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The study examined three broad categories of data:

(1) Seven previous research studies in this subject area;
(2) Four separate bodies of HSRI-held traffic accident and medical data;
(3) Five sets of mortality records maintained by various state or national fire protection or public health organizations.

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FIRE IN MOTOR VEHICLE ACCIDENTS

An HSRI Special Report
April, 1974

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CONTENTS

ABSTRACT

An HSRI study of fire in motor vehicle accidents examined four aspects of this subject: the number of such fires that occur annually, the number of fatalities accompanied by such fires, the number of fatalities resulting directly from such fires, and relationships between types of crashes, fuel leakage, fuel-fed fires, and associated fatalities.

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1. INTRODUCTION

Fire in motor vehicle accidents is a disturbing and controversial subject. It is disturbing because vehicular fires are so spectacular and lethal. It is controversial because the findings of the few research studies undertaken on this problem have been susceptible to multiple and conflicting interpretations.

Government agencies, vehicle manufacturers, and the general public need more precise and reliable answers to some basic questions in this subject area: How often do fires result from motor vehicle accidents? How many fatalities result from those fires? How can those fires and fatalities be effectively reduced?

Those questions and their answers are the subject of this report. The report presents the findings of a study of this subject conducted by the University of Michigan Highway Safety Research Institute during the period September, 1973, through March, 1974, with general research support funds contributed by the Motor Vehicle Manufacturers Association. The purpose of this study was to arrive at more precise and reliable answers by evaluating all prior research studies and by analyzing all currently available data on the subject.

Additional copies of this report or further information on this subject may be obtained from the Highway Safety Research Institute, The University of Michigan, Huron Parkway and Baxter Road, Ann Arbor, Michigan 48105 (Telephone 313-764-0248.)

2. MAJOR QUESTIONS CONSIDERED IN THIS STUDY

The major questions considered in this study were:

(1) How often do fires occur as a result of motor vehicle accidents? That is, what is the rate or frequency of fires in motor vehicle accidents?

(2) How often are occupants fatally injured or killed as a result of fire in motor vehicle accidents? That is, what is the rate or frequency of fatalities resulting from fire in motor vehicle accidents?

(3) How often are occupants fatally injured or killed in motor vehicle accidents accompanied by fire? That is, what is the rate or frequency of fatalities in motor vehicle accidents in which the occupants are fatally injured or killed, whether or not it is known that death resulted solely from fire-induced injuries?

(4) What are the relationships between types of crashes, fuel leakage, and fires? That is, what types of crashes result in fuel leakage, how often does such fuel leakage result in fires, and how do these relate to fatalities in motor vehicle accidents accompanied by fire?

One source of public confusion concerning past research findings has been the tendency of some researchers and most reporters to ignore the difference between questions 2 and 3, above. Both questions are important, and both are answered in this report. However, the answers hold somewhat different implications for the problem of developing cost-effective means of reducing fatalities in motor vehicle accidents.

3. SUMMARY OF CONCLUSIONS

Fires resulting from motor vehicle accidents in the U.S. occur at the rate of approximately 0.1 percent of the 17 million motor vehicle accidents estimated by the National Safety Council as occurring annually in the U.S.

Fatalities resulting from fire in motor vehicle accidents in the U.S. number from 450 to 650 annually. Those deaths represent 1 to 1.5 percent of the 44,800 fatalities of vehicle occupants (excluding pedestrians and bicyclists) in 1972 U.S. motor vehicle accidents.

Fatalities accompanied by fire in motor vehicle accidents in the U.S. number from 720 to 1,250 annually. Those deaths represent 1.7 to 2.8 percent of the 44,800 fatalities of vehicle occupants (excluding pedestrians and bicyclists) in 1972 U.S. motor vehicle accidents, and they include the 450 to 650 fatalities resulting directly or solely from fire in motor vehicle accidents.

The type of crash that results in the greatest number of cases of fuel leakage is not the type of crash that results in the greatest number of fatalities in motor vehicle accidents accompanied by fire. Rear-end impacts result in the most cases of fuel leakage, but single-vehicle severe frontal crashes result in the greatest number of fatalities in accidents accompanied by fire.

If all vehicles on U.S. roadways were to meet the fuel system integrity tests specified in the newly amended Motor Vehicle Safety Standard #301, this might eliminate from 180 to 260 (40 percent) of the 450 to 650 annual fatalities which now result from fires in motor vehicle accidents. This means that if new vehicles complying with MVSS #301 are introduced into the total vehicle population at the rate of 10 percent per year (i.e., 10 million new cars in a vehicle population of 100 million cars), the annual reduction of 180 to 260 such fire fatalities might be achieved by 1984.

4. DISCUSSION

The HSRI study discussed in this report examined three kinds of data: (1) previous research studies relating to questions of fire in motor vehicle accidents; (2) HSRI accident-file data; and (3) medical and fire protection data provided by various state and national organizations.

4.1 Evaluation of Previous Research Studies

Several previous research studies have been directly or indirectly concerned with post-crash vehicle fires. Their findings concerning the magnitude of the problem have varied considerably, and have often been cited selectively to understate or overstate the scope and seriousness of the problem. Those studies are described here in chronological order and are evaluated in terms of their strengths, weaknesses, biases, and overall significance.

