Source: Fatal Accident Reporting System, NHTSA.
Calendar Years 1975 through 1988.

of reporting vehicle fires and the magnitude of fire frequencies observed in these States make them the preferred choice on which to base the effectiveness estimates. The Illinois and Indiana data produced somewhat higher effectiveness estimates, but the small frequencies of reported fires in these States introduces more variation in the analyses and make the results less reliable. Also in Illinois, the very high rate of unknown codes for the fire variable together with the more indirect method of reporting fires are two additional reasons why the analyses results from this State are considered less reliable. While the Indiana data did not suffer from these same two problems, the overall fire rates were very similar to those for Illinois. The incidence of reported fires in Michigan, Ohio, and Maryland were considerably higher than for Illinois and Indiana, and this fact makes the data from these more suitable for analyses. It is difficult to conceive of police officers over-reporting vehicle fires - i.e., reporting fire when it did not occur. Therefore, the Michigan, Ohio, and Maryland data are believed to more nearly reflect the actual rate of fire occurrence, and that the consistently lower rates for the other two States are likely a result of under-reporting of fires (rather than an indication that fire rates are markedly lower in these two States).

For injury crashes, mixed results were obtained from the analyses. Analysis of Ohio data showed a statistically significant reduction of approximately 14 percent for post-standard vehicles whereas the Michigan data showed no significant difference between the fire rates for pre-standard and post-standard vehicles. Maryland data on fires in injury crashes were too sparse to support reliable statistical analyses. Although not statistically significant, post-standard cars from Michigan did show a 10 percent lower fire rate in injury crashes, compared to the 14 percent lower rate in Ohio. It is therefore possible to postulate that an actual, modest, reducation in fires in injury crashes may have resulted from FMVSS 301. For example, if a larger sample size had been available from the State of Michigan, the 10 percent difference might have been statistically significant. However, the 10 percent difference in fire rate between pre-standard and post-standard vehicles was not close to being significant (α =.20), and regardless of the magnitude or direction of the difference, the statistical conclusion to be drawn is that the difference is not significantly different from zero. Also, even if a larger sample size were available, statistical significance might, or might not be obtained. While the larger sample would be more likely to produce significance for a given percent difference, it must be remembered that the difference, itself, is subject to (sampling) variation and a new sample could produce an estimated difference lower than the 10 percent obtained in the current sample. Ninety-five percent confidence limits on this 10 percent show that the actual, or true, difference could lie anywhere between -5.2 percent and + 25.6 percent. Therefore, while the results of the analyses of the Ohio and Michigan data do provide some evidence that fire rates in injury crashes may be lower for post-standard vehicles, the information is inadequate to support definitive conclusions.

The analyses of fatal crashes did not show that fire rates for Post-standard cars differed significantly from the fire rates for Pre-standard cars.

Light Trucks

For light trucks, the analyses did not indicate that Post-standard vehicles experienced lower fire rates than Pre-standard vehicles - in either the all accident category or the fatal accident category. The finding of no effect on all accidents was supported by the analyses results of data from Michigan, Ohio, Maryland, and also by analyses of the Indiana data, although the latter is considered less reliable due to the shortcomings discussed above. The single State of Illinois did show a significantly lower fire rate for Post-standard vehicles, but this is considered a spurious finding likely due to the small frequencies of fires and greater variation in these data. Four out of five States and all three "preferred" States showed no significant difference between Pre- and Post-standard light trucks. Fires in light truck injury crashes in State data were too sparse for analysis. Additionally, since no effect was found in either the all accidents or the fatal accidents analyses, no effect would reasonably be expected for injury crashes, which have a severity level in between that for all accidents (least severe) and that for fatal accidents (most severe).

School Buses

For school buses, the data were simply too sparse - even at the State level - to permit reliable conclusions of the effect of FMVSS 301 in reducing vehicle fires. Only simple overall comparisons could be made. While not conclusive, these analyses did not support a significantly lower fire rate for school buses produced subsequent to the Standard's promulgation.

Consistency of Findings

Overall, the analyses and findings were generally consistent, with a few instances of disparateness. For passenger cars and light trucks in all reported crashes, the effectiveness findings were generally consistent for the five State data sources, and particularly so for the three States of Michigan, Ohio, and Maryland. For passenger cars in injury crashes, the two States with sufficient data for anlysis both produced estimates of a reduction in fires for post-standard vehicles. However, one reduction was statistically significant (State of Ohio), while the other was non-significant (State of Michigan).

Findings for fatal accidents were similar for cars and for light trucks, with no reduction in fires noted for Post-standard vehicles. It may be that the crash force levels typically experienced in fatal crashes simply exceed those levels which are covered by the FMVSS 301 requirements (i.e., 20 mph to 30 mph force levels).[36]

As to why effectiveness was found for all accidents for passenger cars, but not for light trucks; it may be that the design and placement of fuel system components (viz., the fuel tank) on light trucks is such that they are

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[36] More insight into this possibility is provided in Chapter 3 which shows that fatal fire crashes typically involved more severe conditions than fatal crashes not accompanied by fire.

inherently less vulnerable to crash forces than the fuel systems on passenger cars, and therefore, the modifications made in response to FMVSS 301 had less effect for trucks than did the modifications for passenger cars.

Post-crash Versus Pre-crash Fires

With respect to the State data, it is recalled that both pre-crash and post-crash fires are included. A limited check of two States (Ohio and Maryland) which attempt to separate fires on this basis, via police reporting, indicated that pre-crash fires could approach 1/2 or more of the total fires reported in all crashes. In the more severe set of crashes that are most likely to produce injury, or fatality, it would be expected that the majority of the fires would have resulted from the crash.

Another estimate of the proportion of pre-crash fires in police reported data comes from a special study of "post-crash" factors in automobile crashes in the State of Utah in 1972 - 1973.[37] Fire was one of the post-crash topics of interest in this special study which utilized a bi-level (i.e., supplemental) reporting form as an addition to typical police reports to flag certain phenomena of interest, such as fires. These fire accidents were followed up by special accident investigation personnel, who categorized these

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[37] Study of Post-Crash Factors in Automobile Collisions," Volume 1, DOT HS-801 519, April 1975, Final Report.

fires as due to the crash, or other (non-collision) causes. Data were collected in a five county area in Utah for a one-year period. While the data cannot be considered nationally representative, 23 percent of 43 fire cases collected were classed as non-collision, with the remaining 67 percent being credited as collision fires.

While reliable estimates may not be available, the fact that pre-crash fires are included in the data implies that the true effectiveness for FMVSS 301 for passenger cars is greater than the estimate of 14 percent for all accidents. Assuming that pre-crash and post-crash fires are equally affected by vehicle age, and if the proportion of pre-crash fires is denoted by P, then the actual effectiveness estimate of the Standard would be 14/(1-P) percent. While the inclusion of pre-crash fires will result in underestimating percent effectiveness, it will not affect estimates of total fire crashes or injuries avoided (see Chapter 4).

The Effect of Age

The age factor was a consistent effect throughout the analyses. This is likely a reflection of the weakening of vehicle structures and components due to age-related degradation and corrosion (i.e., rust). Other studies have noticed this corrosion - induced weakening which can, in turn, reduce the energy absorbing qualities of the vehicle structures.[38], [39] Also flexible fuel hoses harden and become brittle with age, increasing the chances of failure and fuel leakage. Another aspect of the age effect could be artifactual in nature - the underreporting of older vehicles in accident files due to the lower economic value of older vehicles. This factor could be included in the State (i.e., all accident severities) data, but would not be expected to occur with fatal accident data. For fatal accidents, the injury severity would be sufficient to override any likelihood of not reporting due to old, low-value vehicles.

Age effects have been noted in other studies of motor vehicle fires, as well as in other studies of the effects of motor vehicle safety standards.

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[38] "Corrosion of Motor Vehicles: Safety and Environment: the User's View," by Marcus A. Jacobson, CEng, FIMechE, MIProdE, M Inst C Tech. - Article published in: "Corrosion of Motor Vehicles." Conference arranged by the Automotive Division of the Institution of Mechanical Engineers and the Institution of Corrosion Technology in collaboration with the Society of Chemical Industry; London, 13-14 November, 1974, published by Mechanical Engineers, London and New York.

[39] "Weak Points of Cars" - 1987, 1988 Ed's; AB SVENSK BILPROVNING, the The Swedish Motor Vehicle Inspection Company.

The basic analytical assumption regarding age in the analyses of the effectiveness of FMVSS 301 conducted in this chapter has been that age affects Pre-standard and Post-standard vehicles in the same manner. This approach seems quite reasonable in that corrosion rates and degradation trends for vehicle components and structures should not vary as a consequence of whether the vehicles were manufactured before, or after, FMVSS 301 took effect. Even so, the question could still be raised as to whether this assumption could be investigated further. It will be noted in the earlier sections which describe the accident data bases analyzed that among the newer vehicles, there were relatively more Post-standard vehicles than Pre-standard vehicles. Conversely, among the older vehicles, there were relatively more Pre-standard vehicles than Post-standard. Could this imbalance of vehicle age distribution between Pre- and Post-standard samples have influenced the results of the effectiveness analyses performed?

In order to further explore these issues of the possible effect of vehicle age on fire rates, two additional sets of analyses were carried out. The first analysis consisted of testing whether the age effects, computed separately for Pre-standard and Post-standard vehicles, were significantly different. The second analysis involved additional computations of the effectiveness of FMVSS 301, but restricting the data to vehicles of the same ages in both the Pre- and Post-standard samples.

The additional analyses are discussed in detail in Appendix E. The results of the analyses support the assumption that the age effect operates in the same manner for Pre-standard vehicles as it does for Post-standard vehicles - i.e., no significant differences were found.

Possible Effects of Other Factors

There exist certain other factors, not studied in the effectiveness analyses described earlier, which could have some influence on crash fire rates. These factors all concern changes in the physical structure and design of vehicles manufactured primarily after FMVSS 301 took effect and were unrelated to the Standard.

For example, the size and weight of passenger cars were substantially reduced over the period encompassed by the accident data studied.[40] It is conceivable that smaller vehicles could be less crashworthy than larger vehicles, and therefore more likely to experience fuel leakage and fire, given a crash occurs. Also during the period, the type of fuel system used saw a nearly universal switch from carburetor systems to fuel injection systems. Fuel injection systems are typically more complex than carbureted systems, in that more components and connection points are required. Fuel injection

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[40] This reduction in size and weight was a primary response of the motor vehicle manufacturers to the world-wide oil crisis of the 1970's and to the Federal Corporate Average Fuel Economy (CAFE) requirements which grew out of that crisis. This "down sizing" was instituted to achieve more fuel-efficient vehicles.

systems also operate under higher fuel pressures. Collectively, these factors imply that the chances of failure could be higher for fuel injected systems, as compared with carbureted systems, all else being equal.[41]

A third item that could potentially icnrease the risk of fuel leakage and fire involves the area of exhaust system emission controls. In the mid-seventies, catalytic converters were added to the exhaust systems of passenger cars to reduce tailpipe emissions. These devices, required by Federal regulation to reduce air pollution, operate at very high temperatures and could therefore contribute to an increase in the risk of vehicle fire.

Since all three of the above factors (decreased vehicle size, fuel injection systems, and catalytic converters apply primarily to vehicles produced after FMVSS 301 took effect, it is possible that their combined influence could serve to increase the fire risk for Post-standard vehicles. To the extent this may be true, it could serve to produce lower effectiveness estimates for the Standard than might otherwise be obtained. The effect of vehicle size on

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[41] Generally, the chances of a failure, or malfunction, in a system are proportional to the complexity of the system - i.e., the number of components comprising the system. However, changes in system design and changes in materials used can offset the chances of failure such that given increases in system complexity may result in less than commensurate increases in the risk of failure. In the example discussed here, no attempt is made to assess the relative risks of system failure in other than a general sense.

fire rate is studied in Chapter 3, where vehicle curb weight is used as a measure of vehicle size. The results of these analyses were that fire rate was not found to be associated with vehicle size (i.e., fire rates did not increase for lighter vehicles).

Data were not available to evaluate the possible effects of the remaining two factors, fuel injection systems and catalytic converters, on vehicle fire rates. In summary, it may be stated that to the extent these two factors increase the risk of crash fires, they could serve to decrease the magnitude of the effectiveness estimates developed for FMVSS 301. No attempt is made here to speculate as to whether the magnitude of any effect due to these factors might be large enough to have significant impact of the probability of vehicle crash fire and hence the effectiveness estimates developed in this study for the Fuel System Integrity Standard.

Other Studies of Motor Vehicle Fires

The effectiveness results obtained in this study, for passenger cars, are lower than the results obtained in the earlier NHTSA evaluation of the Fuel System Integrity Standard, which only studied passenger cars.[42] The earlier study found a substantial benefit for fatal accidents, whereas no reduction in fatal crashes was noted in this study. The earlier study was based on only 3

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[42] NHTSA Technical Report DOT HS 806 335, Op. Cit.

years of data from one State. Fatal accident data were not studied. Available data on vehicle fires at that time were quite scarce and a large part of the effort, including a special contractor study was involved in searching out, and making available accident data which record vehicle fires. That search turned up only one satisfactory State, Michigan, which began recording vehicle fires in 1978, and only three calendar years of data, 1978 through 1980. Elapsed time since the earlier study has generated several additional years of accident experience (including additional FARS years) that make possible more thorough analysis, including a more thorough study of factors such as age.

Flora, et. al., conducted one of the earlier (i.e., 1979) contract support studies for NHTSA on FMVSS 301.[43] This effort was primarily a search for data sources on vehicle fires and focused on two type of sources, fire department data, and police accident data. The report concluded that these data sources were inadequate to provide a definitive evaluation of FMVSS 301.

A followup study was done by Flora and O'Day in 1982, using, police accident data from Michigan and Illinois.[44] The study found: (1) no effect for the 1968 version of FMVSS 301 (passenger cars); (2) a significant reduction in fires for the 1976-1977 upgrade of the standard (passenger cars); (3) no reduction in fires for the 1977 version of FMVSS 301 for light trucks. The latter finding for light trucks was based on limited data.

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[43] "An Evaluation of FMVSS 301, Fuel System Integrity," UM-HSRI-79-12, March 1979.

[44] "Evaluation of FMVSS 301 - Fuel System Integrity - Using Police Accident Data," DOT HS-806-362, Final Report, March 1982.

In 1983, the University of Michigan published an "interview summary" with Dr. Flora entitled "Automobile Fires in Traffic Crashes."[45] This was largely a summary of the 1982 research study cited above. In addition to the 1982 report findings, Dr. Flora was quoted as saying that: (1) "I think we have to conclude that (i.e., 301) has had no measurable effect on reducing fatalities," and (2)". . .we cannot reach any definite conclusion regarding the numbers of . . .injuries it (301) is preventing."

Two other contract studies were conducted for NHTSA by the Highway Safety Research Center, University of North Carolina.[46] The first study, using police (narrative) accident data from North Carolina, only studied the 1968 version of FMVSS 301 for passenger cars. The study found no reduction in fires due to the Standard.

The second North Carolina report studied the 1976 version of FMVSS 301 for passenger cars.[47] North Carolina police (narrative) accident data were again analyzed, together with police acccident data from Maryland. The findings were that, "the 1976 modification of FMVSS 301 was at least

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[45] "Automobile Fires in Traffic Crashes," the UMTRI Research Review, May-June 1983, Vol. 13, No. 6.

[46] "A Statistical Evaluation of the Effectiveness of FMVSS 301: Fuel System Integrity," DOT HS-805-969, Report No. 7 of 7, June 1981, Final Report.

[47] "A Statistical Evaluation of the Effectiveness of the 1976 Version of FMVSS 301: Fuel System Integrity," DOT HS 806-365, November 1982, Final Report.

marginally effective in reducing the incidence of post-crash fires." Neither this report, nor the first North Carolina report attempted to evaluate the effect of any reduction in fires on occupant injury or fatality.

CHAPTER 3

THE NATURE AND MAGNITUDE OF FIRES IN MOTOR VEHICLE CRASHES

This chapter presents selected statistical data which describe the nature and magnitude of fire in motor vehicle crashes. The statistics are based on the same data sources as used in the effectiveness analyses of FMVSS 301 presented in Chapter 2, i.e., the Fatal Accident Reporting System and selected vehicle accident files compiled by the States. In the first section, fires in fatal crashes are presented, while the following section contains data on fires in all motor vehicle crashes.

3.1 FIRES IN FATAL CRASHES

Based on the data in FARS, from its inception in 1975 through calendar year 1988, an average of 2.6 fires per 100 fatal motor vehicle crashes have occurred. This is the rate for all vehicle types (passenger cars, light trucks, heavy trucks, motorcycles, etc.). For the three vehicle types of primary interest in this study, the average fire rates have been:

passenger cars: 2.4 per 100 crashes
light trucks: 2.8 per 100 crashes
school buses: 1.0 per 100 crashes

Table 3-1 lists the number and rate of vehicle fires for each of these classes for the 14 FARS years.

Table 3-1

Fires in Fatal Motor Vehicle Accidents

Calendar Year	All Vehicles No.	Rate*	Passenger Cars No.	Rate*	Light Trucks No.	Rate*	School Buses No.	Rate*
1988	1,804	2.88	1,017	2.75	443	2.95	1	0.95
1987	1,713	2.77	961	2.63	399	2.80	4	3.03
1986	1,755	2.89	972	2.69	396	3.04	2	1.98
1985	1,483	2.55	809	2.36	318	2.55	1	0.79
1984	1,554	2.68	847	2.44	321	2.68	1	0.84
1983	1,420	2.58	836	2.51	265	2.38	1	1.01
1982	1,521	2.69	863	2.51	320	2.83	1	0.96
1981	1,809	2.89	1,031	2.65	373	3.02	0	0.00
1980	1,720	2.71	931	2.38	360	2.84	2	1.71
1979	1,774	2.74	978	2.45	379	3.02	2	1.33
1978	1,580	2.46	867	2.14	327	2.75	0	0.00
1977	1,505	2.49	832	2.13	290	2.79	1	0.79
1976	1,314	2.34	771	2.03	250	2.69	0	0.00
1975	1,252	2.25	744	1.96	206	2.39	1	0.77
AVERAGE	1,586	2.64	890	2.40	332	2.78	1.21	1.01

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* Rate is number of fires per 100 fatal vehicle crashes.

SOURCE: Fatal Accident Reporting System, NHTSA

3.1.1 TRENDS IN FATAL FIRE CRASHES

In order to investigate the existence of overall trends in fire rates, simple linear functions were fitted to the data in Table 3-1 with fire rate as the dependent variable, and calendar year as the independent variable. Analyses were run for each of the three vehicle classes - passenger cars, light trucks, and "other" vehicles, where other vehicle was defined as all vehicles in FARS (i.e., column 1 of Table 3-1) less passenger cars and light trucks (i.e., minus columns 3 and 4 of the table). The data on school buses are too sparse for analyses of possible trends.

Figures 3-1, 3-2, and 3-3 are the data plots for the three analyses. The results showed that fire rates for passenger cars have increased significantly over the 14-year period, while no change in rates was noted for light trucks, or for (all) other vehicles. The resulting equations were:

passenger cars: $R = .02024 + .0005089$ (cal. year)
light trucks: $R = .02665 + .0001356$ (cal. year)
other vehicles: $R = .03380 - .0001144$ (cal. year)

The passenger car increase in fire rate is about 2.5 percent per year and was significant at the 5 percent level ($t=5.92$) while the changes for the other two vehicle classes (0.5 percent increase per year for light trucks, and -0.3 percent decrease per year in other vehicles were not significant

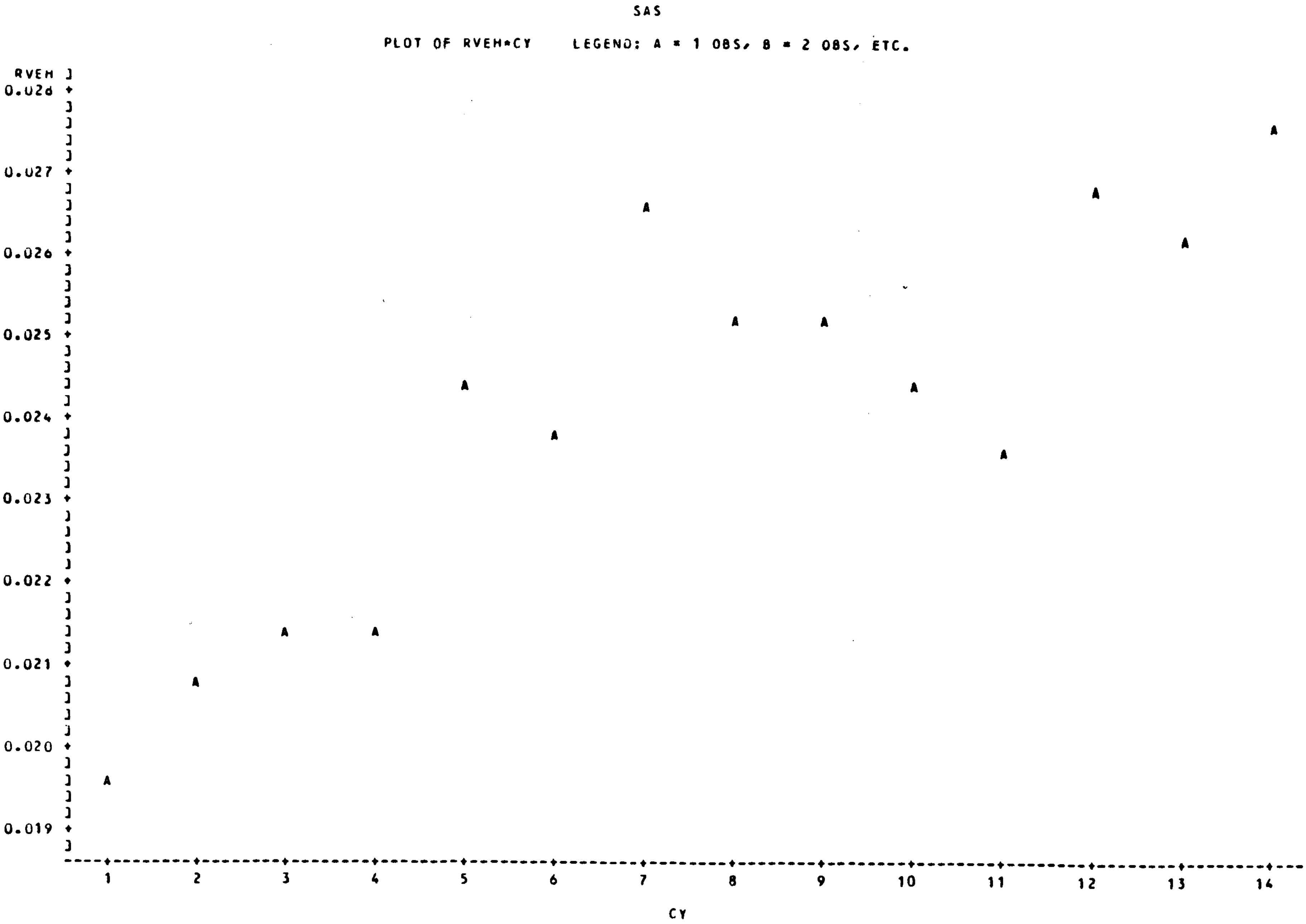

Figure 3-1

FARS, Passenger Cars
(1975=1, 1976=2, etc.)

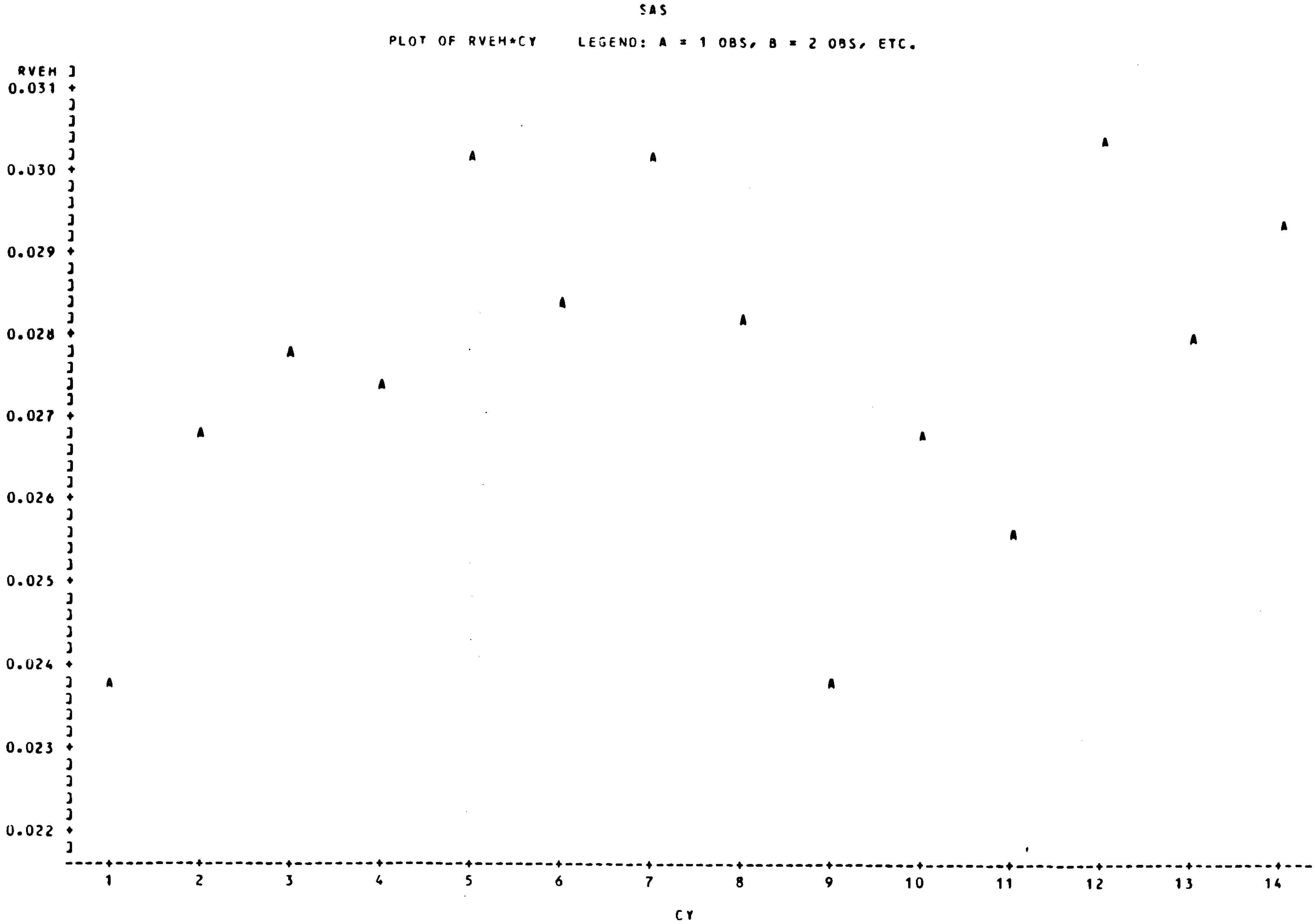

Figure 3-2
FARS, Light Trucks
(1975=1, 1976=2, etc.)

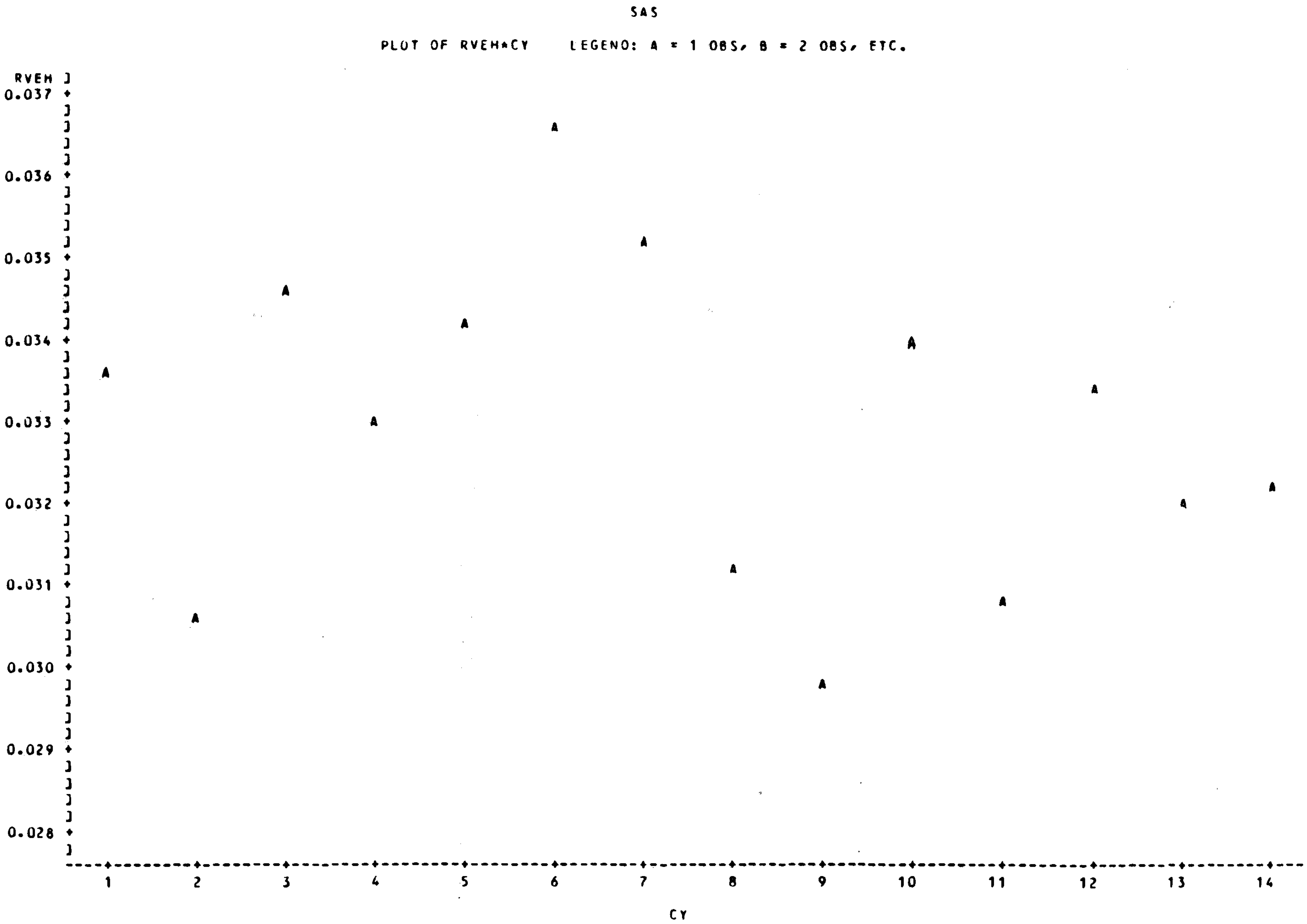

Figure 3-3
FARS, Other Vehicles
(1975=1, 1976=2, etc.)

(t = 0.95; t = -0.90).[1] The calendar year trend for passenger cars was quite strong accounting for nearly 3/4 of the variation in fire rate (R^2= .74). The fits were very poor for the light truck and other vehicle models, both having R^2 values of only .07.

Given the increasing trend in fire rates for passenger cars, an ensuing question is: " What could be contributing to the increase?"

Several factors could be involved. Age of the vehicle is a logical candidate - it was almost universally found to be a significant factor in the effectiveness analyses, and over the last several years, the average age of the passenger car population has increased. Vehicle size is a second possibility. Over the period from the late seventies into the mid-to-late eighties, -- the period generally encompassed by the FARS data -- the U.S. new car population underwent significant downsizing, the vehicle becoming both smaller and significantly lighter.[2] Smaller vehicles could be less crashworthy and hence more likely to experience fuel system breaching in a crash, leading to greater fire risk.

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[1] Probability of greater t for passenger cars (calendar year) coefficient = .0001. Probability of greater t for light trucks (calendar year) coefficient = .3623. Probability of greater t for other vehicles (calendar year) coefficient = .3878.

[2] Actually, most of the size reduction, as measured by vehicle curb weight, was confined to the domestically manufactured portion of the passenger car fleet. The average curb weight of the imported passenger car fleet actually increased over the period.

Other vehicle technology changes which took place over the study period, and which may have altered the risks of fuel leakage (and hence fire) include such factors as the switch from carburetor fuel systems to fuel injection systems and the addition of air pollution emission controls. Carburetors, which a decade or so ago were used almost exclusively to meter fuel to the vehicle's engine, have now been almost universally replaced with fuel injection systems. Fuel injection systems are substantially more complex than carburetted systems, requiring more fuel lines and connections and they also operate under higher fuel pressures. While changes in system design and in materials utilization can serve to reduce the risk of failure or malfunction, in general, the greater the number of components and connection points in a system the greater the chances of a failure occurring. Given a crash-induced breach in the fuel system, higher line pressures could also result in the discharge of more fuel and over a greater area or space. The fuel return line feature on fuel injected systems also results in increasing the temperature of the fuel in the lines and in the tank.