4.1.1 The Dunn and Halpin Study (1951)

This study, entitled "Fire Casualty Statistics," was published in the July, 1951, Quarterly of the National Fire Protection Association. It is of considerable interest to the highway safety research community because its findings have been widely and repeatedly used as a base for estimates of the annual number of fatalities in motor vehicle accidents accompanied by fire.

The purpose of the study was to compile statistics on various types of accidental fatalities in which fire was identified as an associated cause. In 1951, H. H. Dunn and E. H. Halpin were associated with the National Office of Vital Statistics (now called the National Center for Health Statistics) of the U.S. Public Health Service. To compile their figures, Dunn and Halpin reviewed a one-tenth sample of death certificate transcripts for the year 1948. They presented their findings relating to motor vehicle accidents in the table reproduced here:

"NUMBER OF DEATHS FROM SPECIFIED TYPES OF ACCIDENTS, AND ESTIMATED NUMBER OF DEATHS IN WHICH BURNS WERE AN ASSOCIATED CAUSE OF DEATH: UNITED STATES, 1948

Cause of Death	Number of Deaths	Percent Due to Burns[1]	Estimated Number of Deaths Due To Burns Received in Accidents
Total	43,403	9.0	3,910
Railway accidents	2,502	3.8	100
Motor-vehicle accidents	32,259	7.9	2,550
Water-transport accidents	1,364	3.5	50
Air-transport accidents	1,912	44.8	860
Accidents in mines and quarries	1,348	6.8	90
Agricultural and forestry accidents	2,294	6.3	140
Other accidents involving machinery	1,240	8.1	100
Streetcar and other road transport	484	4.8	20

[1]Based on nature of injury tabulation of a 10-percent sample of death certificates, 1948."

The third line of that table is the one of primary interest. It states that of the total motor-vehicle-accident fatalities occurring during 1948, 2,550 of them, or 7.9 percent, were estimated to be due to burns as an associated cause of death.

4.1.1.1 HSRI Evaluation

What is puzzling about this study is that its findings differ markedly from the findings of all other comparable research studies conducted since 1951. Because the Dunn and Halpin total of 2,550 estimated fatalities differs so greatly from subsequent findings, this researcher telephoned Dr. Halpin in January, 1974, to obtain more information concerning the coding and sampling methods used in the 1951 study. Dr. Halpin explained that every tenth death transcript coded for "motor vehicle accident--death due to burns" was separated from the other death transcripts as they were being filed.

Nothing Dr. Halpin volunteered from memory would lead one to suspect that there may have been errors in the coding or sampling of the death certificate transcripts. However, the total number and percentage of deaths due to burns, as reported by Dunn and Halpin, compares closely with findings of subsequent studies when the Dunn and Halpin figures are divided by ten. This suggests the possibility either that all of the motor-vehicle-accident-burn-death transcripts were erroneously pulled from the filing room and then multiplied by ten, or that a one-tenth sample of them was pulled and then erroneously multiplied by 100. One can appreciate that possibility only by running through a little arithmetic.

Assume that the actual number of burn-associated motor vehicle accident fatalities in 1948 may have been 255 and not 2,550 as presented in the Dunn and Halpin table. That 255 would then have represented .79 percent of the 32,259 total motor vehicle fatalities presented in the Dunn and Halpin table, instead of the 7.9 percent shown.

The 32,259 fatalities reported by Dunn and Halpin included all traffic accident fatalities, including those involving pedestrians and bicyclists. When those latter categories of fatalities for 1948 (a total of 10,450 fatalities) are subtracted from the Dunn and Halpin total of 32,259, the resulting total of "in-car" fatalities is 21,809. When 255 burn-associated motor vehicle fatalities are expressed as a percentage of that 21,809, they represent 1.17 percent.

That 1.17 percent figure is consistent with the findings of a 1973 HSRI study (discussed later in this report) that included an analysis of death certificates for fatalities incurred in four years of motor vehicle accidents in the State of Michigan. Fatalities resulting from fire in motor vehicle accidents were found to be .98 percent of all "in-car" accident fatalities; and fatalities accompanying fire in motor vehicle accidents were found to be 1.6 percent of all "in-car" accident fatalities.

When it is considered that the rate of fatalities in accidents accompanied by fire rises steadily as a function of pre-crash speed and crash severity, the adjusted Dunn and Halpin percentage figure of 1.17 for the 1948 vehicle population and road system would appear to be consistent with the 1.6 percentage figure derived from the HSRI study of 1968-1972 accident data and death certificates.

Regardless of the above considerations, if one assumes that the Dunn and Halpin study accurately represented the severity of the problem of fire-associated deaths in motor vehicle accidents in 1948, then current statistics show a significant reduction in such deaths over the succeeding two decades. It seems unlikely that such a reduction has actually occurred. Consider that Dunn and Halpin reported the total of all types of burn and fire fatalities for 1948 as approximately 12,000. The current estimated total of all types of burn and fire fatalities is also 12,000 (as reported by the National Commission on Fire Prevention and Control, in May, 1973). Consider also that the system for reporting accidents and causes of death was less developed in 1948 than it is today. Moreover, the characteristics of the vehicle population and the road system have changed significantly over the years since 1948. Therefore, regardless of whether the Dunn and Halpin percentage figure for fire-associated vehicle-accident fatalities should have been 7.9, .79, or 1.17, the findings are not a very reliable basis for estimating current annual fatalities in motor vehicle accidents accompanied by fire.

4.1.2 Automobile Fire in Connection with an Accident (1964)

This study, conducted by B. J. Campbell and J. K. Kihlberg at the Cornell Aeronautical Laboratories in Buffalo, New York, was published in the ACIR Bulletin of February, 1964. The purpose of the study was to assess the danger of fire in rear-engine automobiles in accidents. The investigators used data from the Cornell Automobile Crash Injury Research (ACIR) Program data files. Entries for 33,250 accident-involved passenger cars were machine-accessed for evidence of fire. The investigators concluded that 0.45 percent of passenger cars in injury accidents involved fire. No difference was found in the incidence of fire between front- and rear-engine passenger cars. The incidence of fire in injury accidents was found to be greatest in "moderately severe" accidents.

4.1.2.1 HSRI Evaluation

This study included vehicles only from accidents in which at least one occupant was injured. The vehicles involved were U.S. and foreign passenger cars varying widely in age, with model years ranging from before 1950 up through 1962. The finding that fire occurred in less than one-half a percent of all injury accidents is significant. However, the study appropriately did not touch on the question of fire-related fatalities because of the limited sample size.

4.1.3 Observations on Fire in Automobile Accidents (1965)

This study was conducted by S. J. Robinson at the Cornell Aeronautical Laboratories and published as CAL Report VJ-1823-R14 dated February, 1965. Its objective was to determine the frequency of secondary fires and to relate fire and occupant burns to crash type and accident severity. The source and base of the data were the same as in the Campbell and Kihlberg study discussed above. Robinson came to four conclusions: (1) The incidence of fire in 156 fire accidents studied was greatest in frontal impacts and in rollovers; (2) The total number of rear-end-impact fires was less than half the total of either the frontal-impact fires or the rollover fires; (3) The incidence of fire, fire damage, and fatal burn injuries was most frequent in rollover accidents; (4) There were proportionately more non-fatal burn injuries resulting from rear-end impacts than from frontal crashes or rollovers, but there were proportionately fewer fatal injuries.

4.1.3.1 HSRI Evaluation

One limitation in the data employed in this study is that it originated with various investigative sources, so that the quality and completeness of the data varied. However, the findings are consistent with those found in comparable studies.

4.1.4 Fire in Automobile Accidents (1969)

This study, published as Research Report 1969-2, was conducted by J. O. Moore and D. B. Negri at the New York State Department of Motor Vehicles. The objective of the study was to determine the incidence of fire in motor vehicle accidents through examination of mass accident data at the state level, and to identify fatalities resulting from accidents accompanied by fire. The data included all police accident reports (65,137 reports) for the State of New York completed during two separate months of 1968: March and September. The researchers concluded that 0.07 percent of those accidents involved fire; that 2.38 percent of all the fatal accidents were accompanied by fire; and that accidents which included fatalities had the greatest incidence of fire.

4.1.4.1 HSRI Evaluation

One limitation in this study is that it depended upon investigating police to note on the police accident report if fire occurred in the accident. The standard police reporting form did not include an entry blank for noting the existence of fire, nor did it include anything to prompt the police officers to record somewhere on the form the fact that fire occurred, if it occurred. The researchers attempted to verify the fidelity of the reporting of fire in fatal accidents by conducting a followup on all fatal accident reports pertaining to one make of vehicle. The HSRI analysis of the data reported in this study produced a figure of 1.7 percent for fatal accidents in which death resulted from fire, as distinguished from the 2.38 percent for fatal accidents involving fire, as reported in the Moore and Negri study report.

4.1.5 Vehicle Post-Collision Considerations (1970)

This study, conducted by A. W. Siegel and A. M. Nahum of UCLA, was published in the International Automobile Safety Compendium, 1970. The study dealt with post-crash factors in accidents--fire, fuel leakage, and several other factors. The investigators examined Los Angeles City and County fire department records for the period 1966 to 1969. They examined records of fire department runs to determine the incidence of motor vehicle fires and fuel leakage, and compared this with police accident data for the same period. Siegel and Nahum reported several conclusions: (1) More than 60 percent of all vehicle fires originate in the engine compartment area; 5 percent originate in the fuel tank/trunk area; (2) Vehicle fires represent 18 percent of all reported fires; (3) Fires resulting from collisions represent 5 percent of all vehicle fires; (4) Collision-induced fires resulted in 12 percent of all reported incidents of fuel leakage; (5) Fire and/or fuel leakage occurs in 4 percent of all collisions; (6) Vehicle fires occur in less than 0.5 percent of all vehicle collisions; and (7) Vehicle burn fatalities numbered approximately 50 for the City of Los Angeles during the three-year study period.

4.1.5.1 HSRI Evaluation

One of the conclusions of this study (number 5, above) has often been cited to emphasize the seriousness of the problem of post-crash vehicle fires. The investigators state in their report that "The data indicate the hitherto hidden fact that about 1 in 25 collisions produce fuel leakage and/or collision fire." The problem with the statement is that it combines two separate events--fuel leakage and fire--so as to give a misleading impression of the seriousness of the problem of fuel leakage. As all accident investigators know, fuel leakage frequently seen in crashes only infrequently results in a fire. Fuel leakage occurs before fuel-fed fires occur, but it is an unreliable indicator of the frequency of post-crash vehicle fires.