Emission controls could also affect the chances of fuel-fed fires. Underhood cannisters to capture gasoline vapors were installed on passenger cars in the early seventies. These cannisters are connected to the vehicle's fuel tank and to the fuel intake area of the engine via vapor lines and valving. The escape of vapors from a break in this system could increase the opportunity for fire. In the mid-seventies catalytic converters were also added to the vehicle's exhaust system to control exhaust emissions. These converters operate at very high temperatures and therefore may increase the risk of fire.

Higher travel speeds over the last several years could also be a contributing factor to more vehicle fires; higher speeds lead to more severe crash forces. Increases in fuel volatility could be involved. The average volatility of gasoline has steadily trended upward over the last 30 years. Evaporation of fuel (vapors) increases with higher volatility levels, thereby increasing the risk of escape of vapors.[3] Still another possibility is the maturity of the FARS data. Increasing quality and completeness of the data, from the beginning years of the data system, could have increased the degree of reporting of certain data elements. The more rare, or unusual elements, such as vehicle fires, could have been more likely to be affected by better quality control and reporting procedures.

As one attempt at testing the reporting system maturity possibility, the calendar year model was rerun, dropping the initial two FARS years, 1975 and 1976. The calendar year effect still remained significant.[4] Moreover, since fire rates for the other two classes of vehicles (light trucks, other vehicles) did not increase over the same 13-year period, the possibility that reporting system maturity has contributed to the increase in passenger car firs can be further discounted.

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[3] Federal Register, Vol. 52, No. 160, August 19, 1987. Environmental Protection Agency, 40 CFR Parts 80, 86, and 600. Regulation of Fuels and Fuel Additives: Volatility Regulations for Gasoline and Alcohol Blends Sold in 1989 and Later Calendar Years and Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines: Evaporative Emissions Regulations for 1990 and Later Model Year Gasoline - Fueled Light-Duty Vehicles, Light-Duty Trucks, and Heavy-Duty Vehicles.

[4] $t = 3.85$, probability of greater $t = .0032$.

Age is perhaps the strongest possibility, owing to its previously demonstrated significant and consistent effect in the effectiveness analyses. Also, car size is considered a reasonable possibility and since an automated file of passenger car weights by vehicle, make, model, and model year was readily available, a third analysis was conducted to investigate the effect of age and vehicle weight.[5]

A two variable model with fire rate as a function of vehicle age and weight was fitted to the FARS data. The individual observations were fire rates (R) by each calendar year by model year combination (age = calendar year - model year) and vehicle weight (wgt. = average curb weight for each calendar year by model year cell). The data were weighted to compensate for the variation in number of vehicles per cell.

The resulting model found age significant, but vehicle weight not significant. Figures 3-4 and 3-5 show the fire rate as a function of age and vehicle weight, respectively. The resulting equation was:

$$R = .02163 + .0005894\,(\text{age}) - .0000002\,(\text{wgt.})$$

Age was highly significant with a t-value of 7.25.[6] Vehicle weight was far from being significant at a t-value of -0.16 and, in fact, the estimate for

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[5] Vehicle weights were the curb weights, in pounds, by individual make, model, and model year, as taken from the Automotive News Annual publications for the respective model years, 1968 through 1987.

[6] Probability of greater t = .0001

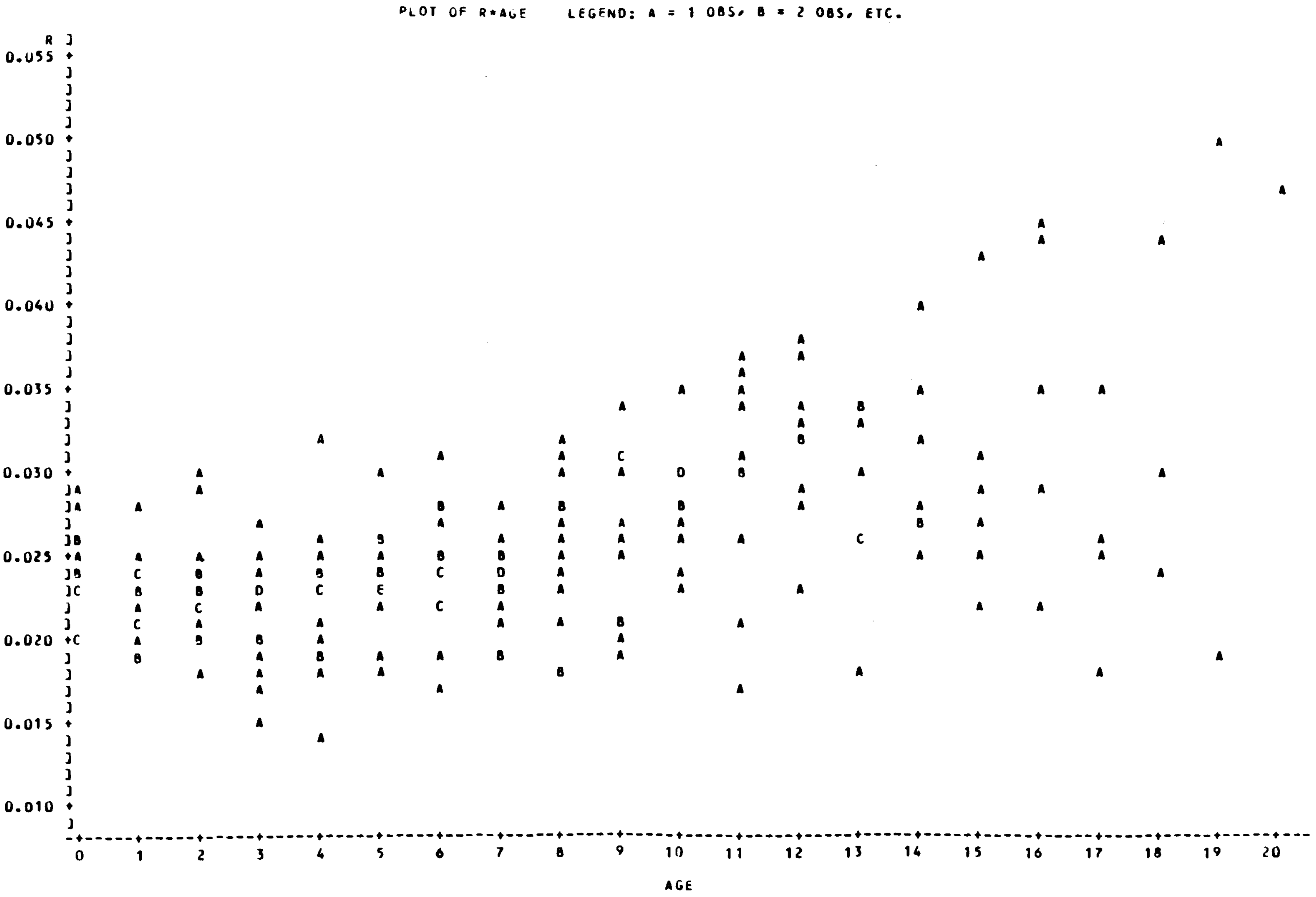

Figure 3-4
FARS, Passenger Cars

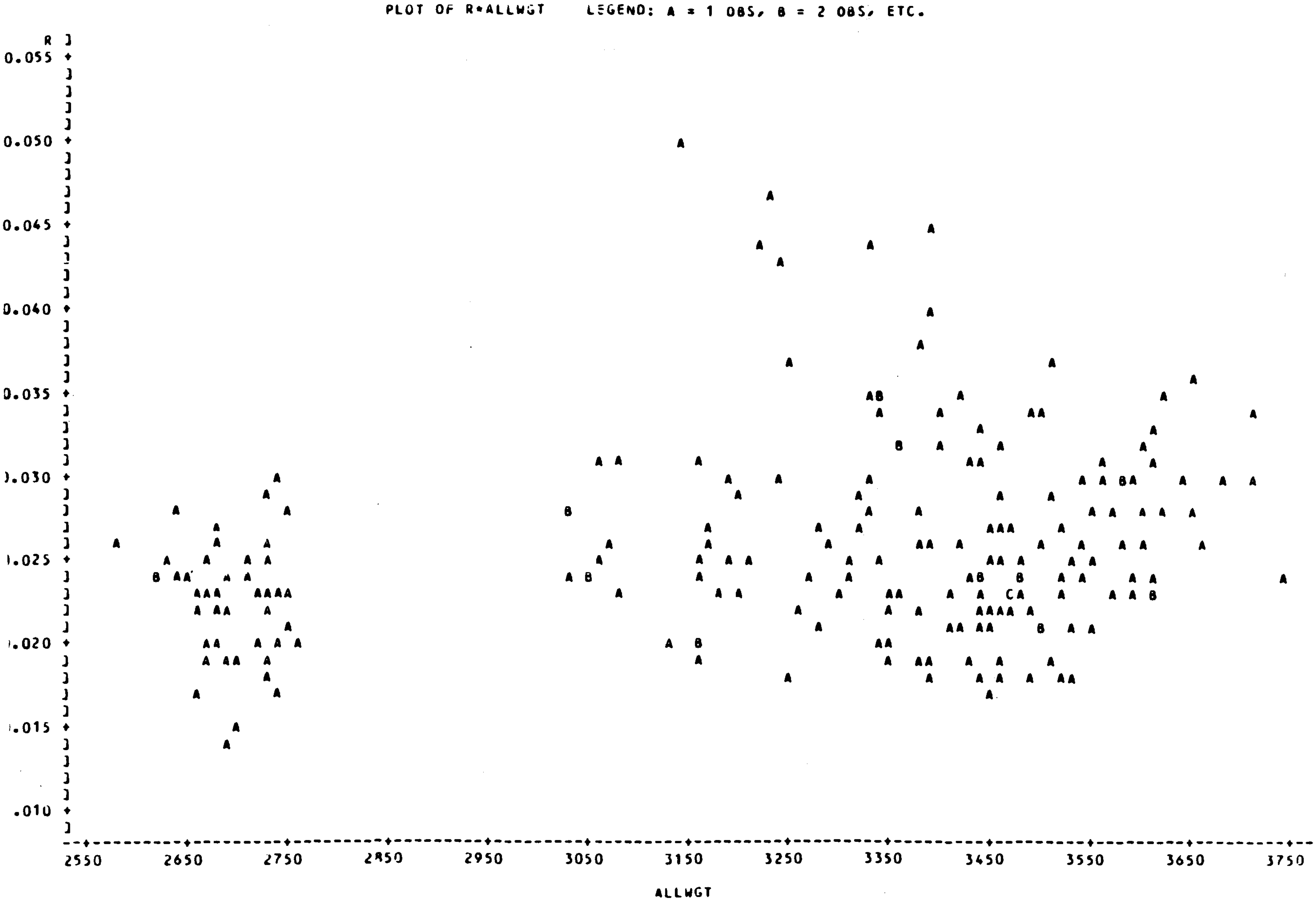

Figure 3-5
FARS, Passenger Cars

the weight effect was extremely close to zero.[7] Of course, the statistical conclusion from this analysis is that the effect of vehicle weight on fire rate is, indeed zero. R^2 for the model was .25.

Data to permit analyses of the effects of other potential factors (switch to fuel injection, emissions controls, higher travel speeds, increased fuel volatility) are not available. Therefore, the summary finding of these analyses is that a primary reason for the increase in fire rate for passenger cars, over the last several years, is age. An indication of the increasing age of the passenger car fleet can be seen in Table 3-2 which shows, by calendar year: (1) the percentage of all passenger cars in fatal accidents that were 10 years old, or older, at the time of the accident, and (2) the percentage of all fire-involved passenger cars in fatal accidents that were 10 years, or older for the same years. The trend of an increasingly older car population is clearly evident.

The percentage of older cars in fatal accidents (column 2) closely follows the percentage of older cars in the total population (i.e., total registered vehicles.[8] Another item of note from Table 3-2 is the over-involvement of older cars in fire crashes. This trend is noted to have begun in about 1980

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[7] Probability of greater t = .8694.

[8] Data on total vehicle population from "MVMA Motor Vehicle Facts and Figures" -- '89 and '85 editions.

Table 3-2

Percentage of Total Passenger Cars in Fatal Crashes, and Fire-Involved Passenger Cars in Fatal Crashes That were Ten Years Old or Older at the Time of the Crash

Calendar Year	Percent of Cars ≥ 10 Years Old	
	All Fatal Crashes	Fire-Involved Fatal Crashes
1975	15.5%	13.4%
1976	18.1%	16.3%
1977	18.4%	16.8%
1978	19.2%	16.7%
1979	20.2%	19.1%
1980	21.4%	21.5%
1981	22.1%	24.7%
1982	24.7%	29.4%
1983	27.5%	30.5%
1984	28.7%	32.6%
1985	26.5%	35.2%
1986	28.8%	33.9%
1987	29.0%	33.5%
1988	29.8%	35.9%

Source: Fatal Accident Reporting System, NHTSA with the latter 3 to 4 years evidencing a leveling-off of the trend. The trend appears to coincide with the general increase in the mean age of the passenger car population which began in the late seventies (following the oil crisis), and has leveled off in the last 3-4 years.[9]

3.1.2 COMPARISONS OF FIRE FATAL CRASHES AND ALL FATAL CRASHES

In this section, selected statistics are presented which compare fatal crashes accompanied by fire with all fatal crashes.

Occupant Fatality Risk in Fire Crashes

The first comparison involves the risk of fatality in fire crashes versus the risk of fatality in all crashes. Comparisons are made for passenger cars and for light trucks. The key data are the occupant fatality rates for vehicles with fire and the occupant fatality rates for all vehicles. The data are summarized in Tables 3-3 and 3-4.

The primary observation from the tables is the considerably higher fatality rate for crashes accompanied by fire. Passenger car fatal crashes, with fire, average 66 percent more occupant fatalities than fatal car crashes without fire. For light trucks, the difference is even more pronounced, with fire crashes having 82 percent more occupant fatalities. The differences here are exaggerated somewhat since the all crash category includes pedestrian crashes

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[9] Data on mean age of passenger cars from "MVMA Motor Vehicle Facts," Op. Cit.

Table 3-3

Passenger Cars: Occupant Fatality Rates for Fatal Crashes with Fire and All Fatal Crashes

Calendar Year	All Crashes No. Vehicles	All Crashes No. Occupant Fatalities	All Crashes Fatality Rates	Fire Crashes No. Vehicles	Fire Crashes No. Occupant Fatalities	Fire Crashes Fatality Rates
1985	34,277	23,212	0.68	809	901	1.11
1984	34,648	23,620	0.68	847	971	1.15
1983	33,298	22,979	0.69	836	959	1.15
1982	34,334	23,330	0.68	863	994	1.15
1981	38,864	26,645	0.69	1,031	1,138	1.10
1980	39,059	27,449	0.70	931	1,073	1.15
1979	39,999	27,808	0.70	978	1,155	1.18
1978	40,544	28,153	0.69	867	1,033	1.19
1977	39,038	26,782	0.69	832	949	1.21
1976	37,206	26,166	0.70	771	937	1.22
1975	37,897	25,929	0.68	744	838	1.13
AVG	37,197	25,643	0.69	864	995	1.15

Source: Fatal Accident Reporting System (FARS), NHTSA

Table 3-4

Light Trucks: Occupant Fatality Rates for Fatal Crashes with Fire and All Fatal Crashes

	All Crashes			Fire Crashes		
Calendar Year	No. Vehicles	No. Occupant Fatalities	Fatality Rates	No. Vehicles	No. Occupant Fatalities	Fatality Rates
1985	12,464	6,689	0.54	318	315	0.99
1984	11,973	6,496	0.54	321	316	0.98
1983	11,118	6,202	0.56	265	266	1.00
1982	11,317	6,359	0.56	320	320	1.01
1981	12,331	7,081	0.57	373	374	1.00
1980	12,680	7,486	0.59	360	382	1.06
1979	12,544	7,178	0.57	379	418	1.10
1978	11,898	6,745	0.57	327	339	1.04
1977	10,400	5,976	0.57	290	320	1.10
1976	9,300	5,438	0.58	250	273	1.09
1975	8,636	4,856	0.56	206	224	1.07
AVG	11,333	6,410	0.57	310	322	1.04

Source: Fatal Accident Reporting System (FARS), NHTSA which typically do not result in vehicle occupant fatalities. Adjustment for this factor reduces the above differences to 45 percent and 62 percent for cars and light trucks, respectively - still markedly higher fatality rates for fatal crashes with fire. These data are evidence that the presence of fire increases the lethality of even fatal crashes. However, other factors may also be at play, as will be seen in some of the other statistics presented in this chapter.

A secondary observation from Tables 3-3 and 3-4 is that the occupant fatality rates, for both fire and all crashes have remained quite consistent over the years, within the two vehicles classes.

Fatal Fire Crashes by First Harmful Event

The next comparison, in Table 3-5, shows fire crashes and all crashes by the "first harmful event" of the accident.

The distributions by first harmful event are reasonably similar for passenger cars and light trucks. With respect to fire crashes compared to all crashes, the biggest differences are that fire crashes rarely involve collisions with pedestrians, but are much more likely to be single vehicle collisions (i.e., with fixed objects, or with trees). Collectively, these data indicate that vehicles in fatal collisions with fire are more likely to experience greater collision forces than vehicles in non-fire fatal collisions. Greater impact forces would be expected to have grater potential for occupant injury, as well as greater potential for vehicle fire.

Table 3-5

Distribution of Fatal Fire Crashes and All Fatal Crashes by First Harmful Event

First Harmful Event	Passenger Cars		Light Trucks	
	Fire Crashes	All Crashes	Fire Crashes	All Crashes
Non-collision:				
Overturn	4.6%	5.6%	8.7%	10.6%
Collision with:				
Pedestrian	0.8%	12.9%	0.6%	11.9%
Rail Train	0.6%	1.0%	2.1%	1.2%
Parked Motor Vehicle	1.1%	1.4%	2.0%	1.3%
Vehicle in Transport	49.7%	52.8%	50.1%	52.2%
Fixed Object	29.7%	18.2%	25.8%	14.7%
Pedalcycle	0.06%	1.6%	0.0%	2.0%
Tree	11.1%	5.7%	9.4%	3.9%
Other	1.1%	0.8%	1.3%	2.4%

Data are percent of involved vehicles in each event category.

Source: Fatal Accident Reporting System (FARS), NHTSA. Distributions based on average of six calendar years (1975, 1977, 1979, 1981, 1983, 1985).

Fatal Fire Crashes by Speed Limit

A third comparison of fire fatal crashes and all fatal crashes involves the speed limit of the roads on which the crashes occurred. While speed limit obviously does not indicate the actual traveling speed, or impact speed of the involved vehicles, it nonetheless should have a positive correlation with these and thus with the impact forces sustained by the vehicles.

Table 3-6 shows the speed limits, for both passenger cars and light trucks, for fatal crashes involving fire and for all fatal crashes.

For both vehicle types, the likelihood for fire crashes to involve higher speeds and, by inference, higher impact forces, is clearly seen. Passenger car fatal crashes with fire are 31 percent more likely to involve higher speeds (i.e., happen at speed limits of 50-55 m.p.h.) than all passenger car fatal crashes. For light trucks, fire fatal crashes are 28 percent more likely to occur at higher speeds than all fatal crashes.

Again, the presence of pedestrian accidents in the data (which primarily occur at lower speeds, and rarely involve a vehicle fire) will inflate the above comparisons, but the data are still sufficient to show that fire fatal crashes more often involve higher speeds than all fatal crashes.

Table 3-6

Distribution (percent) of Fatal Fire Crashes and All Fatal Crashes by Roadway Speed Limit

Speed	Passenger Cars		Light Trucks	
Limit (mph)	Fire Crashes	All Crashes	Fire Crashes	All Crashes
5 - 25	2.80%	5.28%	1.90%	4.92%
30 - 45	23.00%	33.57%	16.58%	32.19%
50 - 55	65.93%	50.33%	74.16%	58.10%
UNK	8.27%	10.82%	7.36%	4.79%

Data are percent of involved vehicles in each speed limit.

Source: Fatal Accident Reporting System (FARS), NHTSA.
Distributions based on average of six calendar years
(1975, 1977, 1979, 1981, 1983, 1985).

Fatal Fire Crashes by Impact Direction

The last comparison to be made in this section on fatal crashes concerns the direction of impact to the vehicle.

From the data in Table 3-7, one of the principal observations is the over-involvement of passenger car fires in fatal rear end collisions. Among collisions with fire, the probability that the vehicle sustained an impact from the rear is over three times as likely as for all fatal passenger car involvements. This over-involvement rate for rear impacts does not appear for light trucks. This may be a reflection of the different location for fuel tanks in cars as compared with the location of tanks for many light trucks. In cars, the tank is typically located near the rear of the vehicle whereas for many light trucks, the tank is situated near the center of the vehicle.

Another item of note in Table 3-7 is that frontal impacts account for the large majority of fires, for either type of vehicle, with frontal plus rear impacts accounting for almost 3/4 of the fire crashes.

3.2 FIRES IN ALL REPORTED CRASHES

This section presents data on fire in all police reported motor vehicle crashes based on the accident files of the States used for the effectiveness analyses in Chapter 2.

Table 3-7

Distribution (percent) of Fatal Fire Crashes and All Fatal Crashes by Impact Direction

Impact	Passenger Cars		Light Trucks	
Direction	Fire Crashes	All Crashes	Fire Crashes	All Crashes
Front	59.3%	65.0%	65.8%	66.3%
Right Side	9.0%	11.0%	8.4%	7.3%
Rear	14.6%	4.5%	3.8%	4.9%
Left Side	7.6%	10.7%	7.3%	7.2%
Non-Collision	5.3%	5.4%	8.5%	10.9%
UNK	4.2%	3.4%	6.2%	3.4%

Data are percent of involved vehicles in each impact direction.

Impact direction is the initial impact point. Front-side-rear directions are defined by the "o'clock" direction data contained in the data files as follows:

front = 11-12-1
right side = 2-3-4
rear = 5-6-7
left side = 8-9-10
non-collision = non-collision

Source: Fatal Accident Reporting System (FARS), NHTSA. Distributions based on average of six calendar years (1975, 1977, 1979, 1981, 1983, 1985).

Table 3 - 8

Fire Rates in All Police Reported Crashes
by Vehicle Class and State
1982 through 1987

	STATE				
	Ohio	Michigan	Maryland	Illinois	Indiana
Passenger Cars:					
Total Vehicles	2,932,274	2,657,781	1,017,579	4,210,341	1,711,575
Total Fires	10,540	5,554	2,796	3,713	1,620
Fire Rate*	3.594	2.090	2.748	0.882	0.947
Light Trucks:					
Total Vehicles	463,842	491,372	162,581	545,882	319,832
Total Fires	1,728	995	553	598	323
Fire Rate*	3.725	2.025	3.401	1.095	1.010
School Buses:					
Total Vehicles	11,143	9,084	5,755	15,882	5,824
Total Fires	39	15	8	16	4
Fire Rate*	3.500	1.651	1.390	1.007	0.687

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* Fire rates given in terms of fires per 1,000 involved vehicles.

Source: Accident data files from above States for calendar years 1982 through 1987. Above data are totals for the 6 years.

3.2.1 Fire Rates and Total Fires in Motor Vehicle Crashes

Table 3-8 lists the overall fire rates for passenger cars, light trucks, and school buses, based on the 5 State data bases. The data represent totals, over the six years (1982 through 1987) for each State. The difference in rates among States was pointed out earlier in the effectiveness analyses. The States of Ohio, Michigan, and Maryland were considered the preferable sources, so these three States will be used here as the basis for developing national estimates of fires in all reported vehicle crashes. Combining the rates, from Table 3-8, for these three States produces the following estimates of fire rates for the three vehicle classes:

passenger cars: 2.86 fires per 1,000 vehicle crashes
light trucks: 2.93 fires per 1,000 vehicle crashes
school buses: 2.39 fires per 1,000 vehicle crashes

The fire rate for passenger cars and light trucks is about the same at 2.9 fires per 1,000 accident involved vehicles, while the rate for school buses is somewhat lower at 2.4 fires per 1,000 involved vehicles.[10]

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[10] Although not shown in Table 3-8, the estimated fire rate for <u>all</u> vehicle types (cars, light trucks, heavy trucks, motorcycles, motor homes, etc.) in police reported data is 2.97 fires per 1,000 vehicles involved in accidents. This estimate is based on the data from Michigan and Ohio for the years 1982, 1984, and 1987, and for Maryland for the years 1981, 1984, and 1987.

In order to project these rates to the National level, estimates of annual totals of vehicles in accidents are required, for each of the three vehicle classes. These estimates are: 8,239,000 passenger cars, 1,758,000 light trucks, and 25,500 school buses.[11]

Applying the above fire rates to the total number of vehicles in accidents gives the following estimates of the total number of accident fires annually:

passenger cars:

$$\frac{2.86 \text{ fires}}{1{,}000 \text{ vehicles}} (8{,}239{,}000 \text{ vehicles}) = 23{,}564 \text{ fires}$$

light trucks:

$$\frac{2.93 \text{ fires}}{1{,}000 \text{ vehicles}} (1{,}758{,}000 \text{ vehicles}) = 5{,}151 \text{ fires}$$

school buses:

$$\frac{2.39 \text{ fires}}{1{,}000 \text{ vehicles}} (25{,}500 \text{ vehicles}) = 61 \text{ fires}$$

As was pointed out earlier in this report, these estimates of total fires include pre-crash as well as post-crash fires. While reliable separation of pre and post-crash fires is not possible, available information indicates that

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[11] Annual totals of police reported passenger cars and light trucks in accidents from National Accident Sampling System (NASS), Annual Report, 1986 (A report on traffic crashes and injuries in the United States); NHTSA. Total school buses in accidents are NHTSA estimates based on prior unpublished analyses of school bus accident data.

pre-crash fires could account for as much as 1/2 of the total reported fires. Also, these data indicate that the proportion of total fires that are post-crash increases as the severity of the accident (as denoted by either vehicle damage or occupant injury) increases (see Table 3-10a).

Given that fires are estimated to occur at the rate of about 3 fires for every 1,000 crashes (for crashes involving either a passenger car or a light truck), it would be of interest to see how the rate changes if the crashes are restricted to those involving injury. Table 3-8a provides this information. The data are based on the overall average for the States of Michigan, Ohio, and Maryland, and for the three calendar years 1982, 1984, and 1987. The rates shown are the number of fires per 1,000 vehicle crashes, passenger car or light truck, where the vehicle driver sustains injury at either the A (serious) or the B (moderate) severity level. As would be expected, the fire rate, ranging from 7 to 8 fires per 1,000 crashes, is higher than the rate of 3 fires per 1,000 crashes for all reported crashes (i.e., those involving both injury and non-injury). Also the fire rate is seen to increase as injury severity increases. Again, this is what would be expected. A complete picture of how fires increase as injury severity increases can be gotten by recalling that earlier in this Chapter the fire rate for fatal crashes involving passenger cars or light trucks ranged from 26 to 28 fires per 1,000 crashes, several times the rate of fires in injury crashes.

Table 3-8a

Number of Fires per 1,000 Injury* Crashes

Injury Severity	Passenger Cars	Light Trucks
A	10.6	12.4
B	5.4	6.2
A or B	6.8	7.8

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* Injury is to vehicle driver. Injury severity is typical police code A (serious) and B (moderate).

3.2.2 Severity of Fire Crashes in All Reported Crashes

Next, fire crashes will be compared with all crashes on the basis of two severity indices - the severity of occupant injury and the severity, or extent, of damage sustained by the vehicle. Data are presented only for passenger cars and light trucks, as the data on school bus fires are too sparse for developing reliable distributions.

Fire Crashes by Injury Severity

Table 3-9 compares the distribution of driver injury for fire crashes with the distribution of driver injury for all crashes. For both classes of vehicles, the much higher severity of injury for fire crashes is clearly evident, particularly for more serious injuries. The data are based on the

Table 3-9

Percent Distribution of Injury Severity* for Fire Crashes and for All Reported Crashes

	Passenger Cars		Light Trucks	
Injury Severity	Fire Crashes	All Crashes	Fire Crashes	All Crashes
K	2.64	0.15	2.94	0.14
A	8.18	2.24	7.60	1.86
B	12.20	6.59	10.79	5.32
C	7.79	11.62	6.83	8.10
O	69.19	79.40	71.84	84.63

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* Injury is to vehicle driver. Injury severity codes are typical police reported codes.

K	fatality
A	serious
B	moderate injury
C	minor injury
O	no injury

Table 3-10

Estimated Annual Injuries in Fire Crashes for Passenger Cars and Light Trucks

Injury Severity	Passenger Cars	Light Trucks
A	2,892	587
B	4,313	834
C	2,754	528

overall average of the three States (Michigan, Ohio, and Maryland) for the years 1982, 1984, and 1987. Individual injury distributions by each calendar year were quite similar, so that the overall average of the three years should provide reliable estimates.

By combining the injury rates for fire crashes in Table 3-9 with total estimated fire crashes from Section 3.1.1, estimates of the total numbers of fire related occupant casualties can be obtained. These estimates appear in Table 3-10, for all injuries below fatalities. Actual counts of fatalities, based on FARS were given in Section 3.1, so these are not estimated from the State injury data. One other adjustment is included in the injury estimates in Table 3-10. Since the injury distribution (Table 3-9) is based on the vehicle driver, an adjustment is needed for injuries that occur to occupants of other seated positions in the vehicle. This estimate is 0.5 injuries to other vehicle occupants for each driver injury.[12]

The final table (Table 3-10a) in this section shows the proportion of total reported fires that are post-crash in nature (i.e., fires that result from the crash) as a function of the injury sustained by the vehicle driver. The data are from only one State, Ohio, and therefore the distributions are not necessarily considered as reliable estimates of the national situation. Also, it is likely a difficult task for investigating police officers to be able to

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[12] National Accident Sampling System, 1986. Op. Cit.

Table 3-10a

Driver Injury Severity By Type of Fire

Passenger Cars

Type of Fire	Injury Severity UNK	K	A	B	C	O	TOTAL
Fire Due to Crash	531	218	591	1,087	598	2,391	5,416
Other Fires	152	7	65	298	223	4,229	4,974
TOTAL	683	225	656	1,385	821	6,620	10,390
Percent Due to Crash	77.7%	96.9%	90.1%	78.5%	72.8%	36.1%	52.1%

SOURCE: State of Ohio. Numbers are totals for 6 calendar years, 1982 through 1987.

distinguish between crash fires and fires due to other causes, based on available evidence and information from the crash. Even so, the increasing proportion of crash fires with increasing injury severity certainly accords with intuition. For example, it seems quite reasonable to expect that most all fires in vehicle crashes where an occupant is killed are fires that resulted from the crash, rather than from some other source (i.e., pre-crash fire).

Fires Crashes by Vehicle Damage Severity

Another indication of the severity of fire crashes, as compared to all crashes, can be gotten from comparing variables which denote the extent of damage to the involved vehicles. Vehicle damage indicators are available in each of the three State data bases -- Michigan, Ohio, and Maryland. These damage variables differ somewhat among the States, as to the number of damage levels coded, etc. For simplification, the levels have been condensed to two - one for lower damage, and one for more severe damage. Table 3-11 summarizes these data for passenger cars and clearly shows the more severe levels associated with fire crashes. As with the data on injury severity, the table is based on the overall average of calendar years 1982, 1984, and 1987.

Table 3-11

Percent Distribution of Fire Crashes and All Crashes
by Vehicle Damage Severity - Passenger Cars

State:	Michigan		Ohio		Maryland	
Vehicle Damage:	Low to Moderate	Major	Slight to Moderate	Major	Minor to Moderate	Major
Fire Crashes:	54.1%	45.9%	34.0%	66.0%	8.0%	92.0%
All Crashes:	90.6%	9.4%	79.8%	20.2%	65.4%	34.6%

Table 3-12 shows the same distributions light trucks. Again, the higher vehicle damage for fire crashes is evident. Generally, the vehicle damage codes are to indicate damage due to impact forces and not due to the presence of fire.

Table 3-12

Percent Distribution of Fire Crashes and All Crashes
by Vehicle Damage Severity - Light Trucks

State:	Michigan		Ohio		Maryland	
Vehicle Damage:	Low to Moderate	Major	Slight to Moderate	Major	Minor to Moderate	Major
Fire Crashes:	58.2%	41.8%	38.7%	62.3%	6.3%	93.7%
All Crashes:	92.0%	8.0%	84.0%	16.0%	70.6%	29.4%

Fire in All Crashes by Direction of Impact

Tables 3-13 and 3-14 compare fire crashes and all crashes by the direction (or point of) impact to the vehicle. Separate tables are shown for the States of Michigan and Maryland, since the category definitions differ somewhat between the States, and since the distributions differ between the two States, especially for the category of "other/unknown," for fire crashes, which is unusally large for Maryland. The large proportion of other/unknown here may imply that vehicles with fire are more apt to experience complex crashes -- i.e., impacts from more than one direction -- or to have severe enough damage that a single impact direction can not be discerned. To facilitate comparisons of the data, the distributions for fire crashes have been recomputed, deleting the other/unknown category. The adjusted distributions are shown in parentheses.

Examination of the distributions leads to the following observations:

- the distributions by impact are generally similar for cars and trucks.
- the over-representation of fire in rear impact crashes for cars does not appear for all crashes as it did for fatal crashes. Rather for fire crashes, rear impacts are somewhat under-represented while frontal impacts are over-represented.
- although small in number, rollovers or top impacts are over-represented in fire crashes.

- frontal impacts account for the majority of fires, as was the case for fatal crashes.

3.3 FUEL LEAKAGE IN MOTOR VEHICLE CRASHES

Fuel leakage data were not analyzed in the effectiveness calculations for FMVSS 301 for the reasons stated earlier. However, since the prevention of fuel-fed fires is the purpose of the Standard, summary data on fuel leakage are included in this section from the one State which recorded these data in its accident files.

Table 3-15 summarizes the fuel leak rates for passenger cars and light trucks, as taken from the Michigan accident files for calendar years 1982 through 1987.

Overall, the incidence of fuel leakage is seen to average about 9.7 per 1,000 vehicles, for passenger cars, and about 11.7 per 1,000 vehicles for light trucks. Thus, based on these data, fuel leaks are estimated to occur 4 to 5 times as often as vehicle fires. A second observation is the very strong age (or model year) trend in the data. Although not statistically fitted, it is obvious the relationship is quite robust and likely even stronger than the age effects noted earlier for fire rates.

Table 3-13

Distribution (percent) of Fire Crashes and All Crashes
by Direction of Impact
State of Michigan

	Passenger Cars		Light Trucks	
Impact Direction	Fire Crashes	All Crashes	Fire Crashes	All Crashes
None/ Rollover	4.7% (6.6%)	1.6%	7.7% (9.5%)	3.7%
Front	50.1% (64.5%)	58.9%	49.8% (61.4%)	56.2%
Right Side	4.6% (6.3%)	6.6%	4.6% (5.7%)	6.3%
Rear	15.3% (17.9%)	23.9%	14.8% (18.2%)	24.9%
Left Side	3.8% (4.8%)	7.0%	4.2% (5.2%)	6.5%
Other/ Unknown	21.6%	2.0%	18.6%	2.4%

Data represent percent of vehicles involved by each impact direction.
Numbers in parentheses are based on deletion of other/unknown category.
Front = left front + center front + right front
Rear = left rear + center rear + right rear
Other/Unknown = other impact + "front & rear" + unknown

Source: Motor Vehicle Accident files from State of Michigan.
Distributions based on average for calendar years
1982, 1984, and 1987.

Table 3-14

Distribution (percent) of Fire Crashes and All Crashes by Direction of Impact State of Maryland

	Passenger Cars		Light Trucks	
Point of Impact	Fire Crashes	All Crashes	Fire Crashes	All Crashes
Top	0.4% (1.2%)	0.2%	0.8% (2.2%)	0.3%
Front	24.9% (70.8%)	58.0%	27.2% (78.0%)	56.9%
Right Side	0.9% (2.7%)	6.4%	1.2% (3.3%)	5.9%
Rear	8.0% (22.6%)	28.0%	5.0% (14.3%)	27.9%
Left Side	0.9% (2.7%)	4.9%	0.8% (2.2%)	5.3%
Other/ Unknown	64.5%	2.5%	65.1%	3.7%

Data represent percent of vehicles involved by point of impact.
Numbers in paratheses are based on deletion of other/unknown category.
Front = left front + center front + right front
Rear = left rear + center rear + right rear
Other/Unknown = other + undercarriage + none/unknown

Source: Motor Vehicle Accident files from State of Maryland. Distributions based on average for calendar years 1982, 1984, and 1987.

Table 3-15
Fuel Leakage Rates for Cars and Light Trucks by Vehicle Model Year

Model Year	Fuel Leak Rate	
	Passenger Car	Light Trucks
1966	26.1	30.8
1967	23.9	28.5
1968	23.0	27.0
1969	24.4	35.3
1970	22.5	31.4
1971	20.3	25.8
1972	18.0	27.4
1973	16.5	20.4
1974	14.5	19.7
1975	12.4	19.8
1976	11.5	17.4
1977	9.3	14.3
1978	8.6	11.2
1979	7.4	10.4
1980	6.9	8.3
1981	6.0	8.1
1982	5.1	6.1
1983	5.0	6.4
1984	4.7	6.5
1985	5.0	5.2
1986	4.7	5.1
1987	5.1	6.2
AVG	9.7	11.7

---

* Rates are fuel leaks per 1,000 vehicles.
Fuel leakage is sum of Michigan codes "01," "02," "03".

SOURCE: Michigan State files for 1982 through 1987.
Total counts of fuel leakage: passenger cars-22,948; light trucks-5,565.

Chapter 4

THE BENEFITS AND COSTS OF FMVSS 301

Drawing upon the results of the effectiveness analyses discussed in Chapter 2 and selected statistical data from Chapter 3, this chapter develops estimates of the safety benefits of FMVSS 301. The costs of vehicle modifications resulting from FMVSS 301 are also developed, along with a detailed discussion of the various types of modifications made for each of the 3 vehicle classes studied in this report, passenger cars, light trucks, and school buses.

4.1 THE BENEFITS OF FMVSS 301

Of the three classes of vehicles studied in this report, statistically significant effectiveness, for FMVSS 301, was found only for passenger cars (Chapter 2). For light trucks, no significant difference - hence, no effectiveness - was found between the fire rates of vehicles manufactured before FMVSS 301, as compared to the fire rates for trucks produced subsequent to the Standard. Data were too sparse for school buses to permit reliable conclusions concerning the Standard's effectiveness. Preliminary indications, however, were that no difference existed between the fire rates Pre-standard and Post-standard buses. Therefore, estimates of safety benefits are applicable only for passenger cars.

4.1.1 BENEFITS FOR PASSENGER CARS

In Chapter 2, it was estimated that FMVSS 301 could be credited with a 14.2 percent reduction in passenger car fires in all police reported accidents. This estimate was based on analysis of the data from the three States of Michigan, Ohio, and Maryland, which were considered to have the most complete police reported accident data on vehicle fires. Also, the analyses of FARS data indicated that the Standard was not effective in reducing fires in fatal passenger car crashes.

Therefore, the task is to estimate the safety benefit of the 14.2 percent reduction in passenger car fires. Ideally, benefit estimates are in terms of numbers of crashes, and injuries avoided, if such detail can be developed from available data.

In Chapter 3, it was estimated that the total annual passenger car fires, as reported by investigating police officers in State accident files was approximately 23,600. Applying the reduction estimate, due to the Standard, of 14.2 percent yields:

$$
\begin{aligned}
\text{Reduction: } & \frac{23,600}{1 - .142} - 23,600 \\
&= 23,600 \left(\frac{1}{1 - .142} - 1\right) \\
&= 23,600\ (.1655) \\
&= 3,906
\end{aligned}
$$

This is the estimated reduction in vehicle fires, annually, once the entire passenger car population conforms to FMVSS 301 modifications. Currently, it is estimated that about 85 percent of the fleet consists of Model Year 1976 and newer vehicles.

One benefit of this reduction could be said to be the dollar value of the property damage to passenger cars of the fires avoided, apart from the value of property damage caused by crash impact forces. Data do not exist with which to estimate this value.

The next step is to consider the reduction in occupant injury due to the 14.2 percent reduction in fires. Since no effectiveness was found for fatal passenger car crashes, no reduction in fire associated fatalities can be expected. The next most serious injuries are police-reported A and B. In Chapter 2, the analyses of fire rates in injury (A + B) crashes gave inconsistent results with respect to whether or not these rates decreased for cars produced after FMVSS 301 took effect. For the 2 States, Ohio and Michigan, which had sufficient data for analyses, one (Ohio) showed a statistically significant reduction, estimated at 14.1 percent, in the fire rate for post-standard vehicle crashes while the other State (Michigan) produced a non-significant result. Although not statistically significant, the estimated difference in fire rate between pre and post-standard vehicles in the Michigan data was in the positive (i.e., the right direction for a beneficial effect of the Standard) direction with post-standard vehicles showing an estimated 10 percent lower fire rate than pre-standard vehicles.

It could be argued that since both States showed lower fire rates in injury crashes for post-standard vehicles (14 percent lower for Ohio and 10 percent lower for Michigan) that there is reasonable evidence that the Standard has had a real effect, say in the 10 to 14 percent range. However, the 10 percent estimate from the State of Michigan was not really close to being significant ($\alpha = .20$) and regardless of the actual percent estimate, the proper statistical conclusion to be drawn, is that there was <u>no</u> effect -- i.e., the 10 percent difference in fire rate is not statistically significant from zero. Since: (1) only 2 States had sufficient injury data for analyses, and (2) these 2 States gave statistically inconsistent results, it is not possible to say whether or not FMVSS 301 has been effective in reducing fires in passenger car injury crashes. Although some evidence has been produced that fire rates in injury crashes may be lower for post-standard cars, the information is insufficient for definitive conclusions to be developed.

Therefore, no estimate of burn injuries prevented can be made. Even if the analyses had shown an overall, statistically significant reduction in fires in injury crashes, it would still not be possible to convert that reduction into an estimate of the number of burn injuries prevented. This is because available accident data do not provide sufficient information to separate the role of the fire vis-a-vis the role of crash forces in causing the injury. For example, of the estimated total injuries in fire crashes (i.e., 2,900 A injuries and 4,300 B injuries) developed in Chapter 3, it is not possible to say what proportions of these injuries are burn injuries as opposed to injuries resulting from crash forces. It is reasonable to assume that all of the injuries do not result from fire.

While not definitive, 3 sources do provide some insight into the role of fire as the injury-producing agent in motor vehicle crashes. The first source comes from a study done by Cooley in the State of Michigan.[1] Using data from various sources (police reports, policeman's confidential reports, certificates of death, pathologist's reports, etc.), Cooley made a study of 81 "fire fatalities" in Michigan which occurred over a 4-year period from 1968-1971. Acknowledging that subjectivety and uncertainties were involved, he estimated that 70 percent of the deaths were either a result of the fire, or were ensured by the fire. A second source of information deals with fire in injury crashes. In 1988, an NHTSA sponsored contract study using data from the agency's National Accident Sampling System estimated that less than 10 percent of the most serious injuries occurring in passenger car crashes accompanied by fire were burn injuries. This estimate was based on a very small sample and the study did not break out burns as a percent of each severity level (i.e., A,B).[2] The last source of information on burn injuries comes from accident data files from the State of Indiana. Under a variable called "Nature of Injury," Indiana files contain burn injuries along with several other types of injuries sustained by motor vehicle drivers in crashes. The injuries are the most severe injury sustained and include the following categories: severed, internal, minor burn, severe burn, abrasion,

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[1] "Fire in Motor Vehicle Accidents," HIT LAB Reports, Highway Safety Research Institute, University of Michigan, September 1974, Vol. 5, No. 1.

[2] NHTSA Docket No. 73-20, "Study of Motor Vehicle Fires," February 1988.

minor bleeding, severe bleeding, fracture/dislocation, and contusion/bruise. Of all the injury types reported, burns (minor and severe) represented approximately eight tenths of one percent (.82 percent). These data are for all types of motor vehicle crashes, not just car crashes, and all reported crashes, not just those involving fires.[3]

Based on the above three sources of information, it appears that the bulk of the fire hazard for vehicle occupants involved in fire crashes is focused at the upper end of the severity spectrum -- i.e., the risk of serious injury or fatality. Since these crashes typically involve high levels of crash or impact severity, it is possible that these levels typically exceed the 20 to 30 mile per hour threshhold set by FMVSS 301. Data developed in Chapter 3 indicate that most fatal crashes involving fire occur at speeds higher than these.

The estimates of benefits for passenger cars in this study are lower than those estimated in the 1983 NHTSA study of FMVSS 301. The primary difference is that in the earlier study, a substantial reduction in fatalities was estimated. As was discussed in Chapter 2, the reason for this difference in findings is due to the limited amount of accident data on fires available at the time the earlier study was conducted. Only three years of data from one

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[3] NHTSA, National Center for Statistics and Analysis, Univariate frequency tables of automated motor vehicle accident data from the State of Indiana, calendar years 1982, 1983, 1989.

State was available which was not sufficient to support a thorough analysis of the effect of vehicle age on fire rates. Also only a few years of FARS data existed at that time and these were not analyzed as the primary emphasis was placed on locating State data which recorded the presence of vehicle fire in their motor vehicle accident files.

This concludes the estimates of safety benefits for FMVSS 301 since no effectiveness in fire reduction was found for light trucks or school buses.

4.2 THE IMPLEMENTATION COSTS FOR FMVSS 301

In order to estimate costs for a particular motor vehicle safety standard, it is first necessary to know what vehicle modifications were introduced in response to the standard. In the past, NHTSA has often obtained information on costs and vehicle modifications attributable to its standards through contractor conducted vehicle "tear-down" studies. The methodology used in these studies has been to disassemble component parts of vehicles which were affected by a given safety standard, to describe the modifications made, and to derive the weight differentials of these parts for vehicles produced before and after the standard went into effect. Based on the types of changes made and the resultant increase in vehicle weight, cost estimates of the modifications were developed. From these individual cost estimates, overall fleet costs were projected, based on sales-weighted data for the various vehicle make model lines represented in the tear-down studies.

FMVSS 301, unlike many other standards whose effectiveness has been analyzed in prior agency studies, did not lend itself readily to cost estimation via tear-down studies. One reason for this is that vehicle modifications made in response to the Standard were not very weight sensitive. While some modifications did produce weight increases, many of the changes required no, or negligible weight increases. In certain, few instances, no modifications of any nature were made since the manufacturer had determined that the vehicle design which existed prior to the issuance of FMVSS 301 was sufficient to satisfy the requirements of the standard. Finally, in certain other instances, although rare, modifications for FMVSS 301 resulted in the deletion of a preexisting vehicle component. Such cases would typically produce weight and cost savings, rather than weight and cost increases.

A second reason why FMVSS 301 costs are not amenable to estimation by vehicle tear-down studies is that while the Standard specifically addresses the vehicle's fuel system, many of the resulting modifications involved vehicle components which were not a part of the fuel system. In such instances, a tear-down study approach, comparing fuel system components of Pre-301 vehicles with Post-301 vehicles, would fail to isolate component modifications (and any resultant weight and cost increases) since many changes did not involve the fuel system. Only by prior knowledge of "what to look for" would the tear-down approach produce valid results, and this prior knowledge did not exist, except within the vehicle manufacturing companies.

A final, additional factor which complicates the cost estimation of FMVSS 301 via the vehicle tear-down approach is that the specific types of modifications varied widely among the different vehicle manufacturers, the various make-model lines within manufacturers, and among body styles (i.e, sedan, station wagon) within make-model lines. This wide variation of 301 modifications within the vehicle fleet not only means that the selection of a representative sample of vehicles for a tear-down study approach would be very difficult, but also cost-prohibitive due to the unusually large number of vehicles (sample size) that would be required to be disassembled.

For the above stated reasons, the primary basis for estimating the costs of FMVSS 301 has been to solicit information from the motor vehicle manufacturers. Specific questionnaires were sent to selected manufacturers requesting, by make-model line of vehicle:

(1) The types of modifications made to vehicles in response to FMVSS 301,
(2) estimates of weight increases due to the modifications,
(3) estimates of costs incurred due to the modifications,
(4) the date(s) such modifications were made.

Copies of specimen manufacturer questionnaires are contained in Appendix D. Separate questionnaires were sent for: (1) 301 modifications made for passenger cars; and for (2) 301 modifications made for light trucks, multipurpose passenger vehicles, and school buses.

Responses were received from all manufacturers. However, the degree of detail provided on 301 modifications varied considerably among manufacturers. Some companies provided a complete breakout by make-model of the specific type, weight and cost of modifications made. Others provided only summary information. In one instance, the manufacturer was not able to furnish any useful information on the type, weight, or cost of modifications. Among the factors affecting the manufacturer responses were: the extent of company records kept on 301 modifications; the availability of personnel who were with the company at the time FMVSS 301 took effect and were familiar with the modifications made for the Standard; and the time that had elapsed between the the issuance of the Standard and the time the manufacturers were surveyed.

Some of the manufacturers requested confidential treatment for the information they provided on the basis that the information was proprietary in nature. For this reason, the information in this section of the report has been summarized into general categories relating to the changes made for passenger cars, light trucks, and school buses. Specific data relating changes to individual manufacturers have been omitted, along with manufacturer names.

The information in the following sections concerning FMVSS 301 modifications, weight, and cost for passenger cars has been adapted from the Agency's 1983 report, the initial evaluation of the Standard as it applied to passenger cars.[4] The information was developed from data supplied by the motor vehicle manufacturers in response to a "special order" request from the NHTSA. The information in the following Sections concerning 301 modifications, weight, and cost for trucks, MPV's and buses

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[4] "Evaluation of Federal Motor Vehicle Safety Standard 301 - 75, Fuel System Integrity: Passenger Cars", Op Cit.

is also based on manufacturer furnished data. These data were obtained in a special, more recent request, which was conducted in support of this second evaluation study of FMVSS 301. Manufacturers did not request confidential treatment for the data on light trucks, MPV's and buses.

4.2.1 THE NATURE OF VEHICLE MODIFICATIONS MADE FOR FMVSS 301.

The purpose of FMVSS 301 is to reduce the likelihood of fuel spillage, given crashes involving frontal, side, or rear impacts, or crashes in which the vehicle rolls over. Of course, the less likely fuel spillage is to occur, the less likely a fire is to occur. Consequently, the vehicle modifications instituted in response to the Standard were aimed at providing greater protection to the vehicle's fuel system during a crash situation. Table 4-1 lists the various components of the fuel system. The primary components are the fuel tank, fuel lines, fuel pump, carburetor or injection pump, and fuel filter.

Although not specifically a part of the basic fuel system, the fuel vapor (evaporation control) system is also included here since it is connected to primary fuel system components (fuel tank, carburetor) via fuel vapor lines. Therefore, it is conceivable that modifications made as a result of FMVSS 301 could involve the evaporation control system, as well as the basic fuel system. The purpose of the evaporation control system is to capture fuel vapors which can be emitted from the fuel system, in order to control environmental emissions. Figure 4-1 illustrates a typical layout of the fuel system for passenger cars.

TABLE 4-1
FUEL SYSTEM COMPONENTS

1. Fuel tank

    - fuel filler neck
    - fuel filler (gas) cap
    - fill vent tube, vapor tubes
    - tank mounting straps
    - tank mounting bolts, anchors
    - fuel gage sensor/sending unit
    - fuel tank skid plates/pads

2. Fuel lines

    - supply, return lines
    - connecting hoses, clamps
    - line clips/retainers

3. Fuel pump

    - mounting bolts
    - line fittings

4. Fuel evaporation (emissions) control system

    - vapor storage canister, air filter
    - vapor lines
    - connecting hoses, clamps
    - purge valve

5. Carburetor, Injection pump, injectors

6. Fuel filter

    - connecting hoses/housing, clamps

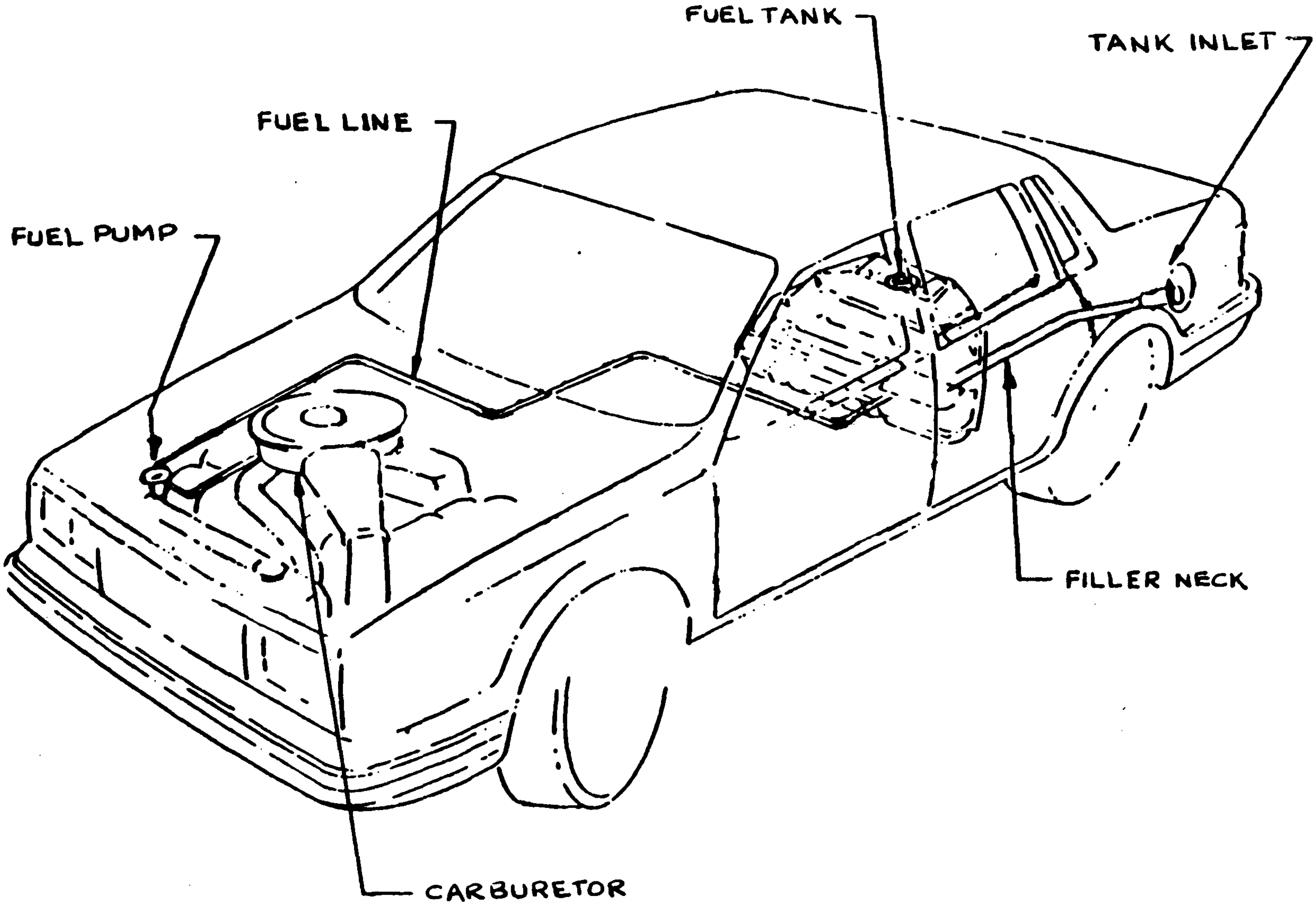

Figure 4-1
Typical Fuel System
Passenger Car

Table 4-2 summarizes the various modifications made to passenger cars in response to FMVSS 301,[5] and is based on the information provided by the vehicle manufacturers.

It is important to note that Table 4-2 is an exhaustive listing of all the <u>types</u> of modifications made to passenger cars by all manufacturers. The specific modification(s) made to a given vehicle, varied widely among the different vehicle manufacturers and also among vehicle lines (make/models) within manufacturers. Some vehicles received only a single, minor modification, such as redesign of the sealing ring of the filler pipe cap (gas cap). In contrast, other vehicles required several changes, entailing not only the redesign of certain existing components, but the addition of new components, such as a fuel tank shield, as well.

As Table 4-2 shows, many of the modifications involved the fuel system itself, primarily the fuel tank. In general, the various modifications made were to strengthen the fuel system components against damage due to a vehicle crash. More specifically, the changes were intended to reduce the chances of fuel system components being contacted by other vehicle components, and to minimize the chances of fuel system component puncture or dislodgment, given a crash.

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[5] Adapted from "Evaluation of Federal Motor Vehicle Safety Standard 301-75, Fuel System Integrity: Passenger Cars, DOT HS-806-335, NHTSA Technical Report, January 1983.

Table 4-2 - SUMMARY OF TYPES* OF VEHICLE MODIFICATIONS MADE TO PASSENGER CARS IN RESPONSE TO FEDERAL MOTOR VEHICLE SAFETY STANDARD 301

Vehicle Components Affected

Fuel System Components	Modifications Made in Response to FMVSS 301
Fuel Tank	- Increase gauge of tank material - Add protective shield - Recontour to minimize contact/puncture by other adjacent vehicle components. - Strengthen/shield filler neck - Increase strength of solder/weld seams - Strengthen mounting by adding brackets, revising mounting bolts, increasing torque of mounting straps. - Strengthen filler cap seal, improve impact resistance. - Strengthen mounting of fuel gage sensor
Fuel Lines	- Recontour
Fuel Evaporation Control System	- Recontour, revise vapor lines; revise clamps
Fuel Pump	- Provide shield
Other Vehicle Components	
Rear Floor Pan/Support Rails/Wheel Housing	- Revise, add supports
Rear Suspension (Springs, Shock Absorbers)	- Change support brackets, revise mounting bolts, revise mounting procedure, add shield
Rear Axle Assembly	- Minor changes in contour of lines, screw heads, mounting clips; recontour vent cover

Table 4-2 (continued)

Vehicle Components Affected (cont.)

Other Vehicle Components (cont.)	Modifications Made in Response to FMVSS 301
Tailgate (station wagon)	- Revise hinge assembly
Seat Belt Brackets	- Revise anchorage
Engine Mount	- Slight revision
Power Steering Pump Bracket	- Slight revision

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* This table is an exhaustive listing of all the types of vehicle modifications listed by the automotive manufacturers. The table should not be interpreted as changes that were made to all vehicles. Actual modifications varied widely among manufacturers and also among the makes, models, and body styles within manfacturers. Some vehicles received several changes, some received few changes, and others received minor changes or no changes at all. Also, some manufacturers were not able to provide information as to the types of modifications made to their vehicles in response to FMVSS 301.

While many changes involved the fuel systems, the table also shows that several modifications for 301 involved other vehicle components as well. Among these were the vehicles' rear floor pan and support rails, rear suspension system, rear axle, engine mounts, and power steering pump. Similar to the modifications made to the fuel system components, however, all changes made to these other vehicle components had the same objective - to minimize the chances of dislodgment or puncture of fuel system components, given a crash. For example, the changes to the rear axle assembly (contour of lines, screwheads, mounting clips) were primarily intended to reduce the chances of fuel tank or fuel line puncture, given a rear end impact.

4.2.1.2 Modifications Made to Light Trucks and Buses

Table 4-3 is similar to Table 4-2 and summarizes the types of modifications made to light trucks, multipurpose passenger vehicles, and buses in response to FMVSS 301.[6] As can be seen, the vehicle components affected are essentially the same for trucks as they were for passenger cars. The fuel tank, as expected, was the subject of a rather large number of modifications. As noted previously for passenger cars, the modifications listed in Table 4-3 are not to be interpreted as having been made to all truck or bus fuel tanks. While changes varied rather widely between vehicle make models and manufacturers, most vehicles were subjected to only a few types of changes. In rare instances, vehicles received rather extensive modifications.

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[6] Light trucks, multipurpose passenger vehicles, and buses are defined as having Gross Vehicle Weight Ratings (GVWR) of 10,000 pounds, or less. FMVSS 301 also applies to school buses with GVWR greater than 10,000 pounds.

Table 4-3

SUMMARY OF TYPES* OF VEHICLE MODIFICATIONS MADE TO TRUCKS, MULTIPURPOSE PASSENGER VEHICLES, AND BUSES IN RESPONSE TO FEDERAL MOTOR VEHICLE SAFETY STANDARD 301

Vehicle Components Affected	Modifications Made in Response to FMVSS No. 301
Fuel System Components	
Fuel tank	o redesign of fuel tank
	o reinforcement of fuel filler neck
	o redesign of fuel filler neck
	o increased length of fuel filler hose
	o redesign of fuel cap
	o revised fuel tank straps
	o added fuel tank straps
	o revised fuel tank mountings
	o revised skid plates
	o revised pads between fuel tank and skid plates
	o increased clearance between fuel tank and vehicle under-body
	o addition of rollover valve
	o revised liquid check valve
	o revised technique for forming flanges
	o upgraded solder joints
	o added inspection for cleanliness, integrity of solder connections (to ensure good hose seals).
	o revised fill vent tube and vapor tubes
	o upgraded pressure testing of tank assemblies
	o modified or eliminated tank baffles
	o revised fuel gage assembly and connectors (auxiliary fuel tanks)
	o elimination of auxiliary fuel tank
	o reinforcements of tank at mounting points
	o increased clearance between fill pipe and adjacent vehicle outer body sheet metal
	o increased gage of tank sheet metal
	o revised tank molding technique to assure more uniform wall thickness
	o relocation of fill pipe opening
	o added fill pipe housing/retainer
	o deleted fill pipe housing
	o added sleeve for vent hose support

Table 4-3 (continued)

Vehicle Components Affected	Modifications Made in Response to FMVSS No. 301
Fuel System Components	
Fuel lines	o revised fuel lines o added check valve in fuel return line o rerouted fuel lines o upgraded armoring of fuel lines o increased number of line clips o upgraded torque requirements for fuel system connectors with controlled clamping load o replaced spring-type hose clamps with screw-type hose clamps
Fuel pump, Injection pump	o added gravity valve to fuel pump o added pump blocker to injection pump (diesel engines)
Fuel Evaporation (i.e., fuel emissions) Control System	o relocated vapor tubes on underbody crossmember o revised vapor lines
Body/Underbody Frame Components	o reinforcement of rear frame o reinforcement of rear body mountings o changes in rear body/frame o elimination of pintle hook o elimination of rear step bumper o redesigned draw bar o redesigned bumperette mountings o increased size of body mount bolts, washers o reshaped outer body sheet metal (to accommodate recessed fuel filler cap) o revised left rear quarter panel o revised mounting of spare tire o addition of metal cage around fuel tank* o slight modification in body skirt and skirt supports* o addition of plastic shield for rear of fuel tank o addition of protector for fuel tank o reinforcement of outer body sheet metal at fill pipe opening o reinforcements to B-pillars at points of fuel tank attachment o towing packages restricted to certain vehicle models o towing packages redesigned for availability on all vehicle models

Table 4-3 (continued)

Vehicle Components Affected	Modifications Made in Response to FMVSS No. 301
Body/Underbody Frame Components	
Rear Suspension	o upgraded rear spring center bolts
Other Vehicle Components	
Alternator Mounting Bracket	o modified alternator mounting bracket

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* This table is an exhaustive listing of all the types of vehicle modifications listed by the automotive manufacturers. The table should not be interpreted as changes that were made to all vehicles. Actual modifications varied widely among manufacturers and also among the makes, models, and body styles within manufacturers. some vehicles received several changes, some received few changes, and others received minor changes or no changes at all. Also, some manufacturers were not able to provide information as to the types of modifications made to their vehicles in response to FMVSS 301.

** Only applies to large school buses, i.e., buses with GVWR >10,000 pounds.

The table is an exhaustive listing of all types of modifications made, across all manufacturers and make/model lines, based on the information received from the special request to manufacturers.

For trucks, a rather large number of 301 modifications involved body, underbody, and frame components. As noted in Table 4-3, changes were made to rear sheet metal, rear bumpers, the mounting of spare tires, trailer towing packages, and the vehicle's B-pillars. The changes to B-pillars involved certain pickup truck lines with metal fuel tanks located in the truck cab, behind the seat. These changes were to strengthen the points at which the tanks were attached to the B-pillar supports.

One unusual type of vehicle modification for 301 is noted in the body/underbody/frame category -- the elimination of certain components which were part of the Pre-301 vehicle design. Two specific examples of this are the elimination of a rear step bumper and the elimination of a pintle hook. These examples of the deletion of certain components in response to FMVSS 301 requirements represent very rare cases. In fact, these are the only known instances of component elimination. The vast majority of modifications for 301 involved either changes to existing vehicle components or the addition of new components. While component modification and addition of new components are potential areas of weight and cost increases, component deletion produces just the opposite -- a decrease in vehicle weight and cost.