Examination of the Los Angeles fire department statistics presented in the Siegel and Nahum report shows why the investigators merged "fuel leakage" and "collision fire" in their statement of findings. The fire department statistic for "washdowns" is presented separately from the statistic for "vehicle fires," and it is impossible to tell how many of the "washdown" cases involved only fuel leakage and how many of them involved both fuel leakage and fire (or only fire).

In another finding (number 7, above), Siegel and Nahum estimated that approximately 50 fatalities occurred during the three-year period as a result of vehicle-crash fires. They determined this, not by a direct count, but by converting a Los Angeles County figure to a Los Angeles City figure on a population proportion basis. The estimate was based on a ratio of numbers of people--not vehicles or vehicle accidents. This was necessary because, as the investigators state in their report, the City of Los Angeles does not keep separate obituary records. HSRI computations employing the Siegel and Nahum estimate of 50 fatalities in vehicle-crash fires resulted in a percentage of 2.7, which, when projected to the national vehicle-accident fatality total for 1972, produced an estimate of 1,215 annual fatalities in motor vehicle accidents accompanied by fire. This estimate is considerably higher than estimates based on findings of most other research studies examined in the HSRI study. This may be because the population of people, vehicles, and roadways in the Los Angeles area is not representative of the United States.

4.1.6 HSRC Report on Post-Crash Fires (1973)

This study, conducted by B. J. Campbell at the Highway Safety Research Center of the University of North Carolina, has thus far been reported on only briefly in the newsletter The Accident Reporter, HSRC, February, 1973. The reported objective of the study was to determine the frequency and severity of post-crash fires in passenger vehicles. The data base was 240,000 accident narratives from North Carolina police accident reports. The investigators computer-searched each accident narrative for certain key words which might relate that accident to a post-crash fire--"flames," "burn," etc. This method resulted in identification of "about 100 cases" of post-crash fire in passenger cars in the 240,000 accidents searched. B. J. Campbell stated in the article that no space is provided on the standard North Carolina accident report form for noting the occurrence of post-crash fires.

4.1.6.1 HSRI Evaluation

The study finding of only 100 cases of post-crash vehicle fire in a population of 240,000 accidents is not significant because of the unreliability of the accident report narratives. It is unknown how many instances of fire occurred but were unreported. One can conjecture that more fires occurred than were reported, but how many more is unknown.

4.1.7 Escape-Worthiness of Vehicles and Occupant Survival (1970)

This study, conducted by C. M. Sliepcevich and several others at the University of Oklahoma Research Institute, was published as a final report on NHTSA Contract No. FH-11-7303, dated December, 1970. This was a multidisciplinary study of the factors involved in escape of occupants from crashed vehicles incapacitated on land, submerged in water, or involved in fire. The conclusions stated in the study report are as follows:

(1) National statistics on motor vehicle fires and motor vehicle submergence are unreliable.

(2) Since the Dunn and Halpin study was based upon fatal injury data that is more reliable than that appearing on accident reports, its results are far more credible than other tabulations.

(3) Traffic deaths in motor vehicle accidents involving fire account for about 3,500 fatalities per year.

4.1.7.1 HSRI Evaluation

One way of regarding the three conclusions of this study relevant to the problem of fire in motor vehicle accidents is to reason that (1) discounts (2) and also (3), because, as the narrative of the report indicates, (3) is based on (2). Sliepcevich and his associates evidently regarded the Dunn and Halpin findings as both unreliable and the most credible. Given the paucity of reliable statistics in this subject area, it is easy to understand how they arrived at that position. However, the study produced no findings tending to confirm or deny any other study findings on the question of fatalities in motor vehicle accidents accompanied by fire. A later study by the same investigators did, and is discussed below.

4.1.8 Escape-Worthiness of Vehicles for Occupancy Survivals and Crashes (1972)

This study, conducted by C. M. Sliepcevich and others at the University of Oklahoma Research Institute, was published as a final report on NHTSA Contract No. FH-11-7512, dated July, 1972. As with the 1970 study, this was a multidisciplinary investigation of factors involved in the escape of occupants from crashed vehicle environments in which the vehicle is incapacitated on land, submerged in water, or involved in fire. The investigators examined Oklahoma and Kansas accident data for 1970-1971 as well as death certificates and newspaper clippings. Their conclusions were as follows:

(1) Based on two years of accident experience, 4.7 percent of all Oklahoma motor vehicle fatalities and 4.9 percent of all Kansas motor vehicle fatalities were deaths in accidents accompanied by fire.

(2) Similarly, 3.3 percent of all Oklahoma motor vehicle fatalities and 2.5 percent of all Kansas motor vehicle fatalities were deaths resulting from fire.

(3) Eight percent of post-crash fires resulted from frontal collisions.

(4) Fifty percent of post-crash fires resulted from rear-end collisions.

(5) Two-thirds of all post-crash fires occurred in passenger cars.

(6) More than half of the accidents resulting in post-crash fires involved a single vehicle striking an object or running off the road.

4.1.8.1 HSRI Evaluation

The findings in this study with respect to the percent of fatalities resulting from fire and the percent of fatalities in accidents accompanied by fire are significantly higher than those found in several other comparable studies discussed in this present report. No obvious reason for this discrepancy was discovered, either in examination of the study report or in personal conversation with the principal author, C. M. Sliepcevich. However, Mr. Sliepcevich, in responding to a question during a professional conference in 1973, stated publicly that the percentage findings published in his report should not be used as a base for projection of national fatalities because of biases in the Oklahoma and Kansas data used in his study. He did not describe the nature of the biases during the 1973 conference, nor did he do so during the telephone conversation with this author in March, 1974.

4.2 Analyses of HSRI Data

The HSRI accident data file analyzed in this study of fire in motor vehicle accidents is called the Collision Performance and Injury Report (CPIR) file. This computerized file, described by the HSRI data codebook, Collision Performance and Injury Report, Revision 3, October, 1973, contains more than 4,000 cases of passenger car accidents investigated and reported by professional investigators, including multidisciplinary accident investigation teams, in the course of studies sponsored by the Motor Vehicle Manufacturers Association, the National Highway Transportation Safety Administration, and the Canadian Department of Transportation. These studies were conducted during the period 1967 to 1973, with investigators using the standardized accident vehicle evaluation form entitled the Collision Performance and Injury Report, Revision III. The strength of the data in the CPIR data bank constructed from those reports stems from the comprehensiveness of the investigations and the depth of detailed information obtained on each accident case. Each file entry for a single accident contains up to 600 discrete items of information, depending on the extent and complexity of the accident. This information is arrayed in three separate files of the CPIR data bank: the Vehicle File, Occupant File, and Injury File. These data were analyzed in terms of key variables relevant to the problem of fire in motor vehicle accidents.

The HSRI CPIR data bank is superior to the large and diverse body of police-reported accident data compiled by the various state departments of public safety because it contains reliable information concerning vehicle fires accompanying accidents. However, the CPIR data file is not a representative sample of a well-defined population of accidents. Therefore, the results of inter-factor analyses of the CPIR file had to be fitted to some body of representative accident data so as to produce findings of relationships between accident type, damage area and extent, fuel leakage, and fire. The body of accident data selected for application of the CPIR findings was the State of Texas Department of Public Safety Accident File for 1972. This file, maintained by HSRI, consists of a 5 percent random sample of all police-reported Texas accidents in the 1972 calendar year. It contains 21,000 accident cases involving 36,505 vehicles.

The CPIR accident data file is not a representative sample of the national population of motor vehicle accidents because of accident-selection criteria employed in the multidisciplinary case studies from which it is derived. The data are biased toward severe and injury-producing accidents as well as toward late-model passenger cars. That is, because of the particular interests of the accident investigators, most of the studies concentrated on severe accidents involving late-model cars, to the exclusion of minor accidents involving all model years and severe accidents involving older cars. However, those biases in the CPIR data have a lesser effect on the validity or reliability of findings from analyses of relationships among variables in the CPIR accident data. These are limited, of course, where the CPIR data file does not contain sufficient numbers of cases to permit valid inferences.

4.2.1 CPIR Fire Data

The group of passenger car accident vehicles in the CPIR file selected initially for analysis included 3,291 passenger cars and excluded trucks, bicycles, and other non-passenger-car vehicles. Of the 3,291 vehicles, 51 (1.37 percent) were found to have been fire-involved.

Of those 51 vehicles, 42 were examined in detail by reading the "hard copy" accident case study report filed by the investigators. Ten deaths were noted in which burns contributed to the death of the occupants. Three of those ten persons died in an intersection collision with a fuel tanker, resulting in a conflagration. Three others died in severe frontal crashes. Three others died in rear-end crashes. One death resulted from an electrical fire in which the vehicle's fuel system was not involved. Of the three burn deaths in rear-end crashes, two of the vehicles were small foreign passenger cars.

These frequencies cannot be viewed as being statistically representative of the general population of vehicle accidents, but they do show the occurrence of fire with both severe frontal crashes and rear-end crashes.

A subset of the CPIR data file was also analyzed. This subset consisted of accidents involving new American-manufactured passenger cars towed away from the scene of the collision, whether or not the accident produced occupant injuries. Of the 1,305 vehicles in this group, 6 experienced minor fires, 2 experienced major fires, and 52 exhibited fuel leakage. Of vehicles exhibiting fuel leakage, 25 percent of them had been struck in the rear, 7 percent had rolled over, and smaller percentages of them had been involved in frontal or side collisions.