Another modification in Table 4-3 which falls, at least partially, in the category of component elimination is the "restriction of trailer-towing packages to certain vehicle models." While trailer-towing packages were optional equipment, on certain truck models, as compared to step bumpers and pintle hooks, which were standard equipment, the deletion of the towing package option nonetheless resulted in a reduction in both vehicle weight and cost.[7]

4.2.1.3 Modifications Made to Large School Buses

One other modification to be noted in Table 4-3, under body/frame changes, is the addition of a metal cage around the fuel tank. This type of modification was peculiar to large school buses (i.e., buses with Gross Vehicle Weight Rating (GVWR) above 10,000 pounds). Large school buses (also referred to as conventional or transit coach school buses) are constructed using a frame-rail chasis. Fuel tanks for these vehicle are typically mounted on the right, outside frame rail, slightly rear of the passenger entrance door, and just

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[7] The normal interpretation of the cost of a vehicle safety standard, according to NHTSA's established methodology for conducting effectiveness evaluations, is the cost to the consumer. The vehicle manufacturer incurs a cost for vehicle modifications made in response to the standard, and this cost is typically passed on to the consumer (vehicle purchaser) via the car dealer. These modifications typically involve changes to existing vehicle components, or the addition of new components.

In the rare cases where components are deleted for the purpose of complying with a safety standard, it is possible to argue that there is a cost, to the manufacturer, in the form of foregone profit. Such an argument is perhaps more tenable if the deleted items were extra cost options (such as trailer-towing packages).

behind the bus body skirt. The only Pre-301 vehicle structure affording protection to the tank, from side impact, was the bus body skirt which consisted of sheet metal. In order to comply with FMVSS 301, large school buses were modified to incorporate a heavy gage steel cage around the fuel tank (Figure 4-2).

Most large school buses are constructed in a two-phase process. School bus companies purchase cab-chassis (including engine) which are built by one of the major truck companies (i.e., Navistar International, Chevrolet, or Ford). Stage one of the school bus construction is the production of the cab chassis. Stage two of the construction is the mounting of the school bus body onto the cab-chassis. In general, it is the responsibility of the cab chassis manufacturer to provide fuel system protection which complies with FMVSS 301.

Some school bus companies do build a limited number of large buses in which they not only construct the bus body, but the chassis as well. (The engine-drive train components are still furnished by a major motor vehicle manufacturer.) These buses are typically referred to as "transit coach" type buses, and are the largest school buses produced, having passenger capacities as high as 70 to 90. In these cases, the school bus manufacturer, since he builds the chassis as well as the bus body, has responsibility for certifying that the bus complies with FMVSS 301 and therefore installs the steel cage around the fuel tank. At least one manufacturer of the large transit coach bus goes a step further in protecting the fuel tank from crash damage. In addition to placing the steel cage around the tank, the manufacturer also locates the tank inboard, between the frame rails, rather than outboard on the right side frame rail. The large frame rails, on either side, provide an additional measure of crash protection for the fuel tank.

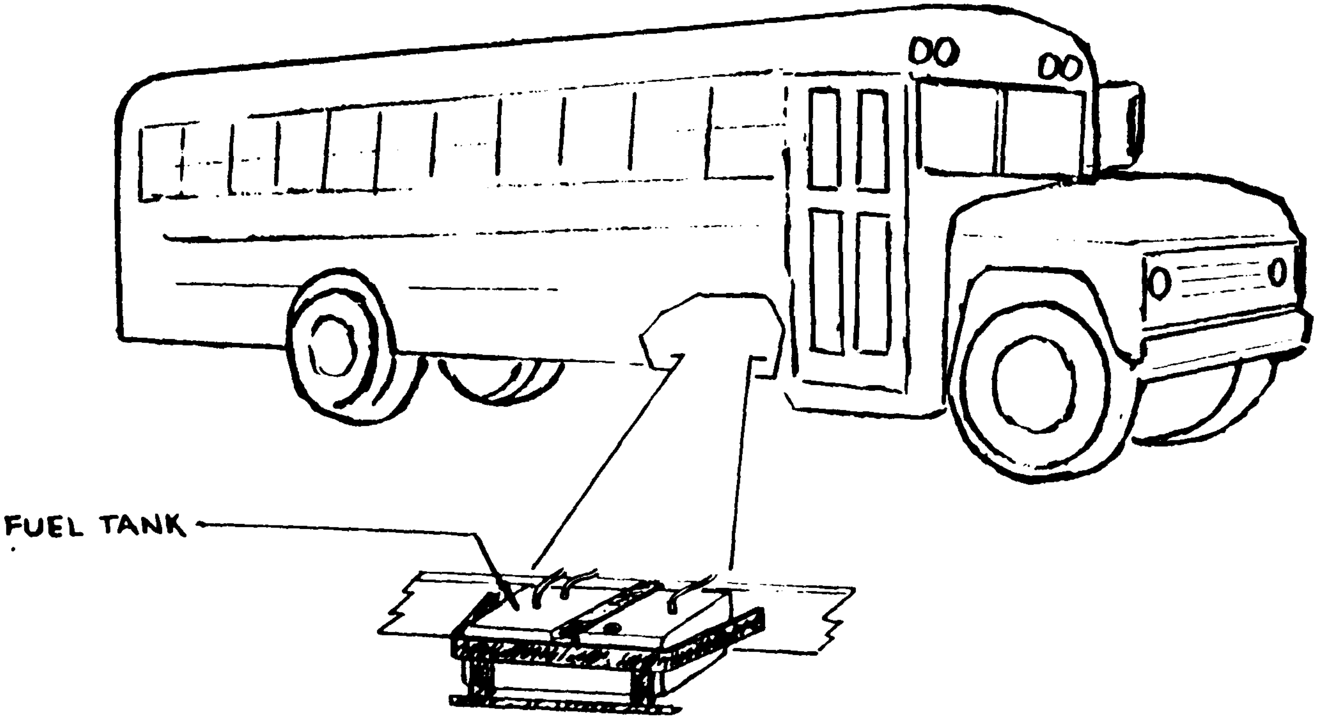

Figure 4-2

Fuel Tank Shield
Type I School Bus

In concluding this section on fuel system integrity modifications to large school buses, it should be noted that the NHTSA is currently engaged in rulemaking action that could result in more stringent requirements for school buses.[8]

4.2.2 THE WEIGHT AND COST OF VEHICLE MODIFICATIONS MADE FOR FMVSS 301

As stated previously in Section 4.2, the data for estimating the costs and weight of FMVSS 301 were obtained from a special request of the motor vehicle manufacturers concerning cost and weight of modifications by vehicle make/model. Separate requests were made for passenger cars, and for light trucks and buses.

Generally, the data received on passenger cars were more detailed than the data received on trucks and buses. Several manufacturers furnished both cost and weight estimates for passenger cars by individual car line or make/model series. For trucks and buses, less detailed data were supplied by the manufacturers. The cost and weight information for these vehicles was typically in the form of average figures for a manufacturer's entire light truck and bus line. No detail was provided as to cost and weight changes to individual make/models. However, manufacturers did provide specific estimates of the cost and weight of 301 modifications made to large school buses (i.e., buses with GVWR $\geq$ 10,000 pounds).

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[8] Preliminary Regulatory Evaluation, **ANPRM** to Upgrade FMVSS No. 301 Fuel System Integrity, Office of Regulatory Analysis, Plans and Policy, National Highway Traffic Safety Administration, December 1988.

The cost and weight data received from the manufacturers has been combined with vehicle sales data to produce sales-weighted averages of the entire fleet of vehicles, both domestic and import, for the particular years in which the versions of FMVSS 301 became effective. Estimates are developed for three classes of vehicles: passenger cars, light trucks, and school buses. The light truck category includes pickup trucks, vans, multipurpose passenger vehicles, and buses, all with gross vehicle weight ratings (GVWR) equal to or less than 10,000 pounds. For school buses, estimates are made for both large buses (i.e., GVWR greater than 10,000 pounds), and small buses (GVWR equal to or less than 10,000 pounds).

It is noted that the sample of weight and cost data upon which the sales-weighted fleet estimates are based do not constitute a representative (i.e., random) sample in a statistical sense. While all major domestic manufacturers and a sample of foreign manufacturers were surveyed, not all were able to provide data on cost and weight of FMVSS 301 modifications. Also, in several instances, the individual cost and weight data received were manufacturer estimates, rather than actual figures, based on company records. In most of these instances, specific cost and weight data were not available within the company. In one instance (for light trucks), a major manufacturer was not able to provide any estimates of cost or weight, and in certain other instances (again for light trucks), manufacturers could only provide general aggregate estimates of 301 costs and weight. over all truck lines. Overall, the data were more detailed for passenger cars than for trucks; cost and weight estimates for cars were typically provided by individual make/model series.

4.2.2.1 Cost and Weight of FMVSS 301 for Passenger Cars

Cost and weight estimates of FMVSS 301 for passenger cars were developed as part of the initial evaluation study [9] of the standard. These estimates are the average (i.e., sales or production weighted) incremental increases, per vehicle for 1977 Model Year cars, as compared to 1976 Model Year cars.

These estimates are:

Average cost increase: $3.10 per vehicle.
Average weight increase: 3.07 lbs. per vehicles.

The cost is the cost to the consumer (vehicle buyer), in 1977 dollars, for FMVSS 301. It includes the variable cost to the manufacturer, the fixed cost to the manufacturer, and an allowance for dealer markup. [10] Updating the 1977 figure to current (1988) economics yields:

Average cost increase: $5.63 per vehicle (1988 dollars).

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[9] "Evaluation of Federal Motor Vehicle Safety Standard 301-15, Fuel System Integrity: Passenger Cars", Op. Cit.

[10] The earlier evaluation study gave the consumer cost of FMVSS 301 as $4.60 per vehicle. This was in terms of 1982 economics, which was consistent with the date of publication of the earlier study.

4.2.2.2 Cost and Weight of FMVSS 301 for Light Trucks

Cost and weight estimates of FMVSS 301 for light trucks were developed from manufacturer data solicited as part of this evaluation study.[11] The truck estimates are the sales-weighted averages, per vehicle, for 1978 Model Year trucks as compared to 1977 Model Year trucks.[12] Included in the light truck category are all trucks in the two weight categories (GVWR $\leq$ 6,000 pounds; and 6,000 pounds < GVWR < 10,000 pounds) of the following types: pickups, multipurpose passenger vehicles, vans, and buses.

The estimates for light trucks are:

Average cost increase: $11.76 per vehicle

Average weight increase: 7.76 lbs. per vehicle.

The consumer cost of $11.76 is in 1978 dollars. Updating this to 1988 economics gives:

Average cost increase: $19.94 per vehicle (1988 dollars)

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[11] See manufacturer questionnaire, Appendix D.

[12] Statistical data on sales, number of production units taken from: (1) "Wards Automotive Reports," Vol. 53, No. 7, February 13, 1978; Vol. 53, No. 2, January 9, 1978; Vol. 53, No. 3, January 16, 1978; Vol. 54, No. 2, January 8, 1979; Vol. 54, No. 3, January 15, 1979; Vol. 53, No. 9, February 27, 1978; Vol. 54, No. 9, February 26, 1979. (2) "Automotive News, 1978 Market Data Book Issue," April 26, 1978.

4.2.2.3 Cost and Weight of FMVSS 301 for School Buses

Cost and weight estimates of FMVSS 301 for school buses were developed from the manufacturer data requested as part of this study (see Appendix D). The data covered both trucks and school buses. Estimates of cost and weight increases are produced for both small school buses and large school buses. Small buses are defined as having GVW ratings less than 10,000 pounds and large buses as having GVW ratings greater than 10,000 pounds. It will be recalled that FMVSS 301 only applies explicitly to large buses. However, school buses in the 10,000 pound or less category are covered, implicitly, by the Standard in the sections that apply to "vehicles with GVWR of 6,000 pounds or less, and vehicles with GVWR of more than 6,000 pounds but not more than 10,000 pounds. Many small school buses are built on a van chassis, sometimes referred to as a van, "front section," or a van, "cut-away chassis."

The type of 301 modification made to large buses -- a steel cage around the fuel tank -- was described in the preceding section. The modifications made to small school buses are among those types listed in Table 4-3 (excluding steel cages around the fuel tank).

For large school buses, the cost and weight estimates of 301 modifications are:

Cost increase, per vehicle = \$100.00 [1978 dollars]
= \$169.53 [1988 dollars]

Weight increase, per vehicle = 140.5[13] pounds

For small school buses, the cost and weight estimates of 301 modifications are the same as for light trucks, i.e.,[14]

Cost increase, per vehicle = \$11.76 [1978 dollars]

= \$19.94 [1988 dollars]

Weight increase, per vehicle = 7.76 pounds

4.2.3 The Overall Cost of Standard 301

In the preceding section, the per vehicle weight and cost estimates for FMVSS 301 modifications have been developed. The cost estimate is the incremental increase in the (new) vehicle purchase cost borne by the vehicle

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[13] The estimates of 140.5 pounds, per vehicle, assumes the standard 60, 65 gallon fuel tank for the large (Type I) school bus. Some large school buses are equipped with smaller 22 and 35 gallon tanks, which require smaller protective steel cages weighing about 100 pounds, or some 42.5 pounds less than the average estimated cage weight for large buses. While no estimate is available for the proportion of large buses with 22, 35 gallon fuel tanks, it is assumed their number would be small as compared to the number with 60, 65 gallon tanks.

[14] As noted above, small buses are often built on a van chassis. Manufacturer submitted data was typically aggregate in form, and therefore did not permit separation of weight and cost changes by specific type of truck within the light truck category.

buyer. In order to arrive at the total, or overall cost to the consumer, it is customary, in the Agency's evaluation studies, to also consider the additional fuel required to transport the increase in vehicle weight due to the modifications. This fuel cost would be an operational cost, over the lifetime of the vehicle, also to be borne by the original buyer and any subsequent owners. Adding this fuel cost to the vehicle purchase cost gives a total, vehicle lifetime estimate of the cost of FMVSS 301.

4.2.3.1 Fuel Costs of FMVSS 301

For purposes of estimating fuel costs for FMVSS 301, the following data and assumptions have been used:

Average total miles, per vehicle = 100,000
(vehicle lifetime mileage for passenger car, light truck or school bus)

Average on-road miles per gallon:[15]

Passenger car = 15.2 miles per gallon
Light truck (pickup, van, MPV) = 13.2 miles per gallon
Small (Type II) school bus = 9.5 miles per gallon
Large (Type I) school bus = 7.5 miles per gallon

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[15] Miles per gallon for passenger cars and light trucks taken from: "Fuel Economy and Annual Travel for Passenger Cars and Light Trucks: National On-Road Survey," NHTSA Technical Report, DOT HS 806 971, May 1986. Miles per gallon for school buses are estimates.

Average, on-road gross vehicle weight:[16]

Passenger car - 3,500 pounds

Light truck - 4,000 pounds

Type I school bus - 20,000 pounds

Type II school bus - 10,000 pounds

Average lifetime fuel consumption, per pound of additional weight due to FMVSS 301:[17]

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[16] Weight estimates are for vehicles of 1976-1977 model year vintage - the period when the Fuel System Integrity Standard became effective.

[17] Fuel consumption estimates are based on the assumption that fuel usage bears an essentially linear relationship to vehicle weight. This follows from the linear relationship between a vehicle's weight and its resistance to motion ("Fuel Economy Trends and Catalytic Devices," SAE Paper by Robert C. Stempel and Stuart W. Marters, General Motors Corporation, published in "Automotive Fuel Economy," Selected SAE Papers 1965-1975). Fuel consumption is in terms of gallons/mile, or the reciprocal of miles per gallon. The form of the relationship is:

$$\frac{1}{MPG_{Post301}} = \frac{W_{Post301}}{W_{Pre301}} \left(\frac{1}{MPG_{Pre301}} \right)$$

where MPG is miles per gallon, W is vehicle weight, in pounds, and subscripts Pre 301 and Post 301 denote, respectively, vehicles produced before and after FMVSS 301 took effect.

Passenger car - 1.8795 gal/lb.

Light truck - 1.8875 gal/lb.

Type I school bus - 0.6648 gal/lb.

Type II school bus - 1.0567 gal/lb.

The additional lifetime fuel costs due to the 301 modifications can now be estimated for the four vehicle types. The following formula is used:

$$LC = WF \sum_{i=1}^{n} f_i C_i D_i$$

where, LC = lifetime fuel cost, in 1988 dollars,

W = weight of Standard 301 modifications, in pounds,

F = lifetime fuel consumption, in gallons/pound,

f_i = the fraction of total lifetime vehicle miles travelled in year i of the n-year, total vehicle lifespan.

C_i = fuel cost for year i, in 1988 dollars/gallon,

D_i = discount rate.

For purposes of estimation, it is assumed that the average vehicle lifespan is 15 years, and that the lifetime mileage of 100,000 is distributed over the 15 years according to the data given in Table 4-4. This distribution of miles travelled by vehicle age incorporates a vehicle survivability factor which is defined as the probability that a vehicle will survive (i.e., still be "on the road") at "i" years of age. Vehicle travel by vehicle age are only available for passenger cars and light trucks. Therefore, in estimating fuel penalty costs for school buses, the travel distribution for light trucks will be used.

Fuel price estimates are for gasoline for the years 1989-2003 and are listed in Table 4-5. A discount rate of 10 percent (Table 4-6) has been used to estimate the present value of fuel consumed in the 14 years beyond 1989.

Substituting into the above formula, the lifetime fuel cost for FMVSS 301, for passenger cars, can now be estimated:

$$LFC = 3.07 \text{ lb. } (1.8795 \text{ gal./lb.}) \sum_{i=1}^{15} f_i C_i D_i$$

Using the appropriate data from Tables 4-4, 4-5, and 4-6, the summation factor is computed to be \$0.70/gallon, the present value per gallon of future fuel consumed. The fuel cost of the standard is therefore:

$$LFC = 3.07 \text{ lbs. } (1.8795 \text{ gal./lb.}) (\$0.70/\text{gal.}) = \$4.04$$

Performing the same computations for light trucks, Type I (large) school buses, and Type II (small) school buses gives the following fuel cost estimates:

Light trucks

LFC = 7.76 lbs (1.88747 gal./lb.) ($0.68469/gal.) = $10.03

Type I school buses

LFC = 140.5 lbs (0.6648 gal./lb.) ($0.68469/gal.) = $63.95

Type II school buses

LFC = 7.76 lbs (1.0567 gal./lb.) ($0.68469/gal.) = $5.61

Table 4-4

Estimated Proportion of Vehicle Miles Travelled Per Calendar Year, Passenger Cars and Light Trucks*

Calendar Year	Proportion Vehicle Miles Travelled Passenger Cars	Light Trucks
1989	.183	.181
1990	.163	.154
1991	.155	.144
1992	.124	.104
1993	.103	.079
1994	.088	.063
1995	.043	.052
1996	.034	.043
1997	.026	.032
1998	.020	.027
1999	.015	.023
2000	.011	.020
2001	.009	.016
2002	.007	.014
2003	.017	.047

* Estimates of proportion of miles travelled include both estimates of miles travelled, by vehicle age, and vehicle survivability factors (i.e., probability that a given vehicle will survive to age 1,2,3,...15 years). Vehicle mile and survivability estimates are taken from "Fuel Economy and Annual Travel for Passenger Cars and Light Trucks: National On-Road Survey," DOT HS 806 971, NHTSA Technical Report, May 1988. Primary source for survival data: "Scrappage and Survival Rates of Passenger Cars and Trucks in 1970-1982," P. Hu, Transportation Energy Group, Oak Ridge National Laboratory, August 10, 1983. Report DOT HS 806 971 assumed a 20-year vehicle life; therefore, vehicle miles occurring within the 16-20 year span are assumed to occur in year 15, for purposes of this study.

TABLE 4-5

Estimated Fuel Prices for Lifetime Fuel Penalty Costs

Year	Estimated Cost* of Gasoline
1989	$0.824
1990	0.864
1991	0.898
1992	0.929
1993	0.983
1994	1.039
1995	1.093
1996	1.147
1997	1.203
1998	1.256
1999	1.289
2000	1.319
2001	1.374
2002	1.427
2003	1.475

* Price projections are in 1988 dollars. Projections for individual years, 1989-2000 are from the U.S. Department of Energy, Energy Information Administration "1989 Annual Energy Outlook, Long Term Projections." DOE projections for "dollars per million BTU" were converted to dollars per gallon using 125,071 BTU's per gallon of gasoline (derived from DOE/EIA "Monthly Energy Review," November 1988. Fuel prices for years 2001-2003 were calculated using Implicit GNP Price Deflator and gasoline price deflator forecasts, DRI Forecast Trend 25YR0189, Long Term Review (Winter 1988-89).

NOTE: The above price projections do not include the effect of the rise in prices at the pump which occurred in late Spring, 1989. This increase was rather substantial and, if sustained, would mean that the fuel price projections used in this study would be underestimated.

Table 4-6

Discount Factors for Estimating Present Value of Future Fuel Consumption

Year of Consumption	Discount Factor
1989	1.0000
1990	.9091
1991	.8264
1992	.7513
1993	.6830
1994	.6209
1995	.5645
1996	.5132
1997	.4665
1998	.4241
1999	.3855
2000	.3505
2001	.3186
2002	.2897
2003	.2633

For discount rate = 10 percent per OMB Circular No. A-94, March 27, 1972.

4.2.3.2 Total Costs of FMVSS 301

The total consumer costs of the fuel system integrity standard can now be computed as the sum of: (1) the cost of the actual hardware modifications made to the vehicle, and (2) the cost of the additional fuel required to transport the weight of those modifications. On a per vehicle basis, these costs in 1988 dollars, for the 4 vehicle types are:

Passenger car: $5.63 (modification cost) + $4.04 (fuel cost) = $9.67

Light truck: $19.94 (modification cost) + $10.03 (fuel cost) = $29.97

Type I school bus: $169.53 (modification cost) + $63.95 (fuel cost) = $233.48

Type II school bus: $19.94 (modification cost) + $5.61 (fuel cost) = $25.55

It may be recalled that in the effectiveness analysis, large and small buses could not be broken out, and hence the effectiveness estimates applied to the entire national school bus fleet. Therefore, a cost estimate for the entire fleet is also given.

Type I school buses account for about 85 percent of the total school bus fleet, with Type II buses comprising the remaining 15 percent. An average cost of the 301 Standard for the entire school bus fleet would therefore be:

.85 ($233.48) + .15 ($25.55) = $202.29, or

approximately $200.

The average weight of the FMVSS 301 modifications corresponding to this overall average fleet cost is:

.85 (140.5 lbs.) + .15 (7.76 lbs.) = 120.6 lbs.

A few observations can be made concerning the overall costs of the fuel system integrity standard:

- Fuel costs represent a substantial portion of total cost, ranging from 22 percent, for small school buses, to a high of 42 percent for passenger cars. Furthermore, it is possible that the fuel cost may be underestimated. This is because the latest available gasoline cost data (i.e., Table 4-5) from the Department of Energy do not include the effect of the rather substantial rise in "price-at-the pump" which occurred in late Spring of 1989. This rise was approximately $0.25/gallon or 30 percent higher than the 1989 per gallon price listed in Table 4-5.[18] While it is admittedly a

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[18] Per Lundberg Survey of gasoline prices, U.S. average price was $1.07 per gallon (per July 1989 article in "USA Today").

difficult exercise to try to project the effect of this 30 percent increase into the 15 year future, it is nonetheless considered likely that it will result in higher pump prices in the near future (i.e., initial 2-3 years) than those given in Table 4-5. Since fuel costs of FMVSS 301 are concentrated in the early years of vehicle life -- owing to the concentration of vehicle miles driven during these same years -- this would constitute yet a second reason to suspect that the fuel cost (and hence total cost) of 301 may be underestimated in this study.

- Modification costs are greater for larger, heavier vehicles, ranging from $5.63 for passenger cars to $169.53 for large school buses.

- With respect to the accuracy of the overall cost estimates (modification plus fuel), it is acknowledged that uncertainty exists. The manufacturer-supplied data on vehicle modifications for FMVSS 301 varied widely with some companies providing quite detailed data while others provided only general data, or no data at all. In this latter instance, the manufacturer stated that it was not possible to develop cost data specific to FMVSS 301.

On the fuel cost side, estimates are subject to uncertainties as well, as evidenced by a review of historical, multi-year gasoline price projections as contrasted with the actual prices which occurred for those periods. For example, in the early 1980's, gasoline prices were projected to climb stadily over the next decade and beyond. In actuality, prices fell in the mid-eighties. On the other hand, projections for the late eighties had prices considerably lower than actually occurred (i.e., the gasoline price rise in early 1989).

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Appendix A

Federal Motor Vehicle Standard 301;

Fuel System Integrity

(49 Code of Federal Regulations,
Parts 400 to 999, October 1, 1984)

HEMISPHERICAL HEAD FORM BASE

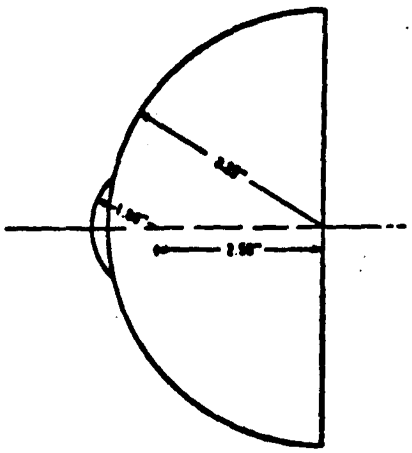


FIGURE 2

(Secs. 103, 119, Pub. L. 89-563, 80 Stat. 718 (15 U.S.C. 1392, 1407); Sec. 203, Pub. L. 93-492, 88 Stat. 1470 (15 U.S.C. 1392); delegation of authority at 49 CFR 1.50)

[41 FR 4016, Jan. 28, 1976, as amended at 41 FR 28528, July 12, 1976; 41 FR 36027, Aug. 26, 1976; 41 FR 54945, Dec. 16, 1976; 42 FR 64120, Dec. 22, 1977; 43 FR 9150, Mar. 6, 1978; 44 FR 18675, Mar. 29, 1979; 48 FR 12386, Mar. 24, 1983]

§ 571.301 Standard No. 301; Fuel system integrity.

S1. *Scope.* This standard specifies requirements for the integrity of motor vehicle fuel systems.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries occurring from fires that result from fuel spillage during and after motor vehicle crashes.

S3. *Application.* This standard applies to passenger cars, and to multipurpose passenger vehicles, trucks, and buses that have a GVWR of 10,000 pounds or less and use fuel with a boiling point above 32° F, and to schoolbuses that have a GVWR greater than 10,000 pounds and use fuel with a boiling point about 32° F.

S4. *Definition.* "Fuel spillage" means the fall, flow, or run of fuel from the vehicle but does not include wetness resulting from capillary action.

S5. *General requirements.*

S5.1 *Passenger cars.* Each passenger car manufactured from September 1, 1975, to August 31, 1976, shall meet the requirements of S6.1 in a perpendicular impact only, and S6.4. Each passenger car manufactured on or after September 1, 1976, shall meet all the requirements of S6, except S6.5.

S5.2 *Vehicles with GVWR of 6,000 pounds or less.* Each multipurpose passenger vehicle, truck, and bus with a GVWR of 6,000 pounds or less manufactured from September 1, 1976, to August 31, 1977, shall meet all the requirements of S6.1 in a perpendicular impact only, S6.2, and S6.4. Each of these types of vehicles manufactured on or after September 1, 1977, shall meet all the requirements of S6., except S6.5.

S5.3 *Vehicles with GVWR of more than 6,000 pounds but not more than 10,000 pounds.* Each multipurpose passenger vehicle, truck, and bus with a GVWR of more than 6,000 pounds but not more than 10,000 pounds manufactured from September 1, 1976, to August 31, 1977, shall meet the requirements of S6.1 in a perpendicular impact only. Each vehicle manufactured on or after September 1, 1977, shall meet all the requirements of S6., except S6.5.

S5.4 *Schoolbuses with a GVWR greater than 10,000 pounds.* Each schoolbus with a GVWR greater than 10,000 pounds manufactured on or after April 1, 1977, shall meet the requirements of S6.5.

S5.5 *Fuel spillage: Barrier crash.* Fuel spillage in any fixed or moving barrier crash test shall not exceed 1 ounce by weight from impact until motion of the vehicle has ceased, and shall not exceed a total of 5 ounces by weight in the 5-minute period following cessation of motion. For the subsequent 25-minute period (for vehicles manufactured before September 1, 1976, other than school buses with a GVWR greater than 10,000 pounds: the subsequent 10-minute period), fuel spillage during any 1-minute interval shall not exceed 1 ounce by weight.

S5.6 *Fuel spillage: Rollover.* Fuel spillage in any rollover test, from the onset of rotational motion, shall not exceed a total of 5 ounces by weight for the first 5 minutes of testing at each successive 90° increment. For the remaining testing period, at each increment of 90° fuel spillage during any 1-minute interval shall not exceed 1 ounce by weight.

S6. *Test requirements.* Each vehicle with a GVWR of 10,000 pounds or less shall be capable of meeting the requirements of any applicable barrier crash test followed by a static rollover, without alteration of the vehicle during the test sequence. A particular vehicle need not meet further requirements after having been subjected to a single barrier crash test and a static rollover test.

S6.1 *Frontal barrier crash.* When the vehicle traveling longitudinally forward at any speed up to and including 30 mph impacts a fixed collision barrier that is perpendicular to the line of travel of the vehicle, or at any angle up to 30° in either direction from the perpendicular to the line of travel of the vehicle, with 50th-percentile test dummies as specified in Part 572 of this chapter at each front outboard designated seating position and at any other position whose protection system is required to be tested by a dummy under the provisions of Standard No. 208, under the applicable conditions of S7., fuel spillage shall not exceed the limits of S5.5.

S6.2 *Rear moving barrier crash.* When the vehicle is impacted from the rear by a barrier moving at 30 mph, with test dummies as specified in Part 572 of this chapter at each front outboard designated seating position, under the applicable conditions of S7., fuel spillage shall not exceed the limits of S5.5.

S6.3 *Lateral moving barrier crash.* When the vehicle is impacted laterally on either side by a barrier moving at 20 mph with 50th-percentile test dummies as specified in Part 572 of this chapter at positions required for testing to Standard No. 208, under the applicable conditions of S7., fuel spillage shall not exceed the limits of S5.5.

S6.4 *Static rollover.* When the vehicle is rotated on its longitudinal axis to each successive increment of 90°, following an impact crash of S6.1, S6.2, or S6.3, fuel spillage shall not exceed the limits of S5.6.

S6.5 *Moving contoured barrier crash.* When the moving contoured barrier assembly traveling longitudinally forward at any speed up to and including 30 mph impacts the test vehicle (schoolbus with a GVWR exceeding 10,000 pounds) at any point and angle, under the applicable conditions of S7.1 and S7.5, fuel spillage shall not exceed the limits of S5.5.

S7. *Test conditions.* The requirements of S5. and S6. shall be met under the following conditions. Where a range of conditions is specified, the vehicle must be capable of meeting the requirements at all points within the range.

S7.1 *General test conditions.* The following conditions apply to all tests.

S7.1.1 The fuel tank is filled to any level from 90 to 95 percent of capacity with Stoddard solvent, having the physical and chemical properties of type 1 solvent, Table I ASTM Standard D484-71, "Standard Specifications for Hydrocarbon Dry Cleaning Solvents."

S7.1.2 The fuel system other than the fuel tank is filled with Stoddard solvent to its normal operating level.

S7.1.3 In meeting the requirements of S6.1 through S6.3, if the vehicle has an electrically driven fuel pump that normally runs when the vehicle's electrical system is activated, it is operating at the time of the barrier crash.

S7.1.4 The parking brake is disengaged and the transmission is in neutral, except that in meeting the requirements of S6.5 the parking brake is set.

S7.1.5 Tires are inflated to manufacturer's specifications.

S7.1.6 The vehicle, including test devices and instrumentation, is loaded as follows:

(a) Except as specified in S7.1.1, a passenger car is loaded to its unloaded vehicle weight plus its rated cargo and luggage capacity weight, secured in the luggage area, plus the necessary test dummies as specified in S6., restrained only by means that are installed in the vehicle for protection at its seating position.

(b) Except as specified in S7.1.1, a multipurpose passenger vehicle, truck, or bus with a GVWR of 10,000 pounds or less is loaded to its unloaded vehicle weight, plus the necessary test dummies, as specified in S6., plus 300 pounds or its rated cargo and luggage capacity weight, whichever is less, secured to the vehicle and distributed so that the weight on each axle as measured at the tire-ground interface is in proportion to its GAWR. If the weight on any axle, when the vehicle is loaded to unloaded vehicle weight plus dummy weight, exceeds the axle's proportional share of the test weight, the remaining weight shall be placed so that the weight on that axle remains the same. Each dummy shall be restrained only by means that are installed in the vehicle for protection at its seating position.

(c) Except as specified in S7.1.1, a schoolbus with a GVWR greater than 10,000 pounds is loaded to its unloaded vehicle weight, plus 120 pounds of unsecured weight at each designated seating position.

S7.2 *Lateral moving barrier crash test conditions.* The lateral moving barrier crash test conditions are those specified in S8.2 of Standard No. 208, 49 CFR 571.208.