4.2.2 CPIR Fuel Leakage Data

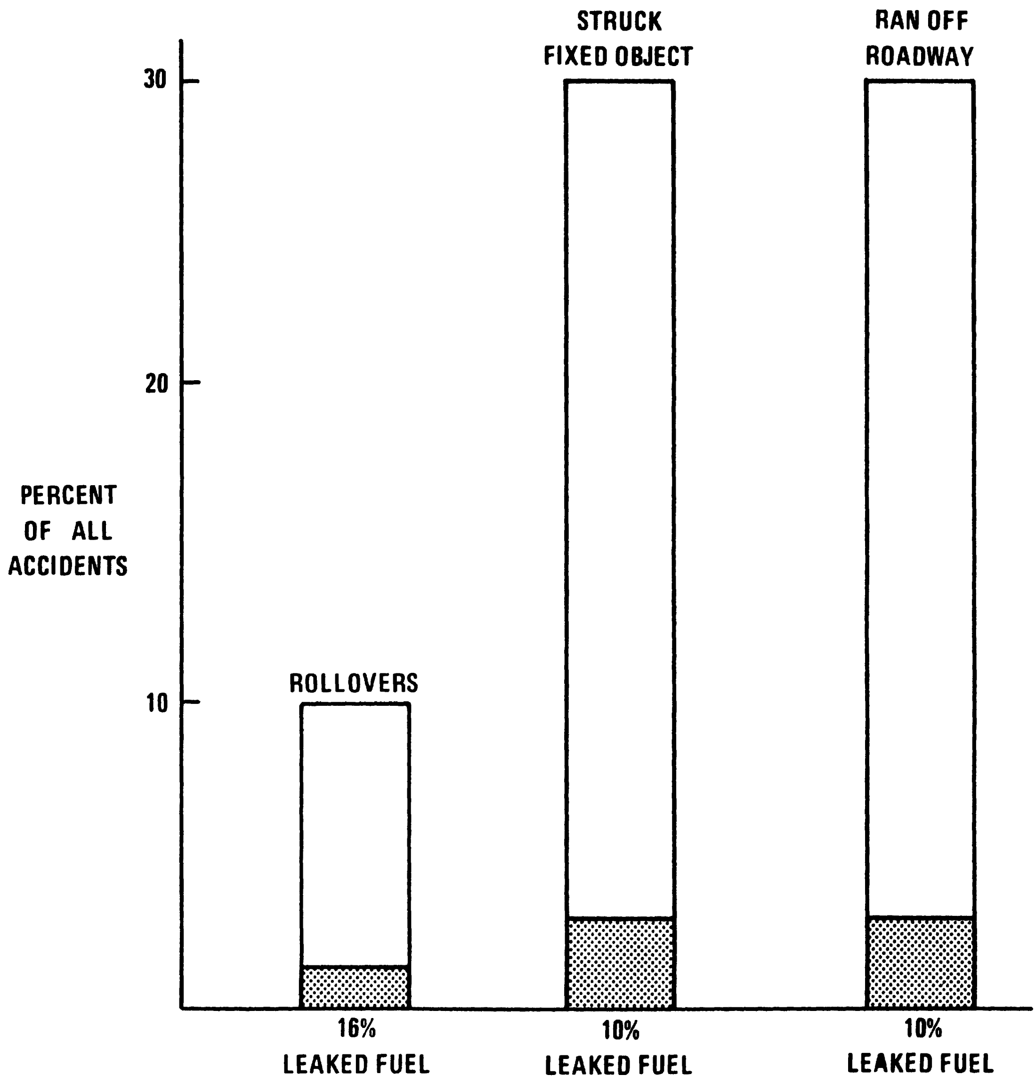
Although fuel leakage frequently results from minor collisions, fuel leakage in minor collisions is usually not accompanied by fire.

However, since most post-crash fires are fuel-fed fires--as opposed to electrical or internal-matter fires--the presence of fuel leakage may be viewed as a prerequisite fire condition, and it is certainly a critical piece of evidence for any study of post-crash vehicle fires. The NHTSA has established Motor Vehicle Safety Standard #301 in an attempt to reduce fires in motor vehicle accidents. The measure of merit relative to fuel system integrity in crash tests specified by this newly amended standard is the rate of flow of fuel leakage.

The one data source where fuel leakage is specifically noted in accidents is the HSRI CPIR File. In these cases, a professional accident investigator determined whether fuel leakage occurred as a result of the accident. Only the presence of leaked fuel was noted. The quantity of leaked fuel, or its rate of flow, was not measured. Analysis of the CPIR File showed that 7.5 percent of accident vehicles in the file evidenced post-crash fuel leakage. CPIR data relating to the vehicles represented by that 7.5 percent were analyzed in terms of the types of accidents the vehicles were involved in and the types of damage they sustained.

Single-vehicle accidents (rollover, striking fixed objects, loss of control) were found to represent the largest proportion of accidents with fuel leakage. (The three categories of accident descriptors are not mutually exclusive; that is, one accident could include loss of control, rollover, and striking of a fixed object. Hence, to a certain extent, the categories are interdependent.) The histogram in Figure 1 shows that rollovers, fixed object impacts, and ran-off-roadway accidents account for 10, 30, and 30 percent, respectively, of accidents in the CPIR file. The cross-hatched areas in Figure 1 represent the finding that fuel leakage occurred in 16, 10, and 10 percent, respectively, of those types of accidents. The analysis of all accident types showed that fuel leakage occurred in 6.5 percent of the total accident population in the CPIR file.