S7.3 *Rear moving barrier test conditions.* The rear moving barrier test conditions are those specified in S8.2 of Standard No. 208, 49 CFR 571.208, except for the positioning of the barrier and the vehicle. The barrier and test vehicle are positioned so that at impact—

(a) The vehicle is at rest in its normal attitude;

(b) The barrier is traveling at 30 mph with its face perpendicular to the longitudinal centerline of the vehicle; and

(c) A vertical plane through the geometric center of the barrier impact surface and perpendicular to that surface coincides with the longitudinal centerline of the vehicle.

S7.4 *Static rollover test conditions.* The vehicle is rotated about its longitudinal axis, with the axis kept horizontal, to each successive increment of 90°, 180°, and 270° at a uniform rate, with 90° of rotation taking place in any time interval from 1 to 3 minutes. After reaching each 90° increment the vehicle is held in that position for 5 minutes.

S7.5 *Moving contoured barrier test conditions.* The following conditions apply to the moving contoured barrier crash test.

S7.5.1 The moving barrier, which is mounted on a carriage as specified in figure 1, is of rigid construction, symmetrical about a vertical longitudinal plane. The contoured impact surface, which is 24.75 inches high and 78 inches wide, conforms to the dimensions shown in figure 2, and is attached to the carriage as shown in that figure. The ground clearance to the lower edge of the impact surface is 5.25 ± 0.5 inches. The wheelbase is 120 ± 2 inches.

S7.5.2 The moving contoured barrier, including the impact surface, supporting structure, and carriage, weighs 4,000 ± 50 pounds with the weight distributed so that 900 ± 25 pounds is at each rear wheel and 1100 ± 25 pounds is at each front wheel. The center of gravity is located 54.0 ± 1.5 inches rearward of the front wheel axis, in the vertical longitudinal plane of symmetry, 15.8 inches above the ground. The moment of inertia about the center of gravity is:

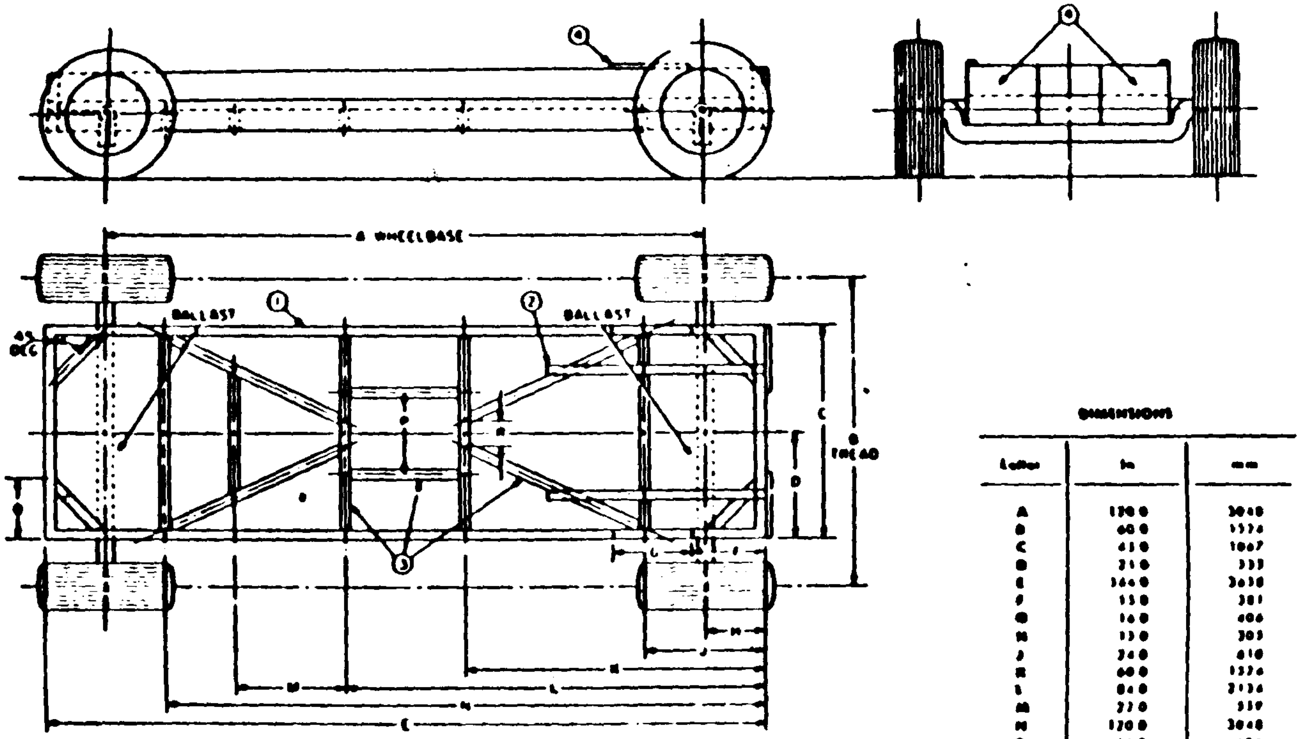
$I_x = 271 \pm 13.6$ slug ft.^{2}
$I_z = 3475 \pm 174$ slug ft.^{2}

S7.5.3 The moving contoured barrier has a solid nonsteerable front axle and fixed rear axle attached directly to the frame rails with no spring or other type of suspension system on any wheel. (The moving barrier assembly is equipped with a braking device capable of stopping its motion.)

S7.5.4 The moving barrier assembly is equipped with G78-15 pneumatic tires with a tread width of 6.0 ± 1 inch, inflated to 24 psi.

S7.5.5 The concrete surface upon which the vehicle is tested is level, rigid, and of uniform construction, with a skid number of 75 when measured in accordance with American Society of Testing and Materials Method E-274-65T at 40 mph, omitting water delivery as specified in paragraph 7.1 of that method.

S7.5.6 The barrier assembly is released from the guidance mechanism immediately prior to impact with the vehicle.



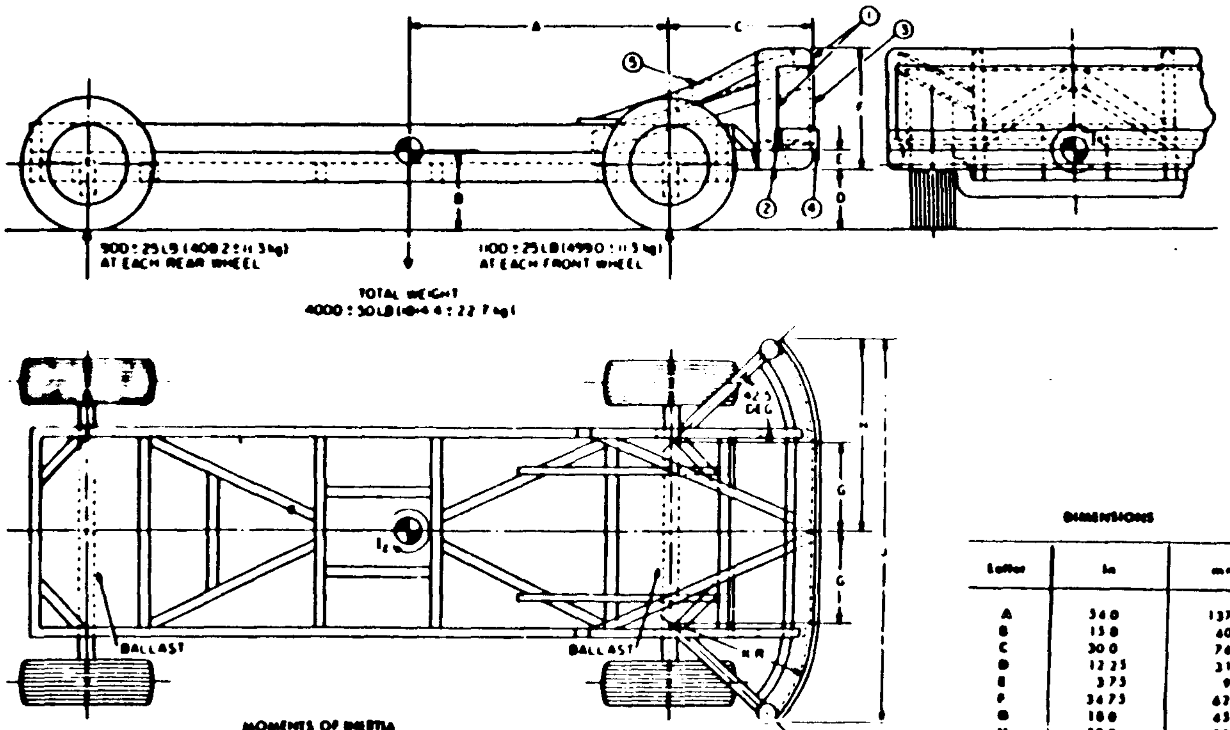
DIMENSIONS

Letter	in	mm
A	120.0	3048
B	60.0	1524
C	42.0	1067
D	21.0	533
E	144.0	3658
F	15.0	381
G	16.0	406
H	12.0	305
J	24.0	610
K	60.0	1524
L	84.0	2134
M	22.0	559
N	120.0	3048
P	16.0	406
Q	12.0	305
R	6.0	152

NOTES.

1. OUTER FRAME 6.0 × 2.0 × 0.19 IN (152 × 51 × 5 mm) STEEL TUBING, TWO PIECES WELDED TOGETHER FOR A 12.0 IN (305 mm) HEIGHT.
2. BALLAST TIE DOWNS
3. ALL INNER REINFORCEMENTS AND FRAME GUSSETS OF 4.0 × 2.0 × 0.19 IN (102 × 51 × 5 mm) STEEL TUBING.
4. REINFORCED AREAS FOR BOLTING ON FACE PLATES.

FIG. 1—COMMON CARRIAGE FOR MOVING BARRIERS



MOMENTS OF INERTIA

$I_x = 271 \pm 13.6$ SLUG · FT² (367 ± 18.4 kg · m²)

$I_z = 3475 \pm 174$ SLUG · FT² (4711 ± 236 kg · m²)

NOTES

1. UPPER FRAME 4.0 IN DIA × 0.25 IN WALL (102 mm DIA × 6 mm WALL) STEEL TUBING (THREE SIDES)
2. LOWER FRAME 6.0 IN DIA × 0.50 IN WALL (152 mm DIA × 13 mm WALL) STEEL TUBING.
3. FACE PLATE 0.75 IN (19 mm) THICK COLD ROLLED STEEL.
4. LEADING EDGE 1.0 × 4.0 IN (25 × 102 mm) STEEL BAND, SHARP EDGES BROKEN
5. ALL INNER REINFORCEMENTS 4.0 × 2.0 × 0.19 IN (102 × 51 × 5 mm) STEEL TUBING.

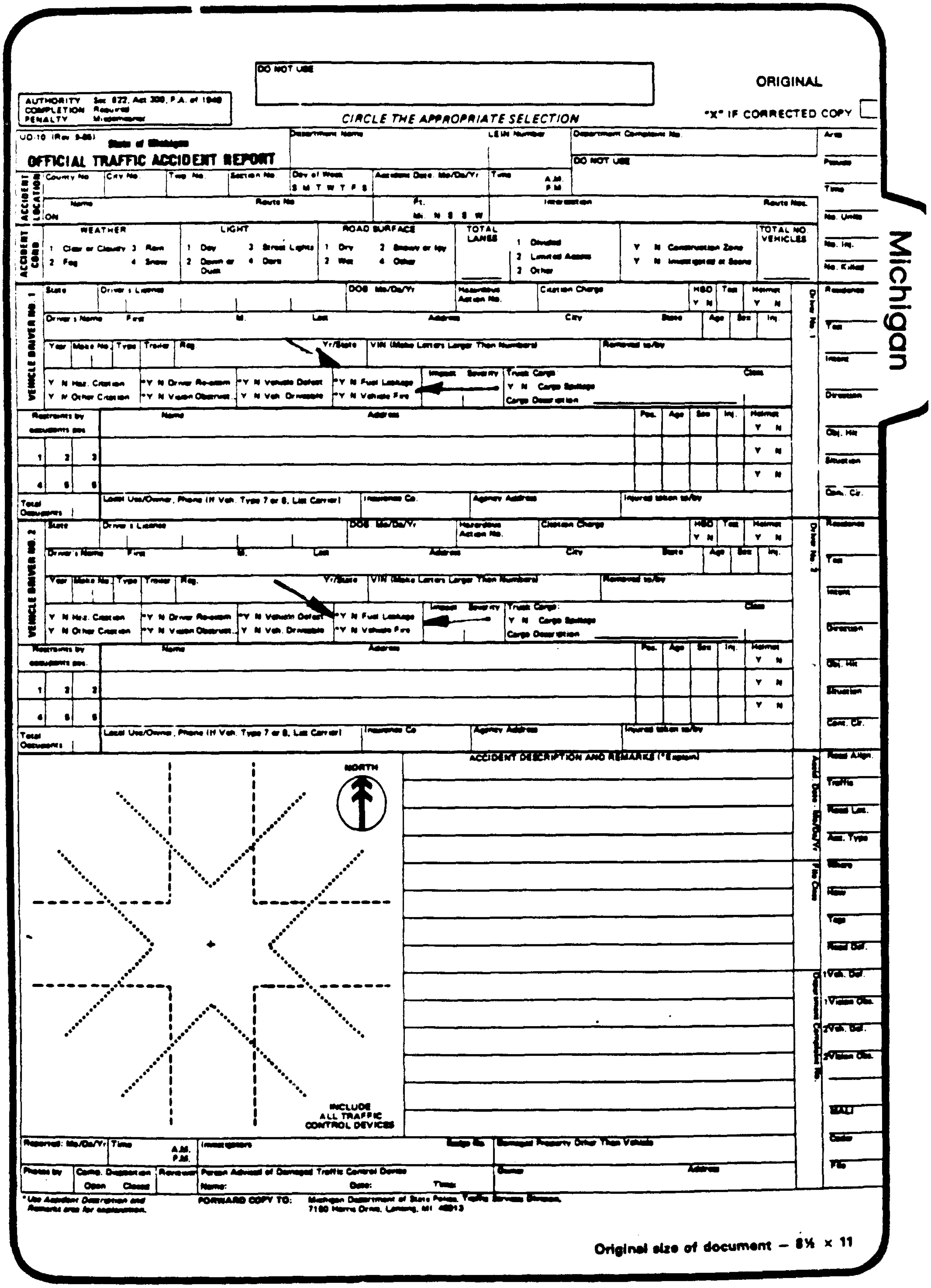
DIMENSIONS

Letter	In	mm
A	54.0	1372
B	15.8	401
C	30.0	762
D	12.25	311
E	3.75	95
F	24.75	629
G	18.0	457
H	39.0	991
J	78.0	1981
K	30.0	762

FIG. 2—COMMON CARRIAGE WITH CONTOURED IMPACT SURFACE ATTACHED

Appendix B

State and FARS Report Forms



Michigan

DO NOT USE

ORIGINAL

"X" IF CORRECTED COPY ☐

AUTHORITY Sec. 622, Act 300, P.A. of 1949
COMPLETION Required
PENALTY Misdemeanor

CIRCLE THE APPROPRIATE SELECTION

UD-10 (Rev. 9-85)
State of Michigan
OFFICIAL TRAFFIC ACCIDENT REPORT

Department Name | LEIN Number | Department Complaint No. | Area
DO NOT USE | [illegible] | Time | No. Units | No. Inj. | No. Killed

ACCIDENT LOCATION: County No. | City No. | Twp. No. | Section No. | Day of Week S M T W T F S | Accident Date Mo/Da/Yr | Time A.M. P.M.

ON Name | Route No. | Ft. Mi. N S E W | Intersection | Route Nos.

ACCIDENT COND.:

WEATHER	LIGHT	ROAD SURFACE	TOTAL LANES			TOTAL NO. VEHICLES
1 Clear or Cloudy 3 Rain 2 Fog 4 Snow	1 Day 3 Street Lights 2 Dawn or Dusk 4 Dark	1 Dry 3 Snowy or Icy 2 Wet 4 Other		1 Divided 2 Limited Access 3 Other	Y N Construction Zone Y N Investigated at Scene	

VEHICLE DRIVER NO. 1

State | Driver's License | DOB Mo/Da/Yr | Hazardous Action No. | Citation Charge | HBD Y N | Test | Helmet Y N

Driver's Name First M. Last | Address | City | State | Age | Sex | Inj.

Year | Make No. | Type | Trailer | Reg. | Yr/State | VIN (Make Letters Larger Than Numbers) | Removed to/by

Y N Haz. Citation | *Y N Driver Re-exam | *Y N Vehicle Defect | *Y N Fuel Leakage | Impact | Severity | Truck Cargo | Class
Y N Other Citation | *Y N Vision Obstruct. | Y N Veh. Drivable | *Y N Vehicle Fire | Y N Cargo Spillage | Cargo Description

Restraints by occupants pos.			Name	Address	Pos.	Age	Sex	Inj.	Helmet
									Y N
1	2	3							Y N
4	5	6							Y N

Total Occupants | Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier) | Insurance Co. | Agency Address | Injured taken to/by

Driver No. 1: Residence | Yes | Impact | Direction | Obj. Hit | Situation | Con. Cir.

VEHICLE DRIVER NO. 2

State | Driver's License | DOB Mo/Da/Yr | Hazardous Action No. | Citation Charge | HBD Y N | Test | Helmet Y N

Driver's Name First M. Last | Address | City | State | Age | Sex | Inj.

Year | Make No. | Type | Trailer | Reg. | Yr/State | VIN (Make Letters Larger Than Numbers) | Removed to/by

Y N Haz. Citation | *Y N Driver Re-exam | *Y N Vehicle Defect | *Y N Fuel Leakage | Impact | Severity | Truck Cargo | Class
Y N Other Citation | *Y N Vision Obstruct. | Y N Veh. Drivable | *Y N Vehicle Fire | Y N Cargo Spillage | Cargo Description

Restraints by occupants pos.			Name	Address	Pos.	Age	Sex	Inj.	Helmet
									Y N
1	2	3							Y N
4	5	6							Y N

Total Occupants | Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier) | Insurance Co. | Agency Address | Injured taken to/by

Driver No. 2: Residence | Yes | Impact | Direction | Obj. Hit | Situation | Con. Cir.

NORTH

INCLUDE ALL TRAFFIC CONTROL DEVICES

ACCIDENT DESCRIPTION AND REMARKS (*Explain)

Accid. Date Mo/Da/Yr | File Class | Department Complaint No.

Road Align. | Traffic | Road Loc. | Acc. Type | Where | How | Type | Road Def. | 1Veh. Def. | 1Vision Obs. | 2Veh. Def. | 2Vision Obs. | MALI | Code | File

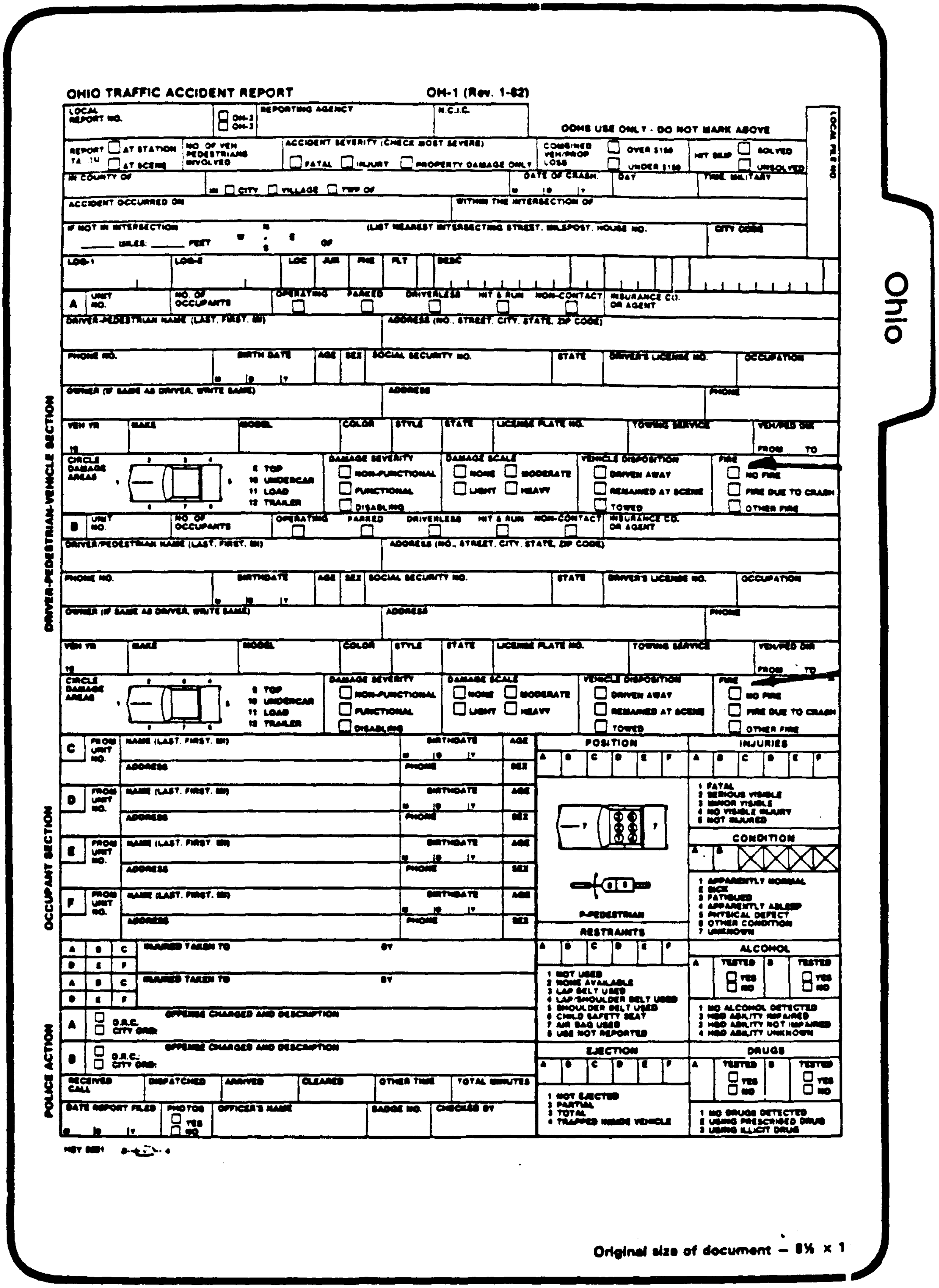
Reported: Mo/Da/Yr | Time A.M. P.M. | Investigators | Badge No. | Damaged Property Other Than Vehicle

Photos by | Comp. Disposition Open Closed | Reviewer | Person Advised of Damaged Traffic Control Device Name: Date: Time: | Owner | Address

*Use Accident Description and Remarks area for explanation.

FORWARD COPY TO: Michigan Department of State Police, Traffic Services Division, 7150 Harris Drive, Lansing, MI 48913

Original size of document — 8½ x 11



Ohio

OHIO TRAFFIC ACCIDENT REPORT OH-1 (Rev. 1-82)

LOCAL REPORT NO. | ☐ OH-2 ☐ OH-3 | REPORTING AGENCY | N.C.I.C.

ODHS USE ONLY - DO NOT MARK ABOVE

LOCAL FILE NO.

REPORT TAKEN ☐ AT STATION ☐ AT SCENE | NO. OF VEH PEDESTRIANS INVOLVED | ACCIDENT SEVERITY (CHECK MOST SEVERE) ☐ FATAL ☐ INJURY ☐ PROPERTY DAMAGE ONLY | COMBINED VEH/PROP LOSS ☐ OVER $150 ☐ UNDER $150 | HIT SKIP ☐ SOLVED ☐ UNSOLVED

IN COUNTY OF | IN ☐ CITY ☐ VILLAGE ☐ TWP OF | DATE OF CRASH M D Y | DAY | TIME MILITARY

ACCIDENT OCCURRED ON | WITHIN THE INTERSECTION OF

IF NOT IN INTERSECTION ______ MILES: ______ FEET N W - E S OF (LIST NEAREST INTERSECTING STREET, MILEPOST, HOUSE NO. | CITY CODE

LOG-1 | LOG-2 | LOC | JUR | FHE | FLT | DESC

DRIVER-PEDESTRIAN-VEHICLE SECTION

A UNIT NO. | NO. OF OCCUPANTS | OPERATING ☐ | PARKED ☐ | DRIVERLESS ☐ | HIT & RUN ☐ | NON-CONTACT ☐ | INSURANCE CO. OR AGENT

DRIVER-PEDESTRIAN NAME (LAST, FIRST, MI) | ADDRESS (NO., STREET, CITY, STATE, ZIP CODE)

PHONE NO. | BIRTH DATE M D Y | AGE | SEX | SOCIAL SECURITY NO. | STATE | DRIVER'S LICENSE NO. | OCCUPATION

OWNER (IF SAME AS DRIVER, WRITE SAME) | ADDRESS | PHONE

VEH YR 19 | MAKE | MODEL | COLOR | STYLE | STATE | LICENSE PLATE NO. | TOWING SERVICE | VEH/PED DIR FROM TO

CIRCLE DAMAGE AREAS 1 2 3 4 5 6 7 8 9 TOP 10 UNDERCAR 11 LOAD 12 TRAILER | DAMAGE SEVERITY ☐ NON-FUNCTIONAL ☐ FUNCTIONAL ☐ DISABLING | DAMAGE SCALE ☐ NONE ☐ MODERATE ☐ LIGHT ☐ HEAVY | VEHICLE DISPOSITION ☐ DRIVEN AWAY ☐ REMAINED AT SCENE ☐ TOWED | FIRE ☐ NO FIRE ☐ FIRE DUE TO CRASH ☐ OTHER FIRE

B UNIT NO. | NO. OF OCCUPANTS | OPERATING ☐ | PARKED ☐ | DRIVERLESS ☐ | HIT & RUN ☐ | NON-CONTACT ☐ | INSURANCE CO. OR AGENT

DRIVER/PEDESTRIAN NAME (LAST, FIRST, MI) | ADDRESS (NO., STREET, CITY, STATE, ZIP CODE)

PHONE NO. | BIRTHDATE M D Y | AGE | SEX | SOCIAL SECURITY NO. | STATE | DRIVER'S LICENSE NO. | OCCUPATION

OWNER (IF SAME AS DRIVER, WRITE SAME) | ADDRESS | PHONE

VEH YR 19 | MAKE | MODEL | COLOR | STYLE | STATE | LICENSE PLATE NO. | TOWING SERVICE | VEH/PED DIR FROM TO

CIRCLE DAMAGE AREAS 1 2 3 4 5 6 7 8 9 TOP 10 UNDERCAR 11 LOAD 12 TRAILER | DAMAGE SEVERITY ☐ NON-FUNCTIONAL ☐ FUNCTIONAL ☐ DISABLING | DAMAGE SCALE ☐ NONE ☐ MODERATE ☐ LIGHT ☐ HEAVY | VEHICLE DISPOSITION ☐ DRIVEN AWAY ☐ REMAINED AT SCENE ☐ TOWED | FIRE ☐ NO FIRE ☐ FIRE DUE TO CRASH ☐ OTHER FIRE

OCCUPANT SECTION

C FROM UNIT NO. | NAME (LAST, FIRST, MI) | BIRTHDATE M D Y | AGE | ADDRESS | PHONE | SEX

D FROM UNIT NO. | NAME (LAST, FIRST, MI) | BIRTHDATE M D Y | AGE | ADDRESS | PHONE | SEX

E FROM UNIT NO. | NAME (LAST, FIRST, MI) | BIRTHDATE M D Y | AGE | ADDRESS | PHONE | SEX

F FROM UNIT NO. | NAME (LAST, FIRST, MI) | BIRTHDATE M D Y | AGE | ADDRESS | PHONE | SEX

POSITION A B C D E F

7 7

P-PEDESTRIAN

INJURIES A B C D E F

1 FATAL
2 SERIOUS VISIBLE
3 MINOR VISIBLE
4 NO VISIBLE INJURY
5 NOT INJURED

CONDITION A B

1 APPARENTLY NORMAL
2 SICK
3 FATIGUED
4 APPARENTLY ASLEEP
5 PHYSICAL DEFECT
6 OTHER CONDITION
7 UNKNOWN

A B C D E F INJURED TAKEN TO BY

A B C D E F INJURED TAKEN TO BY

RESTRAINTS A B C D E F

1 NOT USED
2 NONE AVAILABLE
3 LAP BELT USED
4 LAP/SHOULDER BELT USED
5 SHOULDER BELT USED
6 CHILD SAFETY SEAT
7 AIR BAG USED
8 USE NOT REPORTED

ALCOHOL A TESTED ☐ YES ☐ NO B TESTED ☐ YES ☐ NO

1 NO ALCOHOL DETECTED
2 HBD ABILITY IMPAIRED
3 HBD ABILITY NOT IMPAIRED
4 HBD ABILITY UNKNOWN

POLICE ACTION

A ☐ O.R.C. ☐ CITY ORD: OFFENSE CHARGED AND DESCRIPTION

B ☐ O.R.C. ☐ CITY ORD: OFFENSE CHARGED AND DESCRIPTION

RECEIVED CALL | DISPATCHED | ARRIVED | CLEARED | OTHER TIME | TOTAL MINUTES

DATE REPORT FILED M D Y | PHOTOS ☐ YES ☐ NO | OFFICER'S NAME | BADGE NO. | CHECKED BY

EJECTION A B C D E F

1 NOT EJECTED
2 PARTIAL
3 TOTAL
4 TRAPPED INSIDE VEHICLE

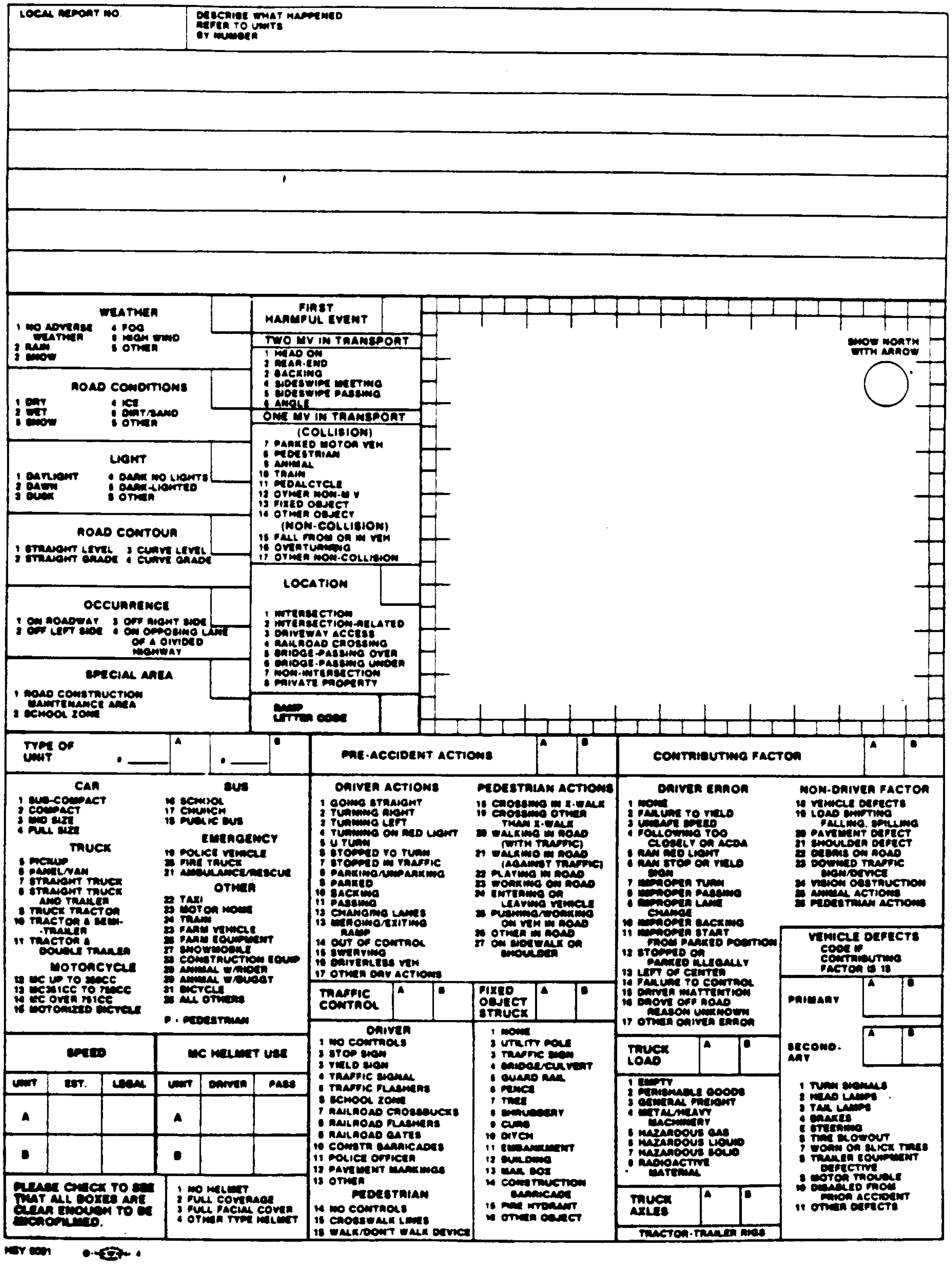
DRUGS A TESTED ☐ YES ☐ NO B TESTED ☐ YES ☐ NO

1 NO DRUGS DETECTED
2 USING PRESCRIBED DRUG
3 USING ILLICIT DRUG

HSY 8881

Original size of document — 8½ x 1

Ohio



LOCAL REPORT NO.

DESCRIBE WHAT HAPPENED
REFER TO UNITS
BY NUMBER

WEATHER
1 NO ADVERSE WEATHER
2 RAIN
3 SNOW
4 FOG
5 HIGH WIND
5 OTHER

ROAD CONDITIONS
1 DRY
2 WET
3 SNOW
4 ICE
5 DIRT/SAND
5 OTHER

LIGHT
1 DAYLIGHT
2 DAWN
3 DUSK
4 DARK NO LIGHTS
5 DARK-LIGHTED
6 OTHER

ROAD CONTOUR
1 STRAIGHT LEVEL
2 STRAIGHT GRADE
3 CURVE LEVEL
4 CURVE GRADE

OCCURRENCE
1 ON ROADWAY
2 OFF LEFT SIDE
3 OFF RIGHT SIDE
4 ON OPPOSING LANE OF A DIVIDED HIGHWAY

SPECIAL AREA
1 ROAD CONSTRUCTION MAINTENANCE AREA
2 SCHOOL ZONE

FIRST HARMFUL EVENT

TWO MV IN TRANSPORT
1 HEAD ON
2 REAR-END
3 BACKING
4 SIDESWIPE MEETING
5 SIDESWIPE PASSING
6 ANGLE

ONE MV IN TRANSPORT
(COLLISION)
7 PARKED MOTOR VEH
8 PEDESTRIAN
9 ANIMAL
10 TRAIN
11 PEDALCYCLE
12 OTHER NON-M V
13 FIXED OBJECT
14 OTHER OBJECT
(NON-COLLISION)
15 FALL FROM OR IN VEH
16 OVERTURNING
17 OTHER NON-COLLISION

LOCATION
1 INTERSECTION
2 INTERSECTION-RELATED
3 DRIVEWAY ACCESS
4 RAILROAD CROSSING
5 BRIDGE-PASSING OVER
6 BRIDGE-PASSING UNDER
7 NON-INTERSECTION
8 PRIVATE PROPERTY

RAMP
LETTER CODE

SHOW NORTH WITH ARROW

TYPE OF UNIT A # ____ B # ____

CAR
1 SUB-COMPACT
2 COMPACT
3 MID SIZE
4 FULL SIZE

TRUCK
5 PICKUP
6 PANEL/VAN
7 STRAIGHT TRUCK
8 STRAIGHT TRUCK AND TRAILER
9 TRUCK TRACTOR
10 TRACTOR & SEMI-TRAILER
11 TRACTOR & DOUBLE TRAILER

MOTORCYCLE
12 MC UP TO 360CC
13 MC361CC TO 750CC
14 MC OVER 751CC
15 MOTORIZED BICYCLE

BUS
16 SCHOOL
17 CHURCH
18 PUBLIC BUS

EMERGENCY
19 POLICE VEHICLE
20 FIRE TRUCK
21 AMBULANCE/RESCUE

OTHER
22 TAXI
23 MOTOR HOME
24 TRAIN
25 FARM VEHICLE
26 FARM EQUIPMENT
27 SNOWMOBILE
28 CONSTRUCTION EQUIP
29 ANIMAL W/RIDER
30 ANIMAL W/BUGGY
31 BICYCLE
35 ALL OTHERS

P - PEDESTRIAN

SPEED

UNIT	EST.	LEGAL
A		
B		

MC HELMET USE

UNIT	DRIVER	PASS
A		
B		

1 NO HELMET
2 FULL COVERAGE
3 FULL FACIAL COVER
4 OTHER TYPE HELMET

PLEASE CHECK TO SEE THAT ALL BOXES ARE CLEAR ENOUGH TO BE MICROFILMED.

PRE-ACCIDENT ACTIONS A B

DRIVER ACTIONS
1 GOING STRAIGHT
2 TURNING RIGHT
3 TURNING LEFT
4 TURNING ON RED LIGHT
5 U TURN
6 STOPPED TO TURN
7 STOPPED IN TRAFFIC
8 PARKING/UNPARKING
9 PARKED
10 BACKING
11 PASSING
12 CHANGING LANES
13 MERGING/EXITING RAMP
14 OUT OF CONTROL
15 SWERVING
16 DRIVERLESS VEH
17 OTHER DRV ACTIONS

PEDESTRIAN ACTIONS
18 CROSSING IN X-WALK
19 CROSSING OTHER THAN X-WALK
20 WALKING IN ROAD (WITH TRAFFIC)
21 WALKING IN ROAD (AGAINST TRAFFIC)
22 PLAYING IN ROAD
23 WORKING ON ROAD
24 ENTERING OR LEAVING VEHICLE
25 PUSHING/WORKING ON VEH IN ROAD
26 OTHER IN ROAD
27 ON SIDEWALK OR SHOULDER

TRAFFIC CONTROL A B

DRIVER
1 NO CONTROLS
2 STOP SIGN
3 YIELD SIGN
4 TRAFFIC SIGNAL
5 TRAFFIC FLASHERS
6 SCHOOL ZONE
7 RAILROAD CROSSBUCKS
8 RAILROAD FLASHERS
9 RAILROAD GATES
10 CONSTR BARRICADES
11 POLICE OFFICER
12 PAVEMENT MARKINGS
13 OTHER

PEDESTRIAN
14 NO CONTROLS
15 CROSSWALK LINES
16 WALK/DON'T WALK DEVICE

FIXED OBJECT STRUCK A B
1 NONE
2 UTILITY POLE
3 TRAFFIC SIGN
4 BRIDGE/CULVERT
5 GUARD RAIL
6 FENCE
7 TREE
8 SHRUBBERY
9 CURB
10 DITCH
11 EMBANKMENT
12 BUILDING
13 MAIL BOX
14 CONSTRUCTION BARRICADE
15 FIRE HYDRANT
16 OTHER OBJECT

CONTRIBUTING FACTOR A B

DRIVER ERROR
1 NONE
2 FAILURE TO YIELD
3 UNSAFE SPEED
4 FOLLOWING TOO CLOSELY OR ACDA
5 RAN RED LIGHT
6 RAN STOP OR YIELD SIGN
7 IMPROPER TURN
8 IMPROPER PASSING
9 IMPROPER LANE CHANGE
10 IMPROPER BACKING
11 IMPROPER START FROM PARKED POSITION
12 STOPPED OR PARKED ILLEGALLY
13 LEFT OF CENTER
14 FAILURE TO CONTROL
15 DRIVER INATTENTION
16 DROVE OFF ROAD REASON UNKNOWN
17 OTHER DRIVER ERROR

NON-DRIVER FACTOR
18 VEHICLE DEFECTS
19 LOAD SHIFTING FALLING, SPILLING
20 PAVEMENT DEFECT
21 SHOULDER DEFECT
22 DEBRIS ON ROAD
23 DOWNED TRAFFIC SIGN/DEVICE
24 VISION OBSTRUCTION
25 ANIMAL ACTIONS
26 PEDESTRIAN ACTIONS

VEHICLE DEFECTS
CODE IF CONTRIBUTING FACTOR IS 18

PRIMARY A B

SECONDARY A B

1 TURN SIGNALS
2 HEAD LAMPS
3 TAIL LAMPS
4 BRAKES
5 STEERING
6 TIRE BLOWOUT
7 WORN OR SLICK TIRES
8 TRAILER EQUIPMENT DEFECTIVE
9 MOTOR TROUBLE
10 DISABLED FROM PRIOR ACCIDENT
11 OTHER DEFECTS

TRUCK LOAD A B
1 EMPTY
2 PERISHABLE GOODS
3 GENERAL FREIGHT
4 METAL/HEAVY MACHINERY
5 HAZARDOUS GAS
6 HAZARDOUS LIQUID
7 HAZARDOUS SOLID
8 RADIOACTIVE MATERIAL

TRUCK AXLES A B
TRACTOR-TRAILER RIGS

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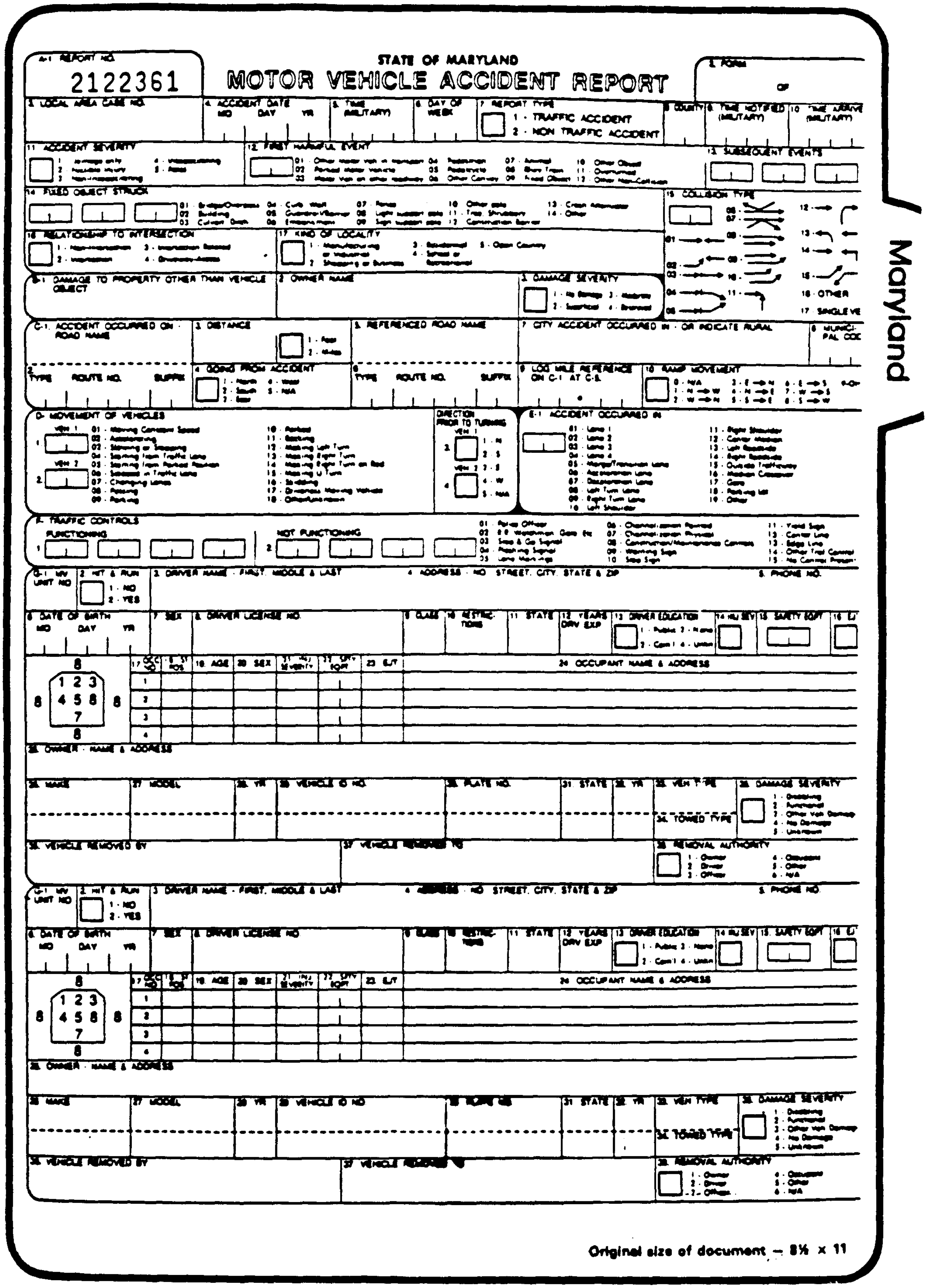

A-1 REPORT NO.
2122361

STATE OF MARYLAND
MOTOR VEHICLE ACCIDENT REPORT

2. FORM ___ OF ___

3. LOCAL AREA CASE NO.
4. ACCIDENT DATE MO DAY YR
5. TIME (MILITARY)
6. DAY OF WEEK
7. REPORT TYPE ☐ 1 - TRAFFIC ACCIDENT 2 - NON TRAFFIC ACCIDENT
8. COUNTY
9. TIME NOTIFIED (MILITARY)
10. TIME ARRIVE (MILITARY)

11. ACCIDENT SEVERITY ☐
12. FIRST HARMFUL EVENT ☐
13. SUBSEQUENT EVENTS ☐ ☐ ☐
14. FIXED OBJECT STRUCK ☐ ☐ ☐
15. COLLISION TYPE ☐ 16 - OTHER 17 - SINGLE VE
16. RELATIONSHIP TO INTERSECTION ☐
17. KIND OF LOCALITY ☐ 5 - Open Country

B-1 DAMAGE TO PROPERTY OTHER THAN VEHICLE OBJECT
2. OWNER NAME
3. DAMAGE SEVERITY ☐

C-1. ACCIDENT OCCURRED ON ROAD NAME
2. TYPE ROUTE NO. SUFFIX
3. DISTANCE ☐ 1 - Feet 2 - Miles
4. GOING FROM ACCIDENT ☐
5. REFERENCED ROAD NAME
6. TYPE ROUTE NO. SUFFIX
7. CITY ACCIDENT OCCURRED IN - OR INDICATE RURAL
8. MUNICIPAL COD
9. LOG MILE REFERENCE ON C-1 AT C-5
10. RAMP MOVEMENT ☐

D- MOVEMENT OF VEHICLES
VEH 1 ☐
VEH 2 ☐
DIRECTION PRIOR TO TURNING
VEH 1 ☐
VEH 2 ☐

E-1 ACCIDENT OCCURRED IN ☐

F- TRAFFIC CONTROLS
FUNCTIONING 1 ☐ ☐ ☐ ☐
NOT FUNCTIONING 2 ☐ ☐ ☐ ☐

G-1 MV UNIT NO
2. HIT & RUN ☐ 1 - NO 2 - YES
3. DRIVER NAME - FIRST, MIDDLE & LAST
4. ADDRESS - NO. STREET, CITY, STATE & ZIP
5. PHONE NO.
6. DATE OF BIRTH MO DAY YR
7. SEX
8. DRIVER LICENSE NO.
9. CLASS
10. RESTRICTIONS
11. STATE
12. YEARS DRV EXP
13. DRIVER EDUCATION ☐
14. INJ SEV ☐
15. SAFETY EQPT ☐
17. OCC NO.
18. ST POS
19. AGE
20. SEX
21. INJ SEVERITY
22. SFTY EQPT
23. E/T
24. OCCUPANT NAME & ADDRESS
25. OWNER - NAME & ADDRESS
26. MAKE
27. MODEL
28. YR
29. VEHICLE ID NO.
30. PLATE NO.
31. STATE
32. YR
33. VEH TYPE
34. TOWED TYPE
35. DAMAGE SEVERITY ☐
36. VEHICLE REMOVED BY
37. VEHICLE REMOVED TO
38. REMOVAL AUTHORITY ☐

G-1 MV UNIT NO
2. HIT & RUN ☐ 1 - NO 2 - YES
3. DRIVER NAME - FIRST, MIDDLE & LAST
4. ADDRESS - NO. STREET, CITY, STATE & ZIP
5. PHONE NO.
6. DATE OF BIRTH MO DAY YR
7. SEX
8. DRIVER LICENSE NO.
9. CLASS
10. RESTRICTIONS
11. STATE
12. YEARS DRV EXP
13. DRIVER EDUCATION ☐
14. INJ SEV ☐
15. SAFETY EQPT ☐
17. OCC NO.
18. ST POS
19. AGE
20. SEX
21. INJ SEVERITY
22. SFTY EQPT
23. E/T
24. OCCUPANT NAME & ADDRESS
25. OWNER - NAME & ADDRESS
26. MAKE
27. MODEL
28. YR
29. VEHICLE ID NO.
30. PLATE NO.
31. STATE
32. YR
33. VEH TYPE
34. TOWED TYPE
35. DAMAGE SEVERITY ☐
36. VEHICLE REMOVED BY
37. VEHICLE REMOVED TO
38. REMOVAL AUTHORITY ☐

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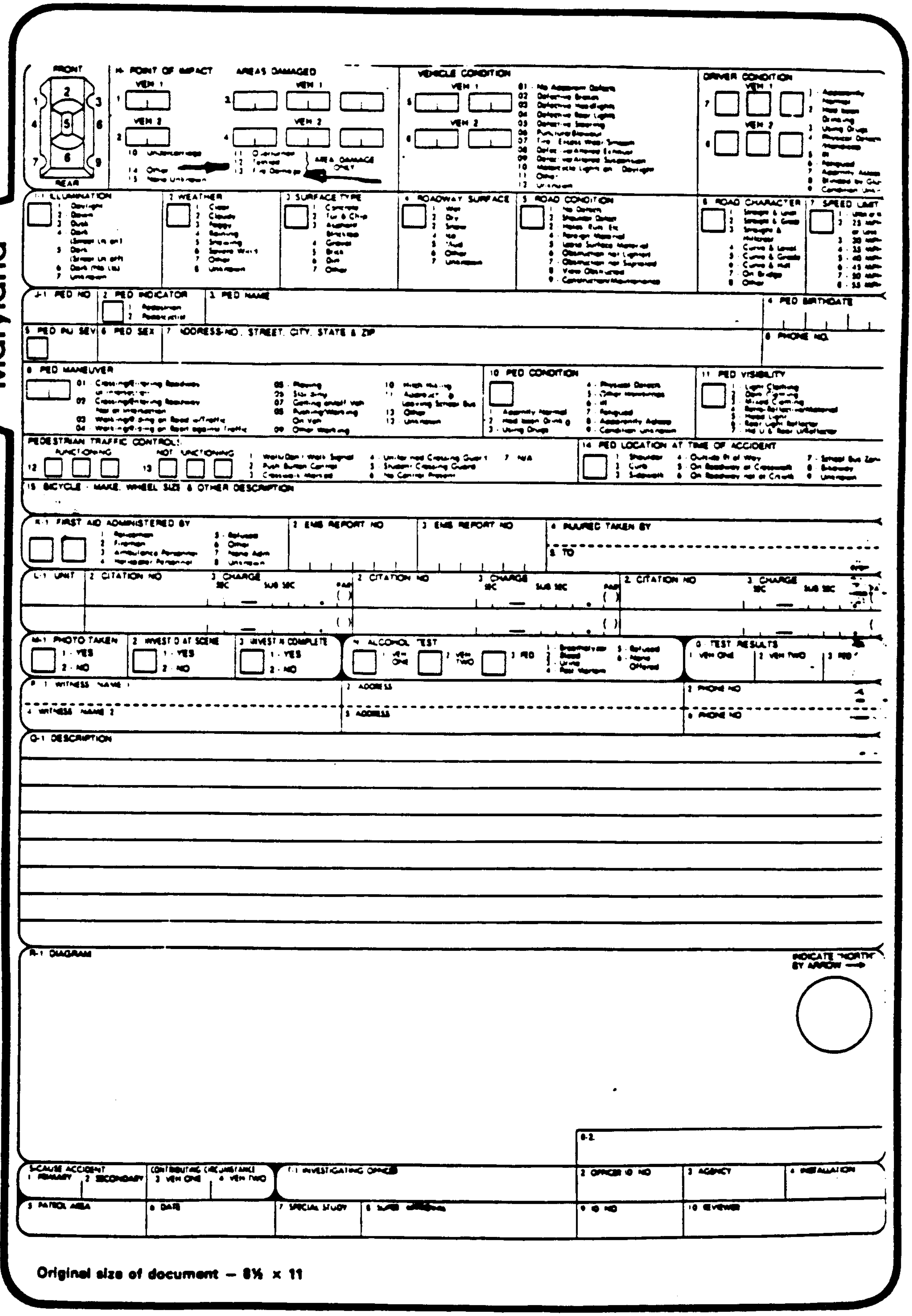

Maryland

FRONT 1 2 3 4 5 6 7 8 9 REAR

14 POINT OF IMPACT
VEH 1 ☐ 1
VEH 2 ☐ 2
10 Undercarriage
14 Other
15 None Unknown

AREAS DAMAGED
VEH 1 ☐ ☐ ☐ 3
VEH 2 ☐ ☐ ☐ 4
11 Overturned
12 Towed
13 Fire Damage
AREA DAMAGE ONLY

VEHICLE CONDITION
VEH 1 ☐ ☐ 5
VEH 2 ☐ ☐ 6
01 No Apparent Defects
02 Defective Brakes
03 Defective Headlights
04 Defective Rear Lights
05 Defective Steering
06 Puncture/Blowout
07 Tire – Excess Wear/Smooth
08 Defective/Improper Exhaust
09 Defective/Improper Suspension
10 Motorcycle Lights on – Daylight
11 Other
12 Unknown

DRIVER CONDITION
VEH 1 ☐ ☐ ☐ 7
VEH 2 ☐ ☐ ☐ 8
1 Apparently Normal
2 Had been Drinking
3 Using Drugs
4 Physical Defects
5 Ill
6 Fatigued
7 Apparently Asleep
8 Blinded by Glare
9 Condition Unknown

I-1 ILLUMINATION ☐
1 Daylight
2 Dawn
3 Dusk
4 Dark (Street Lts on)
5 Dark (Street Lts off)
6 Dark (No Lts)
7 Unknown

2 WEATHER ☐
1 Clear
2 Cloudy
3 Foggy
4 Raining
5 Snowing
6 Severe Winds
7 Other
8 Unknown

3 SURFACE TYPE ☐
1 Concrete
2 Tar & Chip
3 Asphalt/Blacktop
4 Gravel
5 Brick
6 Dirt
7 Other

4 ROADWAY SURFACE ☐
1 Wet
2 Dry
3 Snow
4 Ice
5 Mud
6 Other
7 Unknown

5 ROAD CONDITION ☐
1 No Defects
2 Shoulder Defect
3 Holes, Ruts, Etc
4 Foreign Material
5 Loose Surface Material
6 Obstruction not Lighted
7 Obstruction not Signaled
8 View Obstructed
9 Construction/Maintenance

6 ROAD CHARACTER ☐
1 Straight & Level
2 Straight & Grade
3 Straight & Hillcrest
4 Curve & Level
5 Curve & Grade
6 Curve & Hill
7 On Bridge
8 Other

7 SPEED LIMIT ☐
1 Unknown
2 25 mph or Less
3 30 mph
4 35 mph
5 40 mph
6 45 mph
7 50 mph
8 55 mph

J-1 PED NO
2 PED INDICATOR ☐
1 Pedestrian
2 Pedalcyclist
3 PED NAME
4 PED BIRTHDATE
5 PED INJ SEV ☐
6 PED SEX
7 ADDRESS-NO., STREET, CITY, STATE & ZIP
8 PHONE NO.

9 PED MANEUVER ☐
01 Crossing/Entering Roadway at Intersection
02 Crossing/Entering Roadway Not at Intersection
03 Walking/Going on Road w/Traffic
04 Walking/Going on Road against Traffic
05 Playing
06 Standing
07 Getting on/off Veh
08 Pushing/Working On Veh
09 Other Working
10 Hitch Hiking
11 Approaching/Leaving School Bus
12 Other
13 Unknown

10 PED CONDITION ☐
1 Apparently Normal
2 Had been Drinking
3 Using Drugs
4 Physical Defects
5 Other Handicaps
6 Ill
7 Fatigued
8 Apparently Asleep
9 Condition Unknown

11 PED VISIBILITY ☐
1 Light Clothing
2 Dark Clothing
3 Mixed Clothing
4 Retro-Reflective Material
5 Head Light
6 Rear Light Reflector
7 Hd L & Rear Reflector

PEDESTRIAN TRAFFIC CONTROLS:
FUNCTIONING 12 ☐ ☐ ☐
NOT FUNCTIONING 13 ☐ ☐ ☐
1 Walk/Don't Walk Signal
2 Push Button Control
3 Crosswalk Marked
4 Uniformed Crossing Guard
5 Student Crossing Guard
6 No Control Present
7 N/A

14 PED LOCATION AT TIME OF ACCIDENT ☐
1 Shoulder
2 Curb
3 Sidewalk
4 Outside R of Way
5 On Roadway at Crosswalk
6 On Roadway not at Crswlk
7 School Bus Zone
8 Driveway
9 Unknown

15 BICYCLE – MAKE, WHEEL SIZE & OTHER DESCRIPTION

K-1 FIRST AID ADMINISTERED BY ☐ ☐
1 Policeman
2 Fireman
3 Ambulance Personnel
4 Helicopter Personnel
5 Refused
6 Other
7 None Adm
8 Unknown
2 EMS REPORT NO
3 EMS REPORT NO
4 INJURED TAKEN BY
5 TO

L-1 UNIT
2 CITATION NO
3 CHARGE SEC SUB SEC PAR ( )
2 CITATION NO
3 CHARGE SEC SUB SEC PAR ( )
2 CITATION NO
3 CHARGE SEC SUB SEC

M-1 PHOTO TAKEN ☐ 1 YES 2 NO
2 INVEST'D AT SCENE ☐ 1 YES 2 NO
3 INVEST'N COMPLETE ☐ 1 YES 2 NO
4 ALCOHOL TEST ☐ 1 VEH ONE ☐ 2 VEH TWO ☐ 3 PED
1 Breathalyzer
2 Blood
3 Urine
4 Post Mortem
5 Refused
6 None Offered
O TEST RESULTS 1 VEH ONE 2 VEH TWO 3 PED

P-1 WITNESS NAME 1
2 ADDRESS
3 PHONE NO
4 WITNESS NAME 2
5 ADDRESS
6 PHONE NO

Q-1 DESCRIPTION

R-1 DIAGRAM

INDICATE "NORTH" BY ARROW →

R-2

S-CAUSE ACCIDENT 1 PRIMARY 2 SECONDARY
CONTRIBUTING CIRCUMSTANCE 3 VEH ONE 4 VEH TWO
T-1 INVESTIGATING OFFICER
2 OFFICER ID NO
3 AGENCY
4 INSTALLATION
5 PATROL AREA
6 DATE
7 SPECIAL STUDY
8 SUPER
9 ID NO
10 REVIEWER

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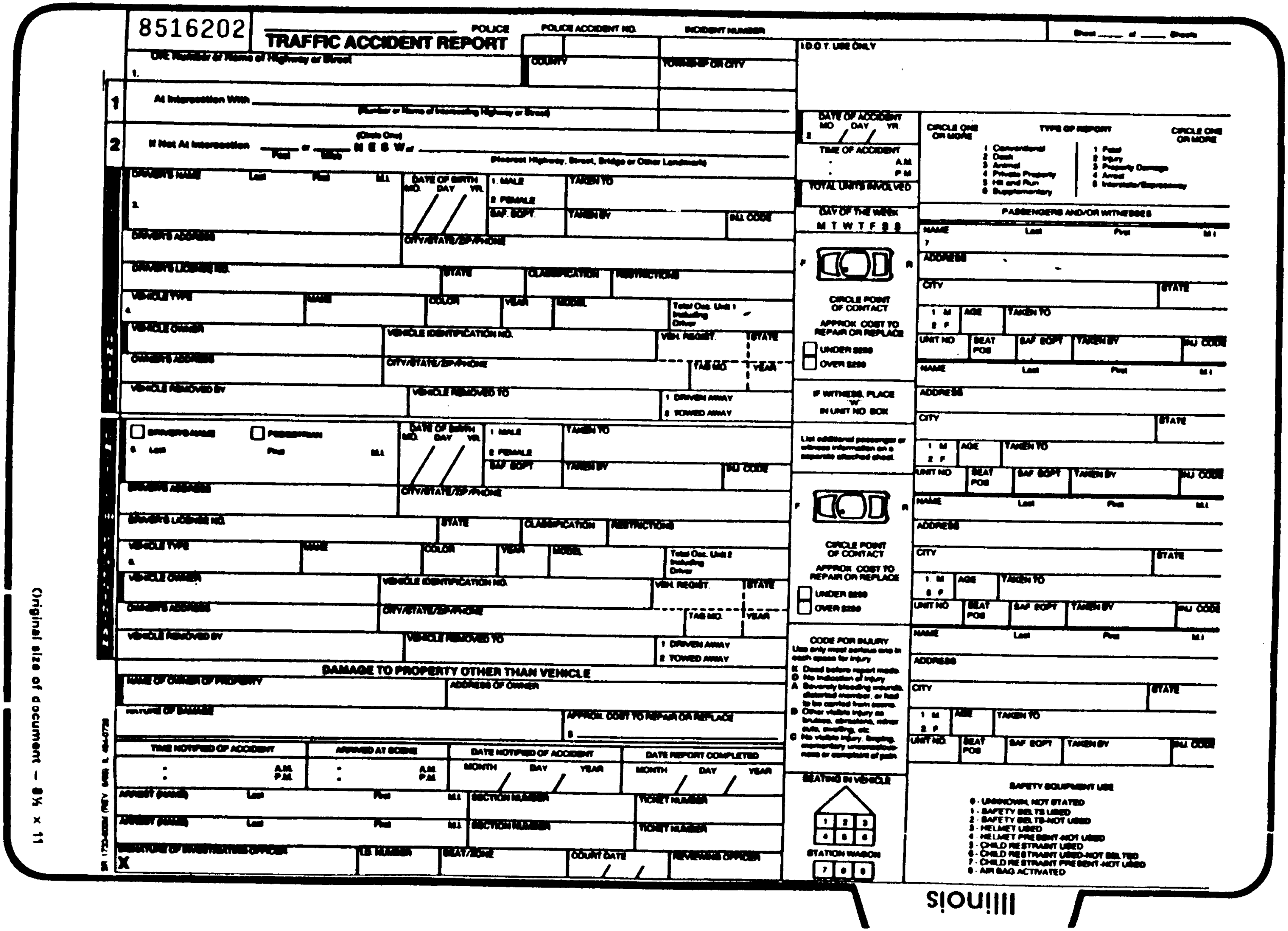

8516202

TRAFFIC ACCIDENT REPORT

POLICE ______ POLICE ACCIDENT NO. ______ INCIDENT NUMBER ______

Sheet ____ of ____ Sheets

I.D.O.T. USE ONLY

1\. On: Number or Name of Highway or Street ______ COUNTY ______ TOWNSHIP OR CITY ______

1 At Intersection With ______ (Number or Name of Intersecting Highway or Street)

2 If Not At Intersection ______ Feet or ______ Miles (Circle One) N E S W of ______ (Nearest Highway, Street, Bridge or Other Landmark)

DATE OF ACCIDENT 2. MO / DAY / YR

TIME OF ACCIDENT : A.M. : P.M.

TOTAL UNITS INVOLVED

DAY OF THE WEEK M T W T F S S

TYPE OF REPORT

CIRCLE ONE OR MORE		CIRCLE ONE OR MORE
1 Conventional		1 Fatal
2 Deer		2 Injury
3 Animal		3 Property Damage
4 Private Property		4 Arrest
5 Hit and Run		5 Interstate/Expressway
6 Supplementary		

3\. DRIVER'S NAME Last First M.I. | DATE OF BIRTH MO. / DAY / YR. | 1. MALE 2. FEMALE | SAF. EQPT. | TAKEN TO | TAKEN BY | INJ. CODE

DRIVER'S ADDRESS | CITY/STATE/ZIP/PHONE

DRIVER'S LICENSE NO. | STATE | CLASSIFICATION | RESTRICTIONS

4\. VEHICLE TYPE | MAKE | COLOR | YEAR | MODEL | Total Occ. Unit 1 Including Driver

VEHICLE OWNER | VEHICLE IDENTIFICATION NO. | VEH. REGIST. | STATE

OWNER'S ADDRESS | CITY/STATE/ZIP/PHONE | TAG NO. | YEAR

VEHICLE REMOVED BY | VEHICLE REMOVED TO | 1 DRIVEN AWAY 2 TOWED AWAY

☐ DRIVER'S NAME ☐ PEDESTRIAN

5\. Last First M.I. | DATE OF BIRTH MO. / DAY / YR. | 1 MALE 2 FEMALE | SAF. EQPT. | TAKEN TO | TAKEN BY | INJ. CODE

DRIVER'S ADDRESS | CITY/STATE/ZIP/PHONE

DRIVER'S LICENSE NO. | STATE | CLASSIFICATION | RESTRICTIONS

6\. VEHICLE TYPE | MAKE | COLOR | YEAR | MODEL | Total Occ. Unit 2 Including Driver

VEHICLE OWNER | VEHICLE IDENTIFICATION NO. | VEH. REGIST. | STATE

OWNER'S ADDRESS | CITY/STATE/ZIP/PHONE | TAG NO. | YEAR

VEHICLE REMOVED BY | VEHICLE REMOVED TO | 1 DRIVEN AWAY 2 TOWED AWAY

F R CIRCLE POINT OF CONTACT

APPROX. COST TO REPAIR OR REPLACE

☐ UNDER $250

☐ OVER $250

IF WITNESS, PLACE "W" IN UNIT NO. BOX

List additional passenger or witness information on a separate attached sheet.