FIG. 1
FUEL LEAKAGE
BY ACCIDENT TYPE



SOURCE: HSRI CPIR Data File

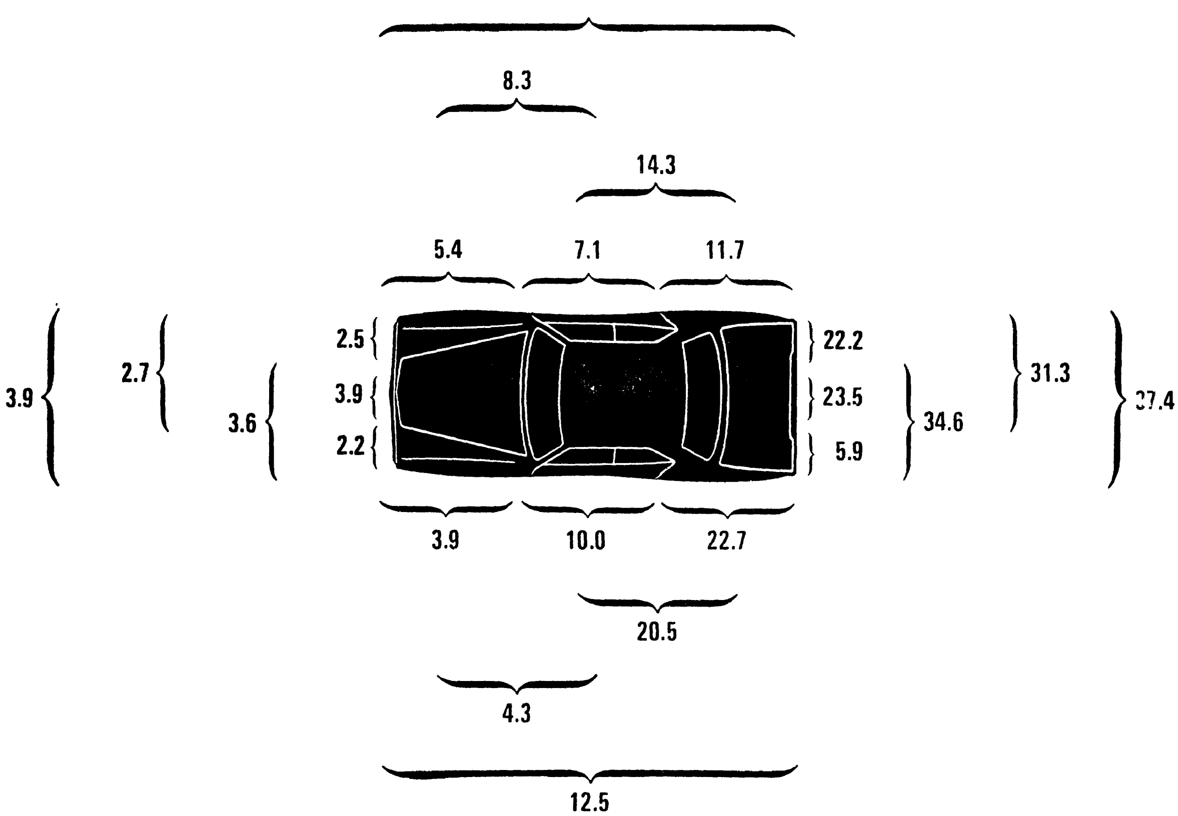
4.2.3 CPIR Fuel Leakage by Damage Area

When damaged areas of accident vehicles were related to the occurrence of fuel leakage, rear-area damage was found to result in the highest incidence of fuel leakage. The overall findings are illustrated in Figure 2. Figure 2 presents the incidence of fuel leakage as a percent of all fuel-leakage accidents involving damage to particular areas of vehicles. These data are incorporated in a Vehicle Damage Index (VDI) established on each vehicle involved in an accident, and were used as a basis for classifying the location and extent of deformation in collisions. For example, the percentage figure of 12.5 at the bottom of the figure means that 12.5 percent of all cases of fuel leakage resulting from accidents occurs in accidents in which the vehicle is damaged on its left side. The area locations (such as rear-center, front-right, etc.) are mutually exclusive; that is, damage noted by the accident investigator as the rear-center is not also included as rear-center and left, rear-center and right, or rear-distributed.

This damage location distribution also indicates that rear-area damage is more often accompanied by fuel leakage. The percentages shown in the figure mean the percentage of times fuel leakage was noted when this damage occurred. One notable feature in this sketch is the rear-left corner of accident-damaged vehicles, where this damage was accompanied by fuel leakage only 5.9 percent of the time. This compares with 22.2 percent for the rear-right corner, and 23.5 percent for the rear-center area. This may be the result of a tendency to assign damage to the vehicle's left side-rear when the left-rear corner of the vehicle is actually damaged. Fuel filler pipes are often located on the left side-rear, which may explain why the incidence of fuel leakage related to damage in this area (22.7 percent) is much higher than the incidence related to other side areas of the vehicle. Note also the higher percentage for left-side-distributed damage (12.5 percent) than for right-side-distributed damage (5.3 percent). Such broadly distributed side-damage is most characteristic of rollover or side-swipe collisions. The left side of a vehicle is also the side most often exposed to greater damage as a result of the American system of driving on the right side of the road.

FIG. 2

FUEL LEAKAGE BY DAMAGE AREAS
(THE FREQUENCY OF CASES OF FUEL LEAKAGE IN ACCIDENT VEHICLES DAMAGED IN SPECIFIC AREAS, BY PERCENT.)