PASSENGERS AND/OR WITNESSES

7\. NAME Last First M.I.

ADDRESS

CITY | STATE

1 M 2 F | AGE | TAKEN TO

UNIT NO. | SEAT POS | SAF. EQPT. | TAKEN BY | INJ. CODE

NAME Last First M.I.

ADDRESS

CITY | STATE

1 M 2 F | AGE | TAKEN TO

UNIT NO. | SEAT POS | SAF. EQPT. | TAKEN BY | INJ. CODE

NAME Last First M.I.

ADDRESS

CITY | STATE

1 M 2 F | AGE | TAKEN TO

UNIT NO. | SEAT POS | SAF. EQPT. | TAKEN BY | INJ. CODE

NAME Last First M.I.

ADDRESS

CITY | STATE

1 M 2 F | AGE | TAKEN TO

UNIT NO. | SEAT POS | SAF. EQPT. | TAKEN BY | INJ. CODE

CODE FOR INJURY

Use only most serious one in each space for injury

- K Dead before report made.
- O No indication of injury
- A Severely bleeding wounds, distorted member, or had to be carried from scene.
- B Other visible injury as bruises, abrasions, minor cuts, swelling, etc.
- C No visible injury, limping, momentary unconsciousness or complaint of pain.

SEATING IN VEHICLE

1 2 3
4 5 6

STATION WAGON

7 8 9

SAFETY EQUIPMENT USE

- 0 - UNKNOWN, NOT STATED
- 1 - SAFETY BELTS USED
- 2 - SAFETY BELTS-NOT USED
- 3 - HELMET USED
- 4 - HELMET PRESENT-NOT USED
- 5 - CHILD RESTRAINT USED
- 6 - CHILD RESTRAINT USED-NOT BELTED
- 7 - CHILD RESTRAINT PRESENT-NOT USED
- 8 - AIR BAG ACTIVATED

DAMAGE TO PROPERTY OTHER THAN VEHICLE

NAME OF OWNER OF PROPERTY | ADDRESS OF OWNER

NATURE OF DAMAGE | APPROX. COST TO REPAIR OR REPLACE $ ______

TIME NOTIFIED OF ACCIDENT : A.M. P.M. | ARRIVED AT SCENE : A.M. P.M. | DATE NOTIFIED OF ACCIDENT MONTH / DAY / YEAR | DATE REPORT COMPLETED MONTH / DAY / YEAR

ARREST (NAME) Last First M.I. | SECTION NUMBER | TICKET NUMBER

ARREST (NAME) Last First M.I. | SECTION NUMBER | TICKET NUMBER

SIGNATURE OF INVESTIGATING OFFICER X | I.D. NUMBER | BEAT/ZONE | COURT DATE / / | REVIEWING OFFICER

SR 1723-6000 (REV 8/88) IL 494-0738

Illinois

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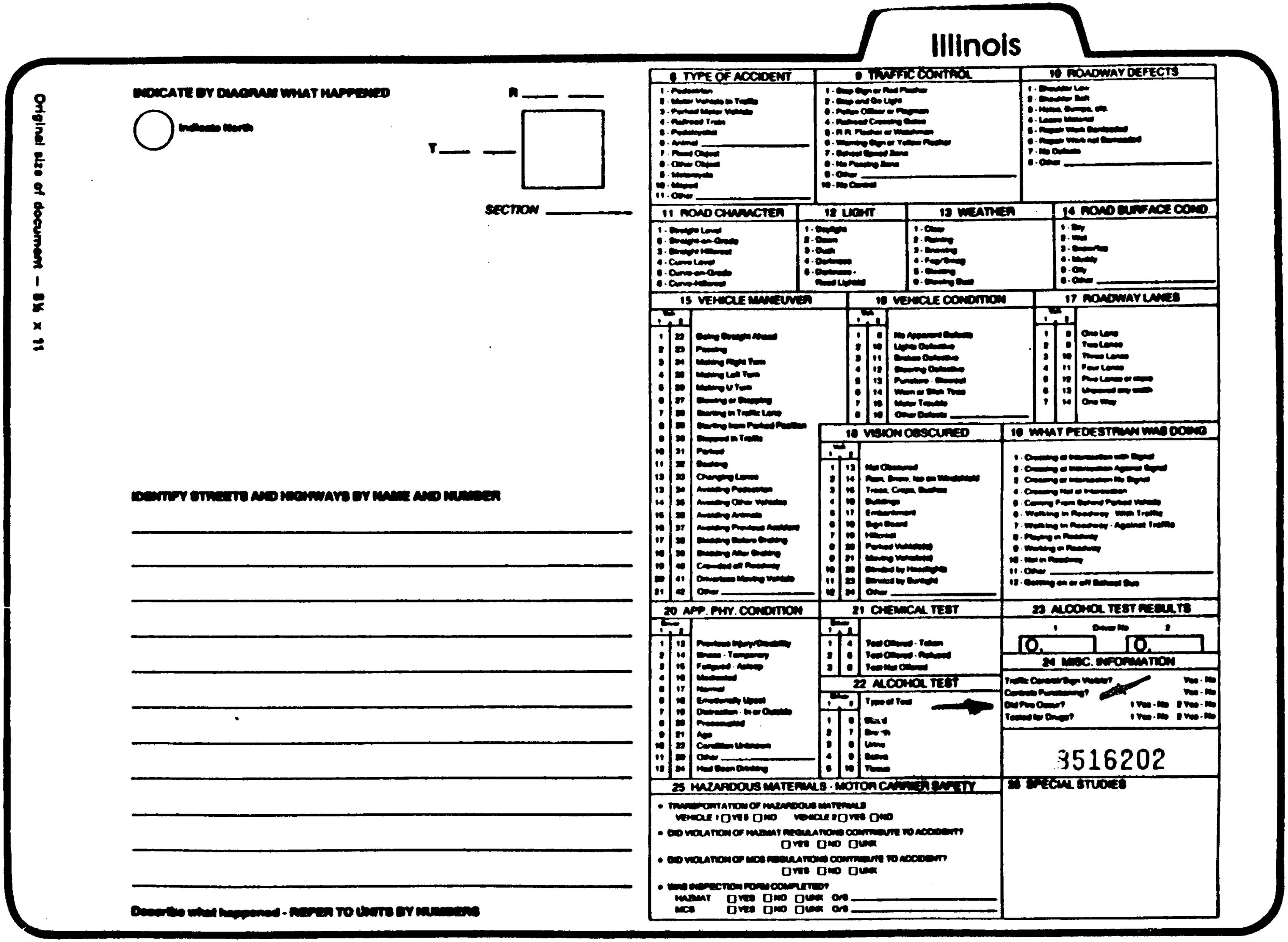

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Illinois

INDICATE BY DIAGRAM WHAT HAPPENED

○ Indicate North

R ___ ___

T ___ ___

SECTION ________

IDENTIFY STREETS AND HIGHWAYS BY NAME AND NUMBER

____

Describe what happened - REFER TO UNITS BY NUMBERS

8 TYPE OF ACCIDENT

1 - Pedestrian
2 - Motor Vehicle in Traffic
3 - Parked Motor Vehicle
4 - Railroad Train
5 - Pedalcyclist
6 - Animal ________
7 - Fixed Object
8 - Other Object
9 - Motorcycle
10 - Moped
11 - Other ________

9 TRAFFIC CONTROL

1 - Stop Sign or Red Flasher
2 - Stop and Go Light
3 - Police Officer or Flagman
4 - Railroad Crossing Gates
5 - R.R. Flasher or Watchman
6 - Warning Sign or Yellow Flasher
7 - School Speed Zone
8 - No Passing Zone
9 - Other ________
10 - No Control

10 ROADWAY DEFECTS

1 - Shoulder Low
2 - Shoulder Soft
3 - Holes, Bumps, etc.
4 - Loose Material
5 - Repair Work Barricaded
6 - Repair Work not Barricaded
7 - No Defects
8 - Other ________

11 ROAD CHARACTER

1 - Straight Level
2 - Straight-on-Grade
3 - Straight Hillcrest
4 - Curve Level
5 - Curve-on-Grade
6 - Curve-Hillcrest

12 LIGHT

1 - Daylight
2 - Dawn
3 - Dusk
4 - Darkness
5 - Darkness - Road Lighted

13 WEATHER

1 - Clear
2 - Raining
3 - Snowing
4 - Fog/Smog
5 - Sleeting
6 - Blowing Dust

14 ROAD SURFACE COND.

1 - Dry
2 - Wet
3 - Snow/Ice
4 - Muddy
5 - Oily
6 - Other ________

15 VEHICLE MANEUVER

Veh. 1	Veh. 2	
1	22	Going Straight Ahead
2	23	Passing
3	24	Making Right Turn
4	25	Making Left Turn
5	26	Making U Turn
6	27	Slowing or Stopping
7	28	Starting in Traffic Lane
8	29	Starting from Parked Position
9	30	Stopped in Traffic
10	31	Parked
11	32	Backing
12	33	Changing Lanes
13	34	Avoiding Pedestrian
14	35	Avoiding Other Vehicles
15	36	Avoiding Animals
16	37	Avoiding Previous Accident
17	38	Skidding Before Braking
18	39	Skidding After Braking
19	40	Crowded off Roadway
20	41	Driverless Moving Vehicle
21	42	Other ________

16 VEHICLE CONDITION

Veh. 1	Veh. 2	
1	9	No Apparent Defects
2	10	Lights Defective
3	11	Brakes Defective
4	12	Steering Defective
5	13	Puncture - Blowout
6	14	Worn or Slick Tires
7	15	Motor Trouble
8	16	Other Defects ________

17 ROADWAY LANES

Veh. 1	Veh. 2	
1	8	One Lane
2	9	Two Lanes
3	10	Three Lanes
4	11	Four Lanes
5	12	Five Lanes or more
6	13	Unpaved any width
7	14	One Way

18 VISION OBSCURED

Veh. 1	Veh. 2	
1	13	Not Obscured
2	14	Rain, Snow, Ice on Windshield
3	15	Trees, Crops, Bushes
4	16	Buildings
5	17	Embankment
6	18	Sign Board
7	19	Hillcrest
8	20	Parked Vehicle(s)
9	21	Moving Vehicle(s)
10	22	Blinded by Headlights
11	23	Blinded by Sunlight
12	24	Other ________

19 WHAT PEDESTRIAN WAS DOING

1 - Crossing at Intersection with Signal
2 - Crossing at Intersection Against Signal
3 - Crossing at Intersection No Signal
4 - Crossing Not at Intersection
5 - Coming From Behind Parked Vehicle
6 - Walking in Roadway - With Traffic
7 - Walking in Roadway - Against Traffic
8 - Playing in Roadway
9 - Working in Roadway
10 - Not in Roadway
11 - Other ________
12 - Getting on or off School Bus

20 APP. PHY. CONDITION

Driver 1	Driver 2	
1	13	Previous Injury/Disability
2	14	Illness - Temporary
3	15	Fatigued - Asleep
4	16	Medicated
5	17	Normal
6	18	Emotionally Upset
7	19	Distraction - In or Outside
8	20	Preoccupied
9	21	Age
10	22	Condition Unknown
11	23	Other ________
12	24	Had Been Drinking

21 CHEMICAL TEST

Driver 1	Driver 2	
1	4	Test Offered - Taken
2	5	Test Offered - Refused
3	6	Test Not Offered

22 ALCOHOL TEST

Driver 1	Driver 2	Type of Test
1	6	Blood
2	7	Breath
3	8	Urine
4	9	Saliva
5	10	Tissue

23 ALCOHOL TEST RESULTS

1	Driver No.	2
0.		0.

24 MISC. INFORMATION

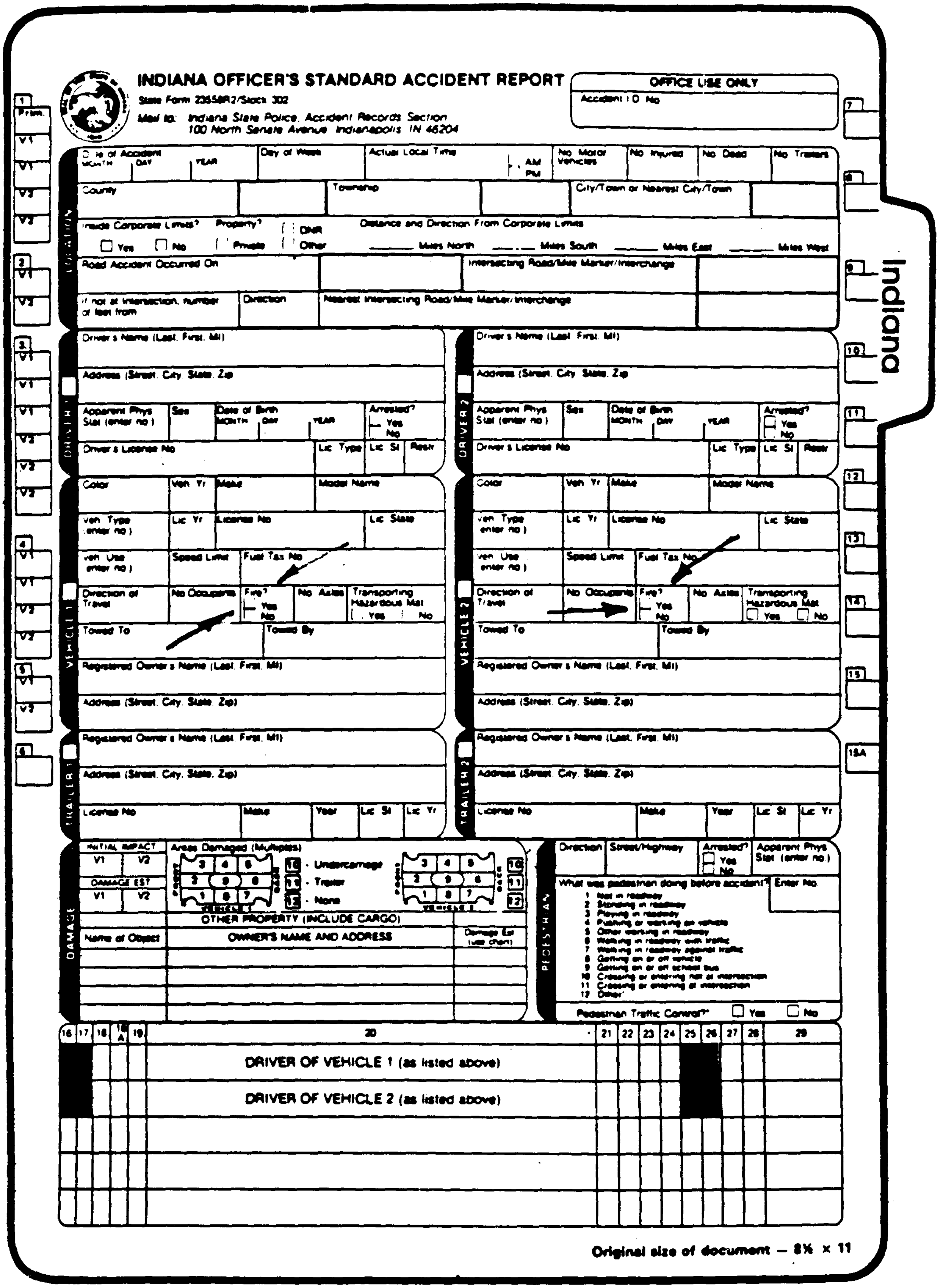
Traffic Control/Sign Visible? Yes - No
Controls Functioning? Yes - No
Did Fire Occur? 1 Yes - No 2 Yes - No
Tested for Drugs? 1 Yes - No 2 Yes - No

3516202

25 HAZARDOUS MATERIALS - MOTOR CARRIER SAFETY

- TRANSPORTATION OF HAZARDOUS MATERIALS
  VEHICLE 1 ☐ YES ☐ NO VEHICLE 2 ☐ YES ☐ NO
- DID VIOLATION OF HAZMAT REGULATIONS CONTRIBUTE TO ACCIDENT?
  ☐ YES ☐ NO ☐ UNK
- DID VIOLATION OF MCS REGULATIONS CONTRIBUTE TO ACCIDENT?
  ☐ YES ☐ NO ☐ UNK
- WAS INSPECTION FORM COMPLETED?
  HAZMAT ☐ YES ☐ NO ☐ UNK O/S ________
  MCS ☐ YES ☐ NO ☐ UNK O/S ________

26 SPECIAL STUDIES



INDIANA OFFICER'S STANDARD ACCIDENT REPORT

State Form 23558R2/Stock 302

Mail to: Indiana State Police, Accident Records Section
100 North Senate Avenue Indianapolis IN 46204

OFFICE USE ONLY
Accident I D No

Indiana

LOCATION

Date of Accident MONTH DAY YEAR | Day of Week | Actual Local Time AM PM | No Motor Vehicles | No Injured | No Dead | No Trailers

County | Township | City/Town or Nearest City/Town

Inside Corporate Limits? ☐ Yes ☐ No — Property? ☐ Private ☐ DNR ☐ Other — Distance and Direction From Corporate Limits ______ Miles North ______ Miles South ______ Miles East ______ Miles West

Road Accident Occurred On | Intersecting Road/Mile Marker/Interchange

If not at intersection, number of feet from | Direction | Nearest Intersecting Road/Mile Marker/Interchange

DRIVER 1 / DRIVER 2

Driver's Name (Last, First, MI)

Address (Street, City, State, Zip

Apparent Phys Stat (enter no.) | Sex | Date of Birth MONTH DAY YEAR | Arrested? ☐ Yes ☐ No

Driver's License No | Lic Type | Lic St | Restr

VEHICLE 1 / VEHICLE 2

Color | Veh Yr | Make | Model Name

Veh Type (enter no.) | Lic Yr | License No | Lic State

Veh Use (enter no.) | Speed Limit | Fuel Tax No

Direction of Travel | No Occupants | Fire? ☐ Yes ☐ No | No Axles | Transporting Hazardous Mat ☐ Yes ☐ No

Towed To | Towed By

Registered Owner's Name (Last, First, MI)

Address (Street, City, State, Zip)

TRAILER 1 / TRAILER 2

Registered Owner's Name (Last, First, MI)

Address (Street, City, State, Zip)

License No | Make | Year | Lic St | Lic Yr

DAMAGE

INITIAL IMPACT V1 V2

DAMAGE EST V1 V2

Areas Damaged (Multiples)

VEHICLE 1 / VEHICLE 2: 1 2 3 4 5 6 7 8 9 — 10 - Undercarriage 11 - Trailer 12 - None

OTHER PROPERTY (INCLUDE CARGO)

Name of Object | OWNER'S NAME AND ADDRESS | Damage Est (use chart)

PEDESTRIAN

Direction | Street/Highway | Arrested? ☐ Yes ☐ No | Apparent Phys Stat (enter no.)

What was pedestrian doing before accident? Enter No.
1 Not in roadway
2 Standing in roadway
3 Playing in roadway
4 Pushing or working on vehicle
5 Other working in roadway
6 Walking in roadway with traffic
7 Walking in roadway against traffic
8 Getting on or off vehicle
9 Getting on or off school bus
10 Crossing or entering not at intersection
11 Crossing or entering at intersection
12 Other

Pedestrian Traffic Control?* ☐ Yes ☐ No

16 17 18 18A 19 20 21 22 23 24 25 26 27 28 29

DRIVER OF VEHICLE 1 (as listed above)

DRIVER OF VEHICLE 2 (as listed above)

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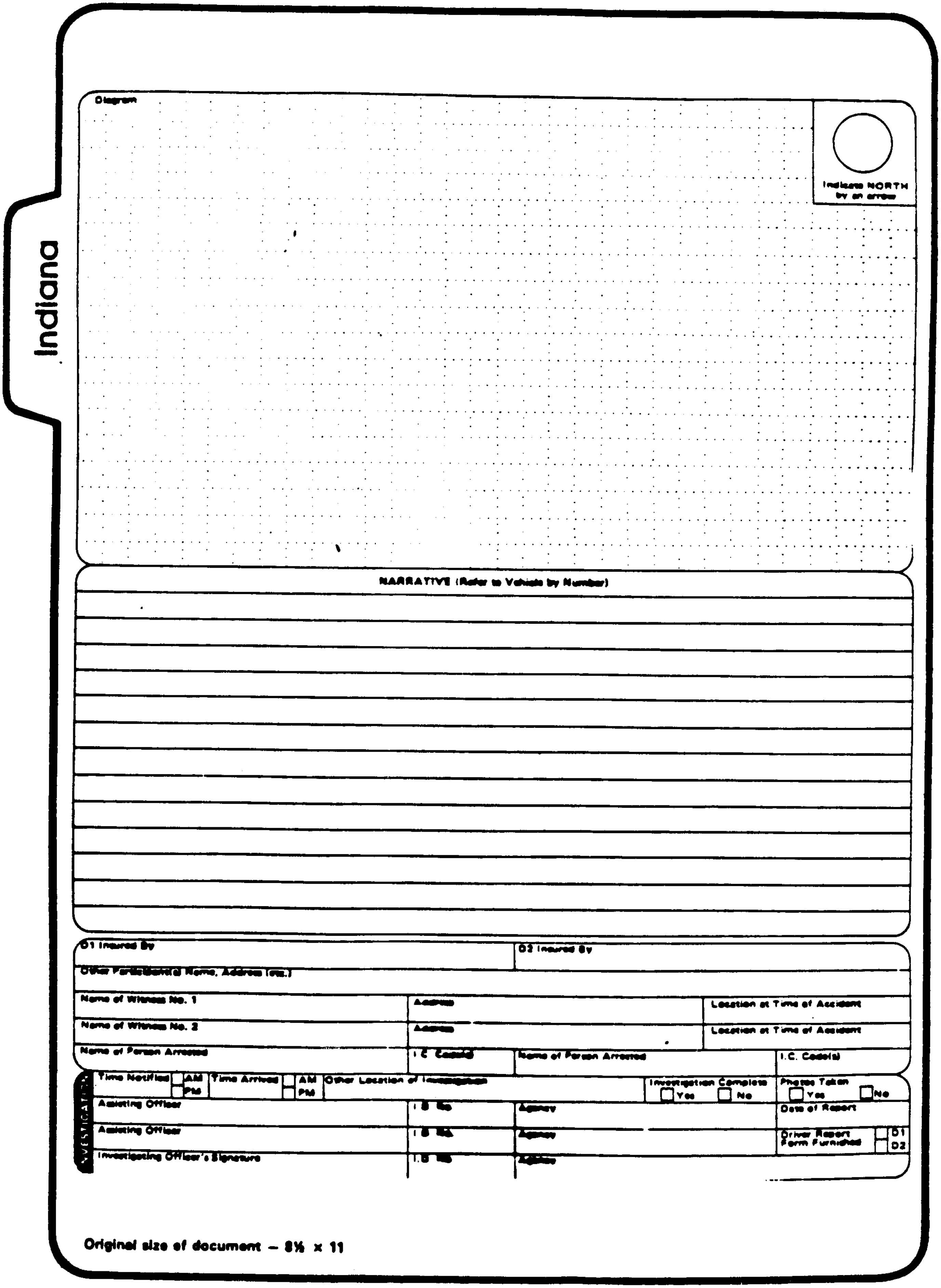


Indiana

Diagram

Indicate NORTH by an arrow

NARRATIVE (Refer to Vehicle by Number)

D1 Insured By

D2 Insured By

Other Participant(s) (Name, Address etc.)

Name of Witness No. 1

Address

Location at Time of Accident

Name of Witness No. 2

Address

Location at Time of Accident

Name of Person Arrested

I.C. Code(s)

Name of Person Arrested

I.C. Code(s)

INVESTIGATION

Time Notified ☐ AM ☐ PM

Time Arrived ☐ AM ☐ PM

Other Location of Investigation

Investigation Complete ☐ Yes ☐ No

Photos Taken ☐ Yes ☐ No

Assisting Officer

I.D. No.

Agency

Date of Report

Assisting Officer

I.D. No.

Agency

Driver Report Form Furnished ☐ D1 ☐ D2

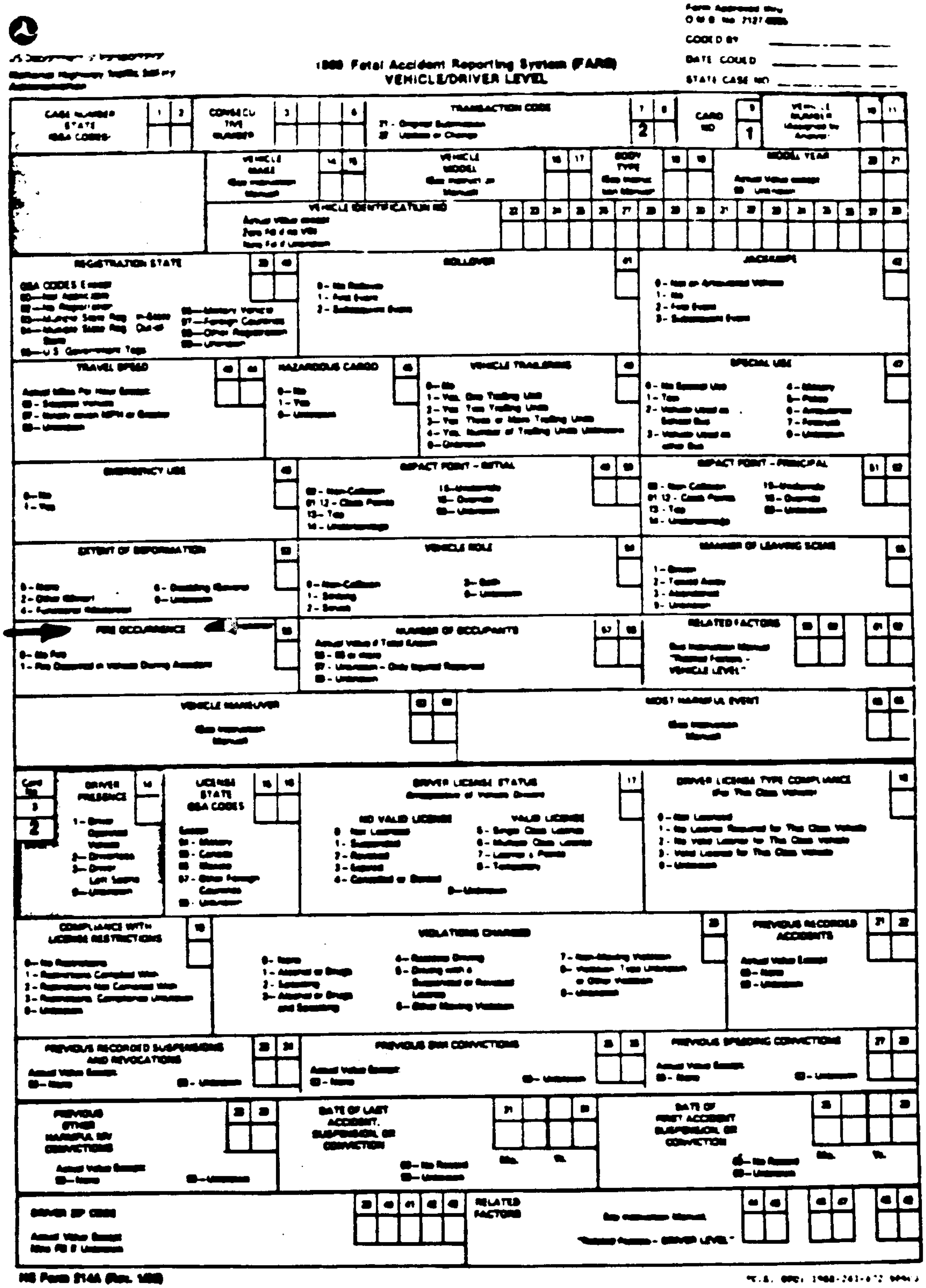
Investigating Officer's Signature

I.D. No.

Agency

Original size of document – 8½ x 11

100-A EXHIBIT FARS CODING FORMS (VEHICLE/DRIVER LEVEL)

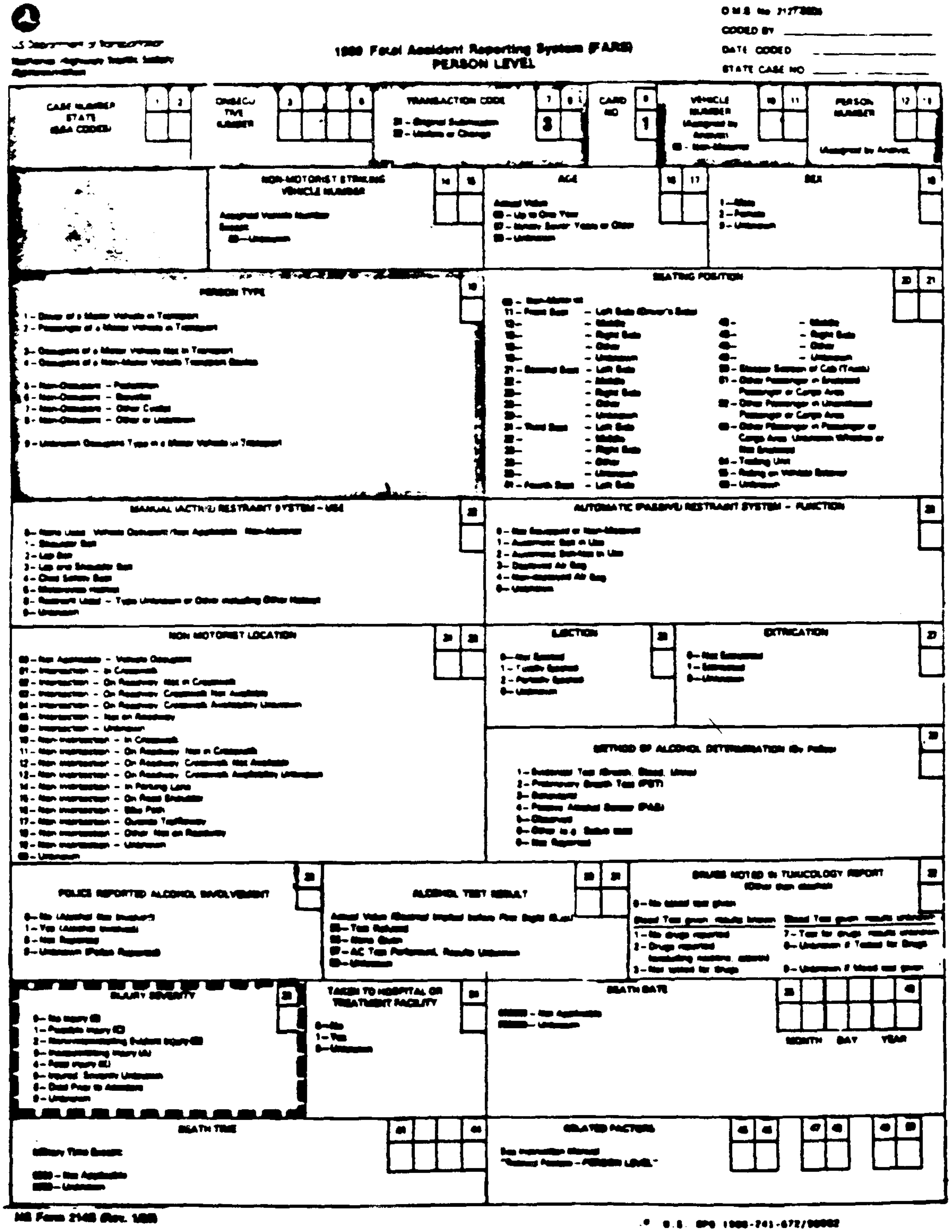


Fatal Accident Reporting System (FARS)
VEHICLE/DRIVER LEVEL

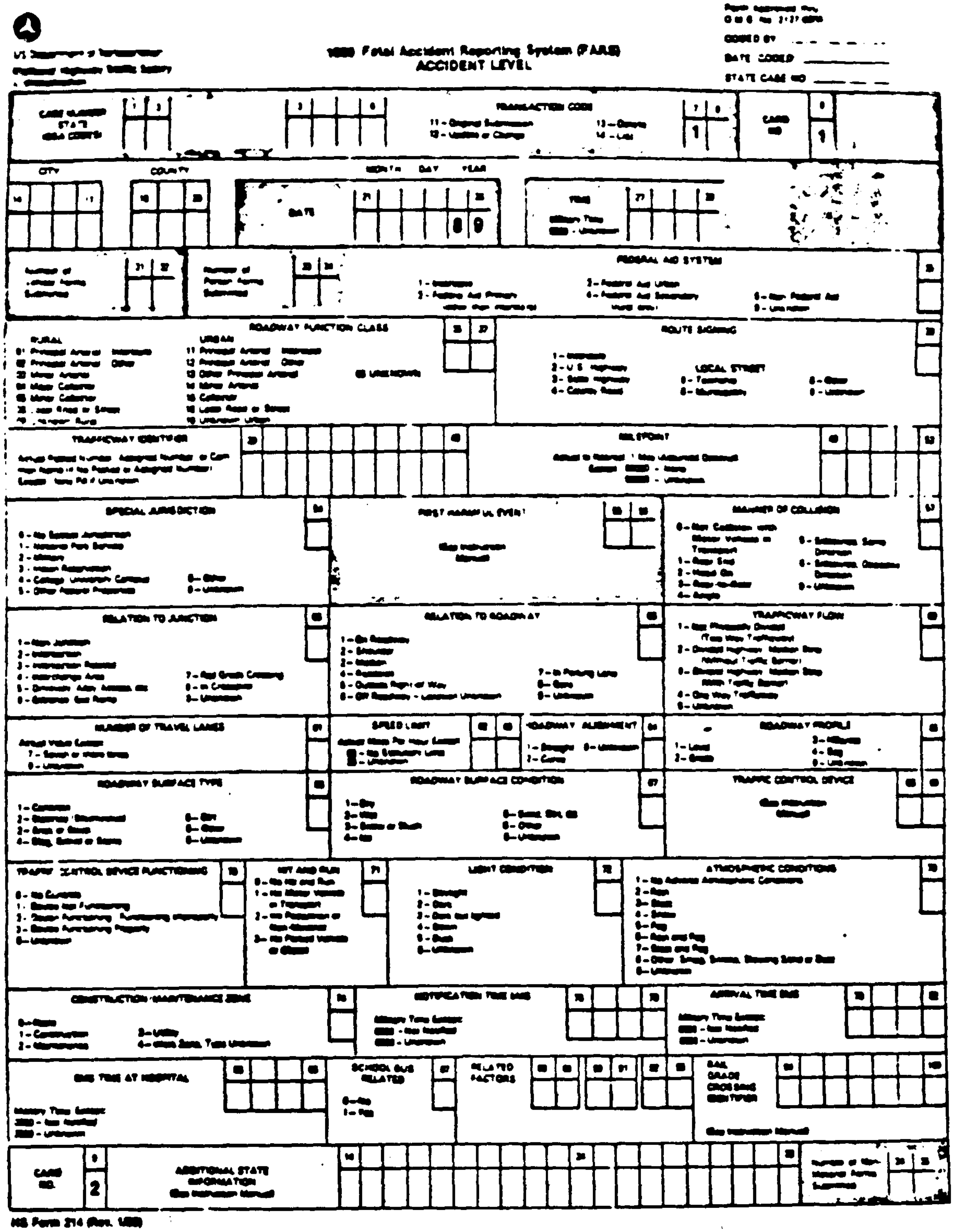
CODED BY
DATE CODED
STATE CASE NO

CASE NUMBER STATE
CONSECUTIVE NUMBER
TRANSACTION CODE
CARD NO
VEHICLE NUMBER
VEHICLE MAKE
VEHICLE MODEL
BODY TYPE
MODEL YEAR
VEHICLE IDENTIFICATION NO
REGISTRATION STATE
ROLLOVER
JACKKNIFE
TRAVEL SPEED
HAZARDOUS CARGO
VEHICLE TRAILERING
SPECIAL USE
EMERGENCY USE
IMPACT POINT - INITIAL
IMPACT POINT - PRINCIPAL
EXTENT OF DEFORMATION
VEHICLE ROLE
MANNER OF LEAVING SCENE
FIRE OCCURRENCE
NUMBER OF OCCUPANTS
RELATED FACTORS
VEHICLE MANEUVER
MOST HARMFUL EVENT
DRIVER PRESENCE
LICENSE STATE
DRIVER LICENSE STATUS
DRIVER LICENSE TYPE COMPLIANCE
COMPLIANCE WITH LICENSE RESTRICTIONS
VIOLATIONS CHARGED
PREVIOUS RECORDED ACCIDENTS
PREVIOUS RECORDED SUSPENSIONS AND REVOCATIONS
PREVIOUS DWI CONVICTIONS
PREVIOUS SPEEDING CONVICTIONS
PREVIOUS OTHER HARMFUL MV CONVICTIONS
DATE OF LAST ACCIDENT, SUSPENSION OR CONVICTION
DATE OF FIRST ACCIDENT, SUSPENSION OR CONVICTION
DRIVER ZIP CODE
RELATED FACTORS

100-A EXHIBIT FARS CODING FORMS (PERSON LEVEL)



100-A EXHIBIT FARS CODING FORMS (ACCIDENT LEVEL)



Fatal Accident Reporting System (FARS)
ACCIDENT LEVEL

CODED BY

DATE CODED

STATE CASE NO

Appendix C

Frequency Counts of Fires and Motor Vehicle Crashes

Table C-1

Counts of Vehicle Fires and Total Accident-Involved Passenger Cars by Vehicle Model Year

States of Michigan, Ohio, Maryland
Calendar Years 1982 - 1987

Vehicle Model Year	Michigan		Ohio		Maryland	
	Fires	Vehicles	Fires	Vehicles	Fires	Vehicles
1987	56	38,585	54	32,913	16	15,597
1986	142	103,274	218	85,398	29	33,978
1985	219	160,467	284	152,450	41	49,948
1984	269	195,298	415	171,949	81	68,620
1983	247	158,620	301	143,877	76	61,950
1982	267	168,774	391	161,844	100	66,998
1981	330	194,501	488	194,371	129	73,166
1980	400	208,851	638	215,992	158	75,797
1979	445	236,391	819	255,927	206	84,591
1978	529	235,440	915	265,801	203	79,861
1977	500	223,984	935	248,648	217	72,159
1976	410	168,825	835	204,047	214	60,130
1975	297	111,654	702	139,723	208	41,498
1974	329	104,112	785	147,308	247	44,695
1973	316	94,520	666	128,837	203	44,723
1972	254	70,664	552	98,541	167	36,023
1971	165	42,126	332	60,770	121	25,307
1970	99	29,292	252	48,718	104	20,272
1969	65	19,705	172	32,470	98	14,411
1968	43	14,857	154	24,815	53	10,702
1967	31	9,496	74	16,702	42	7,310
1966	19	6,481	52	12,673	18	5,393

Table C-2
Counts of Vehicle Fires and Total Accident-Involved Passenger Cars by Vehicle Model Year

States of Illinois and Indiana
Calendar Years 1982 - 1987

Vehicle Model Year	Illinois Fire	Illinois Vehicles	Indiana Fires	Indiana Vehicles
1987	23	60,160	9	18,389
1986	92	133,489	30	45,202
1985	128	201,270	37	64,950
1984	185	265,289	58	82,582
1983	168	235,060	37	68,321
1982	208	255,572	45	76,144
1981	232	277,211	75	92,766
1980	261	292,888	72	98,497
1979	330	368,303	106	121,839
1978	316	338,447	122	126,172
1977	332	321,736	108	120,018
1976	261	283,088	88	97,139
1975	195	189,829	78	66,952
1974	217	185,323	84	69,939
1973	226	167,203	89	68,481
1972	119	123,204	87	52,739
1971	96	73,841	56	32,586
1970	67	53,645	57	26,039
1969	48	35,506	29	18,508
1968	37	25,746	18	14,029
1967	27	17,620	10	9,713
1966	17	12,929	16	8,001

Table C - 2a
Counts of Vehicle Fires and Total Passenger Cars Involved in Injury Crashes by Vehicle Model Year

States of Michigan, Ohio, and Maryland
Calendar Years 1982-1987

Vehicle	Michigan		Ohio		Maryland	
Model Year	Fires	Vehicles	Fires	Vehicles	Fires	Vehicles
1987	10	2,251	13	2,391	8	2,017
1986	32	6,011	54	6,657	4	4,242
1985	40	9,252	53	10,099	13	5,910
1984	61	12,270	72	13,635	12	7,965
1983	40	10,277	65	11,790	7	7,142
1982	44	12,151	76	14,188	8	7,864
1981	61	14,100	85	17,530	14	8,593
1980	85	15,559	120	19,704	25	8,718
1979	104	16,260	173	22,634	24	8,784
1978	106	15,976	189	22,553	16	8,088
1977	98	14,393	162	20,134	26	7,482
1976	103	11,407	154	17,586	24	5,718
1975	63	7,708	132	12,279	17	3,869
1974	64	7,814	163	13,479	17	4,505
1973	66	6,815	128	11,432	18	4,116
1972	56	5,189	118	8,855	19	3,406
1971	41	3,148	60	5,651	9	2,643
1970	20	2,211	50	4,621	7	2,057
1969	17	1,432	45	3,098	8	1,430
1968	8	1,168	35	2,320	6	1,092
1967	12	785	25	1,720	3	834
1966	5	555	13	1,322	1	642
1965	6	433	12	962	4	406

Table entries are: (1) the number of vehicles in crashes where the vehicle catches fire and the driver sustains injury at either the A or the B severity level; (2) the total number of vehicles in crashes where the driver sustains injury at either the A or B severity level

Table C - 3

Counts of Vehicle Fires and Total Accident-Involved Light Trucks by Vehicle Model Year States of Michigan, Ohio, and Maryland

Vehicle Model Year	Michigan		Ohio		Maryland	
	Fires	Vehicles	Fires	Vehicles	Fires	Vehicles
1987	23	11,595	21	8,954	4	3,949
1986	34	28,335	47	21,857	18	9,498
1985	48	38,558	77	29,353	16	12,190
1984	69	39,681	82	30,534	26	14,147
1983	56	31,372	84	24,999	24	11,426
1982	43	26,383	60	23,821	23	10,144
1981	40	23,965	76	23,257	21	9,743
1980	35	23,326	70	22,682	31	9,254
1979	119	51,304	169	46,146	66	14,585
1978	95	46,173	206	45,932	50	11,805
1977	85	40,124	150	37,404	50	10,347
1976	69	29,374	120	27,303	30	7,862
1975	54	17,603	100	17,431	27	5,367
1974	49	16,604	99	19,819	30	6,182
1973	39	14,689	73	15,243	29	5,115
1972	45	11,089	49	11,432	18	4,109
1971	27	6,857	38	7,830	24	2,868
1970	12	5,286	45	6,501	13	2,459
1969	14	4,878	35	6,057	11	2,147
1968	12	3,589	27	4,254	14	1,461
1967	4	2,489	20	3,357	5	1,180
1966	3	1,592	11	2,261	6	910

Source: State accident files from Michigan, Ohio, and Maryland (converted to SAS format by NHTSA for analysis). Data include calendar years 1982 through 1987.

Table C - 4
Counts of Vehicle Fires and Total Accident-Involved Light Trucks by Vehicle Model Year
States of Illinois and Indiana

Vehicle Model Year	Illinois		Indiana	
	Fires	Vehicles	Fires	Vehicles
1987	9	10,665	1	5,108
1986	23	25,083	6	12,073
1985	31	35,429	6	15,664
1984	36	38,208	11	15,844
1983	20	33,176	20	13,611
1982	32	29,668	12	12,712
1981	29	26,075	9	11,557
1980	34	32,090	5	11,545
1979	66	59,947	27	25,450
1978	67	47,546	21	24,564
1977	46	41,493	28	20,758
1976	44	31,332	20	15,444
1975	35	19,390	13	9,784
1974	32	19,766	9	11,133
1973	18	14,436	7	9,631
1972	19	10,796	18	7,595
1971	12	7,131	10	5,055
1970	8	5,741	6	4,404
1969	5	5,369	9	4,781
1968	8	3,661	3	3,269
1967	2	2,947	4	2,815
1966	2	2,079	2	2,091

Source: State accident files from Illinois and Indiana (converted to SAS format by NHTSA for analysis). Data include calendar years 1982 through 1987.

Appendix D

Letters to Motor Vehicle Manufacturers

The National Highway Traffic Safety Administration is engaged in an evaluation of the safety benefits, and attendant costs, of its Federal Motor Vehicle Safety Standard No. 301-75, Fuel System Integrity. The study will consist of the first assessment of the standard as it applies to multipurpose passenger vehicles, trucks, buses and school buses, in addition to an update of an earlier (1983) evaluation of the Standard as it applies to passenger cars.

In order to complete this evaluation, the agency needs certain information from the motor vehicle manufacturers. The information needed pertains only to the latter three vehicle categories listed above; similar information for passenger cars, obtained in a prior request to manufacturers and used in the earlier evaluation, will be updated for use in the current study.

It would be most helpful if you could provide us with answers to the following questions:

1. Did your company make any changes in its vehicles with GVWR of 6,000 pounds or less (i.e., multipurpose passenger vehicles, trucks, or buses) as a result of the test requirements set forth in S6.1 (frontal crash, perpendicular), S6.2 (rear crash), and S6.4 (static rollover), which applied to Model Year 1977 vehicles; or as a result of the test requirements set forth in S6.1 (frontal crash, perpendicular and oblique), S6.2 (rear crash), S6.3 (side crash), and S6.4 (static rollover), which applied to Model Year 1978, and later vehicles?

2. If the answer to question No. 1 is affirmative, please provide the following additional information:

    a. A description or listing of the vehicle modifications made, by make, model and model year in which the changes were effective. (Please provide descriptive information on the type, or nature of the modifications or structural changes made. It is not expected that you supply detailed engineering drawings, or blueprints.)

    b. For each model in each model year listed in your response to a., above, an estimate of the total vehicle weight, if any, attributable to the modifications described.

c. For each model and model year listed in your response to a., above, an estimate of the total amount, per vehicle, of any increase in manufacturer variable costs (including all costs for material, labor, supervision and variable burden that were directly related to the manufacturing, production volume, and assembly of the vehicle) attributable to the modifications described.

3. Did your company make any changes in its vehicles with a GVWR of more than 6,000 pounds, but not more than 10,000 pounds (i.e., multipurpose passenger vehicles, trucks, or buses) as a result of the test requirements set forth in S6.1 (frontal, perpendicular crash), which applied to Model Year 1977 vehicles; or as a result of the test requirements set forth in S6.1 (frontal crash, perpendicular and oblique), S6.2 (rear crash), S6.3 (side crash), and S6.4 (static rollover), which applied to Model Year 1978 and later vehicles?

4. If the answer to question No. 3 is affirmative, please provide the information as listed in the subelements of question No. 2.

5. Did your company make any changes in its truck engine-chassis with a GVWR of more than 10,000 pounds as a result of the test requirements set forth in S6.5 (moving contoured barrier crash), which applied to Model Year 1978 and later vehicles? (This would involve truck engine-chassis ordered by school bus manufacturers who would perform final vehicle assembly via the addition of school bus bodies to the chassis provided by your company.)

6. If the answer to question No. 5 is affirmative, please provide the information as listed in the subelements of question No. 2. Additionally, if question No. 5 is answered affirmatively, were the changes confined to only those chassis ordered by school bus manufacturers or did such changes apply to the entire production volume of engine-chassis of that GVWR rating, regardless of the final type of truck body that was ultimately installed on the chassis?

The information submitted in response to this request is intended for use only in general summaries consisting of information received from all manufacturers. However, should you desire confidential treatment for any of the information submitted, the agency has procedures for handling this.

I would appreciate it if you could provide this information by October 24, 1986. Should you require further information concerning this request, please contact Mr. Glenn Parsons ((202) 366-2562)) of my office.

Thank you for your cooperation.

Sincerely,

Adele Spielberger
Associate Administrator for
Plans and Policy

The National Highway Traffic Safety Administration is engaged in an evaluation of the safety benefits, and attendant costs, of its Federal Motor Vehicle Safety Standard No. 301-75, Fuel System Integrity. The study will consist of the first assessment of the standard as it applies to multipurpose passenger vehicles, trucks, buses and school buses, in addition to an update of an earlier (1983) evaluation of the Standard as it applies to passenger cars.

In order to complete this evaluation, the agency needs certain information from the motor vehicle manufacturers. The information needed pertains only to the latter three vehicle categories listed above; similar information for passenger cars, obtained in a prior request to manufacturers and used in the earlier evaluation, will be updated for use in the current study.

It would be most helpful if you could provide us with answers to the following questions:

1. Did your company make any changes in its vehicles with GVWR of 6,000 pounds or less (i.e., multipurpose passenger vehicles, trucks, or buses) as a result of the test requirements set forth in S6.1 (frontal crash, perpendicular), S6.2 (rear crash), and S6.4 (static rollover), which applied to Model Year 1977 vehicles; or as a result of the test requirements set forth in S6.1 (frontal crash, perpendicular and oblique), S6.2 (rear crash), S6.3 (side crash), and S6.4 (static rollover), which applied to Model Year 1978, and later vehicles?

2. If the answer to question No. 1 is affirmative, please provide the following additional information:

    a. A description or listing of the vehicle modifications made, by make, model and model year in which the changes were effective. (Please provide descriptive information on the type, or nature of the modifications or structural changes made. It is not expected that you supply detailed engineering drawings, or blueprints.)

    b. For each model in each model year listed in your response to a., above, an estimate of the total vehicle weight, if any, attributable to the modifications described.

c. For each model and model year listed in your response to a., above, an estimate of the total amount, per vehicle, of any increase in manufacturer variable costs (including all costs for material, labor, supervision and variable burden that were directly related to the manufacturing, production volume, and assembly of the vehicle) attributable to the modifications described.

3. Did your company make any changes in its vehicles with a GVWR of more than 6,000 pounds, but not more than 10,000 pounds (i.e., multipurpose passenger vehicles, trucks, or buses) as a result of the test requirements set forth in S6.1 (frontal, perpendicular crash), which applied to Model Year 1977 vehicles; or as a result of the test requirements set forth in S6.1 (frontal crash, perpendicular and oblique), S6.2 (rear crash), S6.3 (side crash), and S6.4 (static rollover), which applied to Model Year 1978 and later vehicles?

4. If the answer to question No. 3 is affirmative, please provide the information as listed in the subelements of question No. 2.

The information submitted in response to this request is intended for use only in general summaries consisting of information received from all manufacturers. However, should you desire confidential treatment for any of the information submitted, the agency has procedures for handling this.

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In order to complete this evaluation, the agency needs certain information from the motor vehicle manufacturers. The information needed pertains only to the latter three vehicle categories listed above; similar information for passenger cars, obtained in a prior request to manufacturers and used in the earlier evaluation, will be updated for use in the current study.

It would be most helpful if you could provide us with answers to the following questions:

1. Did your company make any changes in its school buses as a result of the test requirements set forth in: (a) S6.1 (frontal, perpendicular crash), which applied to Model Year 1977 vehicles (under 10,000 pounds, GVWR); or (b) S6.1 (frontal crash, perpendicular and oblique), S6.2 (rear crash, S6.3 (side crash), and S6.4 (static rollover), which applied to Model Year 1978 and later vehicles (under 10,000 pounds, GVWR); or (c) S6.5 (moving contoured barrier crash), which applied to Model Year 1978 and later vehicles (over 10,000 pounds GVWR)?

2. If the answer to question No. 1 is affirmative, please provide the following additional information:

    a. A description or listing of the vehicle modifications made, by bus model and model year in which the changes were effective. (Please provide descriptive information on the type, or nature of the modifications or structural changes made. It is not expected that you supply detailed engineering drawings, or blueprints.)

    b. For each model in each model year listed in your response to a., above, an estimate of the total vehicle weight, if any, attributable to the modifications described.

c. For each model and model year listed in your response to a., above, an estimate of the total amount, per vehicle, of any increase in manufacturer variable costs (including all costs for material, labor, supervision and variable burden that were directly related to the manufacturing, production volume, and assembly of the vehicle) attributable to the modifications described.

The information submitted in response to this request is intended for use only in general summaries consisting of information received from all manufacturers. However, should you desire confidential treatment for any of the information submitted, the agency has procedures for handling this.

I would appreciate it if you could provide this information by October 24, 1986. Should you require further information concerning this request, please contact Mr. Glenn Parsons ((202) 366-2562)) of my office.

Thank you for your cooperation.

Sincerely,

Adele Spielberger
Associate Administrator for
Plans and Policy

Appendix E

Additional Analyses of the Effect of Vehicle Age on Fire Rates

Additional Analyses of the Effect of Vehicle Age on Fire Rates

The analyses described in Chapter 2 to estimate the effectiveness of Federal Motor Vehicle Safety Standard 301 were carried out under the assumption that the effect of vehicle age on fire rates did not differ between vehicles manufactured before the Standard went into effect and vehicles manufactured after the Standard went into effect. This assumption appears reasonable on the basis that age - induced degradation and weakening of motor vehicle structures (and therefore increased likelihood of fuel system breaching and fire) would be expected to occur at the same rate, irrespective of whether the vehicle were produced before or after the Standard were issued.

Nevertheless, the question could be asked as to whether this assumption of a constant age effect between Pre and Post-standard vehicles can be further investigated. It is noted, for example, that among the newer vehicles in the data files analyzed in Chapter 2, there are relatively more Post-standard vehicles than there are Pre-standard vehicles. Conversely, among the older vehicles, there are relatively fewer Post-standard vehicles and relatively more Pre-standard vehicles. This produces somewhat of an imbalance in the data samples for the Pre and Post-standard periods insofar as the age distribution of vehicles within each period. Is it possible that a predominance of Pre-standard vehicles in the older age ranges could contribute to a steeper slope (i.e., greater age effect) for the age factor, and thus affect the estimates of FMVSS 301 effectiveness found in the Chapter 2 analyses?

There are two ways to investigate this isssue. First, age effects can be estimated separately, for Pre-standard and Post-standard vehicles, and then tested to ascertain whether they are significantly different, statistically. Secondly, equations of the Standard's effectiveness can be recomputed, according to the procedures used in Chapter 2, but restricting the accident data to vehicles of the same age in the Pre-standard and Post-standard samples.

Comparison of Age Effects Between Pre and Post-standard Vehicles

Simple linear least squares analyses were performed to estimate the age effect (independent variable) on vehicle fire rate (dependent variable), separately, for Pre-standard and Post-standard vehicles. Computations were made for the two vehicle types, passenger cars and light trucks; for the two data sets, State data [1] and FARS data; for vehicles of equal age and for

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[1] The State data used were the combined data sets from the States of Michigan, Ohio, and Maryland as described in Chapter 2.

all available data; and for both weighted and unweighted data observations. This gave a total of $2^5 = 32$ separate analyses, or $2^4/2 = 16$ separate comparisons of age effects between Pre and Post-standard samples. The preferred test here is between equal age samples; however, comparisons using all available (age) data are also included in order to provide a more comprehensive view of the age effect.

The analyses were run using the General Linear Models statistical subroutine of the SAS system for data analysis, the same as used in the analyses described in Chapter 2 of the report. The result of these analyses are shown in Tables E-1 and E-2, for passenger cars and light trucks, respectively.

It can be shown that the age effects for Pre and Post-standard samples can be tested for significant difference by the following formula:[2]

$$t = \frac{b_1 - b_2}{\left[\frac{(TSS_1 - RSS_1) + (TSS_2 - RSS_2)}{N_1 + N_2 - 4}\right]^{\frac{1}{2}} \left[\frac{b_1^2}{RSS_1} + \frac{b_2^2}{RSS_2}\right]^{\frac{1}{2}}}$$

where,

b = age coefficient estimated from model,
TSS = total sum of squares for model,
RSS = sum of squares component for age variable (i.e., due to regression),
N = sample size (no. of observations),

and subscripts 1,2 refer to Pre-standard and Post-standard samples, respectively.

---

[2] Duncan, Acheson J., Quality Control and Industrial Statistics, Revised Edition, 1959.

Table E-1
Statistical Comparison of the Effect of Age on Fire Rates in Accident Data — Passenger Cars

	Equal Age Data						All Available Data					
	Pre-Std Vehicles	Post-Std Vehicles	df	t-value Calc.	t-Dist. Value	Signi- * ficance	Pre-Std Vehicles	Post-Std Vehicles	df	t-value Calc.	t-Dist. Value	Signi- * ficance
State Accident Data												
No. of Observations	45	45					180	171				
Age Range (Years)	7-11	7-11					7-21	0-11				
Age Coeff. (Unwgtd Model)	1463×10^{-7}	3906×10^{-7}	86	-1.43	±1.99	NS	210×10^{-7}	2655×10^{-7}	347	-5.35	±1.96	S
Age Coeff. (Wgtd. Model)	1676×10^{-7}	3540×10^{-7}	86	-1.06	±1.99	NS	961×10^{-7}	2437×10^{-7}	347	-3.75	±1.96	S
Fatal Accident Data												
No. of Observations	91	91					210	91				
Age Range (Years)	0-12	0-12					0-27	0-12				
Age Coeff. (Unwgtd Model)	3791×10^{-7}	7013×10^{-7}	188	-1.56	±1.96	NS	65×10^{-7}	7013×10^{-7}	297	-2.28	±1.96	S
Age Coeff. (Wgtd. Model)	3837×10^{-7}	6533×10^{-7}	188	-1.39	±1.96	NS	4228×10^{-7}	6533×10^{-7}	297	-1.45	±1.96	NS

---

* S: Statistically significant
NS: Not statistically significant

Significance level α = 5% (two-tailed)

Table E-2
Statistical Comparison of the Effect of Age on Fire Rates in Accident Data -- Light Trucks

	Equal Age Data						All Available Data					
	Pre-Std Vehicles	Post-Std Vehicles	df	t-value Calc.	t-Dist. Value	Signi-ficance *	Pre-Std Vehicles	Post-Std Vehicles	df	t-value Calc.	t-Dist. Value	Signi-ficance *
State Accident Data												
No. of Observations	45	45					198	153				
Age Range (Years)	6-10	6-10					6-21	0-10				
Age Coeff. (Unwgtd Model)	3394×10^{-7}	3467×10^{-7}	86	-0.27	±1.99	NS	1641×10^{-7}	3372×10^{-7}	347	-2.51	±1.96	S
Age Coeff. (Wgtd. Model)	3840×10^{-7}	1288×10^{-7}	86	1.00	±1.99	NS	1992×10^{-7}	2463×10^{-7}	347	-0.78	±1.96	NS
Fatal Accident Data												
No. of Observations	90	78					223	78				
Age Range (Years)	0-11	0-11					0-27	0-11				
Age Coeff. (Unwgtd Model)	2398×10^{-7}	1685×10^{-7}	164	1.17	±1.96	NS	5319×10^{-7}	1685×10^{-7}	297	1.08	±1.96	NS
Age Coeff. (Wgtd. Model)	3789×10^{-7}	1773×10^{-7}	164	1.81	±1.96	NS	6656×10^{-7}	1773×10^{-7}	297	2.94	±1.96	S

---

* S: Statistically significant
NS: Not statistically significant

Significance level α= 5% (two-tailed)

The above formula is equivalent to testing for the difference between the slopes of two fitted simple regression lines with slope coefficients b_1 and b_2, respectively. The basis for significance testing is the comparison of the calculated t-value with the value of the tabled t-Distribution for degrees of freedom (df) = $N_1 + N_2 - 4$. All tests were run to determine whether the age coefficient (slope) differed between the Pre-standard and Post-standard vehicles, without interest in knowing whether the effect was higher, or lower, for Pre-standard versus Post-standard vehicles. Thus, the critical region for rejection of the (null) hypothesis of equivalent slopes was a calculated t-value which was greater than, or less than, the corresponding tabled values of the t-Distribution. All tests were made at the $\alpha = .05$ (i.e., 5%) level of significance.

Referring to Tables E-1 and E-2 for the equal age categories, it is seen that none of the age comparisons is statistically significant. This includes the comparisons for both passenger cars and light trucks, and for both weighted and unweighted estimates. The preferred bases for comparison are those using equal age data, since this provides the "purest" test for age effect difference between Pre and Post-vehicles. Also, the weighted analyses are favored over the unweighted analyses, due to the considerable variation among in the individual observations (i.e., numbers of fires and accident-involved vehicles). The inference drawn from these analyses is that the effect of vehicle age behaves in the same manner for both Pre and Post-standard vehicles.

Turning to the comparisons for the all available data category, Tables E-1 and E-2 show that the age effects for Pre- and Post-standard vehicles are significantly different in 3 out of 4 instances (unweighted data). For the weighted comparisons, 2 are significantly different while the remaining two are not. These latter comparisons are preferred due to the variation among the individual observations as stated above. Statistically, the results of the age effect comparisons in the all data category are mixed, with 2 of the (weighted) tests showing significance, while the remaining 2 are not significant. One possible reason for the two significant results is the larger sample sizes (and hence decreased error variances) for the all data category comparisons, as opposed to the equal age comparisons. A second possibility for the two significant results is the difference in the age range distributions between the Pre-standard and Post-standard samples. The difference may be due to the age effect varying somewhat, depending on the actual ages studied, rather than reflecting a difference between Pre and Post-standard vehicles. In fact, this is the most likely possibility in view of the finding of no significant differences in the age effect comparisons for the situation where vehicle ages are held constant for Pre-standard and Post-standard vehicles.

The summary conclusion based on the additional analyses conducted in this section is that the age effect on fire rates does not differ between Pre-standard and Post-standard vehicles.

Comparison of Effectiveness Analyses Based on Equal Age Vehicles

The second method of further investigating the possible difference in age effect for Pre and Post-standard vehicles, and its possible effect on estimated FMVSS 301 effectiveness, is to rerun the effectiveness analyses that were carried out in Chapter 2. In these additional analyses, the age of the accident-involved vehicles will be restricted so that the ages of the Pre-standard vehicles are the same as the ages of the Post-standard vehicles.

The analyses take the same form as those used in Chapter 2 to estimate the effectiveness of the 301 Standard. Regression models incorporating fire rate as a function of vehicle age and Standard 301 are computed for each vehicle type, passenger cars and light trucks, and for each primary data set, State data and fatal accident data (i.e., FARS). The State data were the same as used in the analyses above and as used in the principal analyses of Chapter 2 -- i.e., the combined data from the States of Michigan, Ohio, and Maryland. Also as in Chapter 2, the data were weighted and balanced to include the same number of model years, Pre and Post, within each calendar year.

The results of the four analyses are shown in Table E-3. The principal item of interest in this Table is whether or not the coefficient for the Standard variable (i.e., FMVSS 301) is significant, thereby indicating positive effectiveness. The table shows that in one instance, passenger cars in the State data set, the Standard coefficient is significant. In the remaining three cases (passenger cars - fatal accident data, light trucks - State data, and light trucks - fatal accident data), the results are not significant. Overall, these results are in essential agreement with the effectiveness analyses performed in Chapter 2 where effectiveness was found only for passenger cars in the State data (i.e., all accidents) set.

Table E-3

Summary of Effectiveness Analyses, Restricting Accident Data to Vehicles of Equal Age for Pre-standard and Post-standard Samples

					Standard Variable				Age Variable			
Vehicle Type	Data Set	Vehicle Age Range (Yrs)	N	df	Coefficient	t-value	t-Dist. Value	Signi- ficance *	Coefficient	t-value	t-Dist. Value	Signi- ficance *
Passenger Cars	State Data	7-11	90	87	-6225×10^{-7}	-2.58	-1.66	S	2739×10^{-7}	3.14	1.66	S
Passenger Cars	FARS Data	0-12	133	130	-1815×10^{-7}	-0.24	-1.65	NS	6723×10^{-7}	6.62	1.65	S
Light Trucks	State Data	6-10	90	87	-834×10^{-7}	-0.23	-1.66	NS	2346×10^{-7}	1.86	1.66	NS
Light Trucks	FARS Data	0-11	114	111	-14953×10^{-7}	-1.13	-1.66	NS	727×10^{-7}	0.41	1.66	NS

N = No observations

* S: statistically significant
NS: not statistically significant

Significance level α= 5% (one-tail)

Summary

The additional analyses described in this appendix were performed to further investigate the effect of age on vehicle fire rates, and to further explore whether the different distribution of vehicle ages between Pre-standard and Post-standard vehicles could have affected the effectiveness estimates of FMVSS 301 developed in Chapter 2. The overall results of these additional analyses are in basic agreement with the effectiveness results obtained in Chapter 2.

Furthermore, as stated earlier, from a purely physical standpoint, there is no reason to suspect that age effects would be manifest differently, depending upon whether a vehicle were manufactured before, or after, FMVSS 301 took effect. In order for such a difference to be expected, the types of vehicle modifications made in response to the Standard would have had to alter the way in which the various vehicle structures and components are affected by corrosion and other degradation processes that occur over the lifetime of the vehicle. This would include not only components of the fuel system, but also other vehicle components and structures whose corrosion and weakening over time could also increase the chances of fuel leakage (and fire), by providing less energy absorption and other crashworthiness protection for the fuel system. Such degradation resistant changes in vehicle components and structures did not occur coincident with the issuance of Federal Motor Vehicle Safety Standard 301.