SOURCE: HSRI CPIR Data File

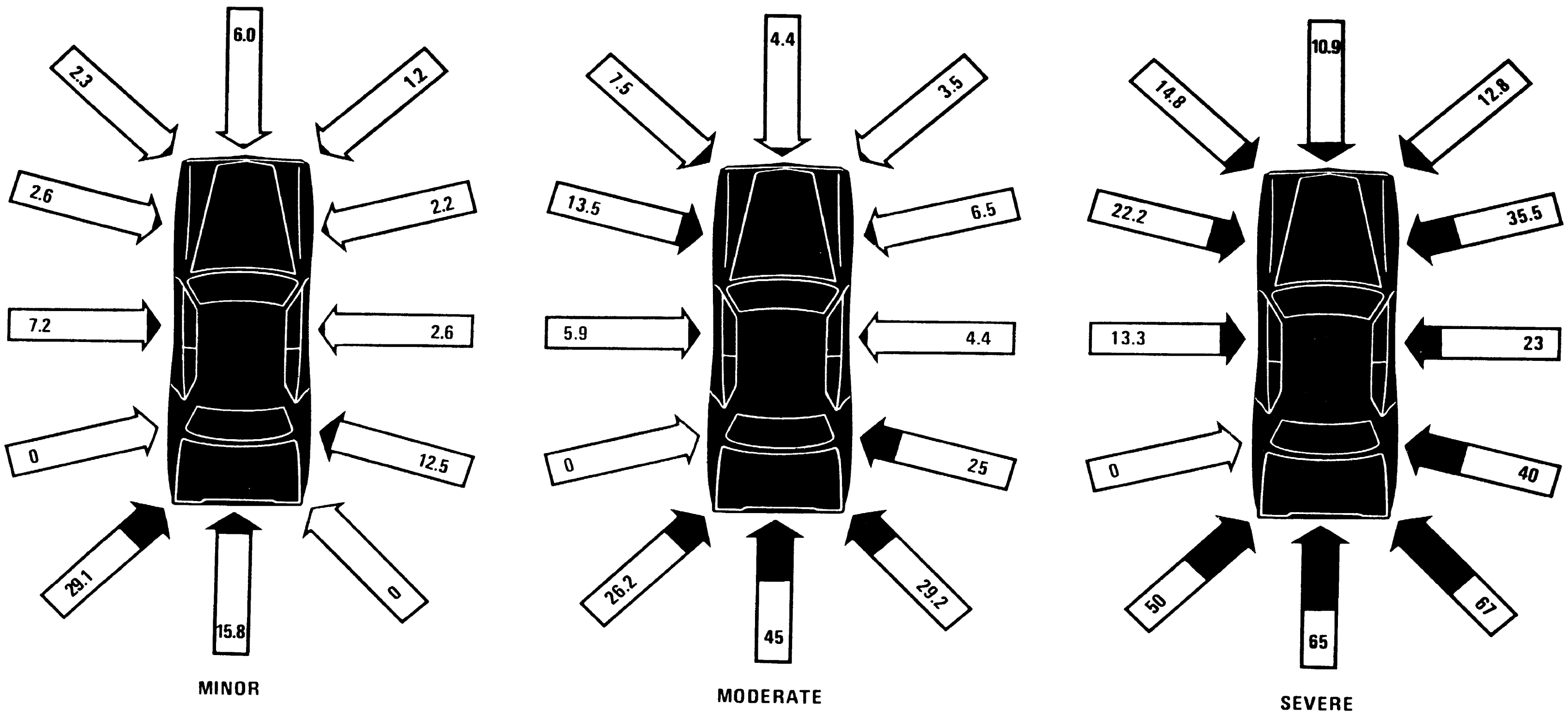
4.2.4 CPIR Fuel Leakage by Collision Force

Fuel leakage by collision force vector about the vehicle, along with damage severity, is illustrated in Figure 3. Figure 3 presents the findings of an analysis of direction-of-impact forces and extent of damage (as documented and recorded in the Collision Deformation Classification, SAE Recommended Practice, SAE Technical Report J224a, Revision of February, 1972) as they relate to fuel leakage. The collision force vector differs from the area of damage. It represents the direction of the principal resultant force of impact. A vehicle struck at 8 o'clock, for example, could sustain damage (crush and sheet metal displacement) from the left-front corner all along the left side to the left-rear corner, and along the rear to the rear-right corner. If the force which induced this damage was incident to the vehicle at a position of 8 o'clock with respect to the vehicle's longitudinal axis, it would be coded as an "8" regardless of the location of the resultant damage. Damage, or deformation extent, is coded in 9 steps (1,2...9) which represent the degree of inward crush. Zones 1 through 5 in this code, for example, represent frontal displacement up to the windshield. Zone 9 (most severe damage) denotes direct frontal damage inward and through the midpoint of the vehicle.

In Figure 3, the 12 impact-force vector positions are noted as a percent of fuel leakage among all cars that sustained damage as a result of being struck at that impact angle. The data have been divided into minor, moderate, and severe crashes. From left to right are representations of where minor damage occurred (VDI code numbers 1 and 2), moderate damage occurred (VDI numbers 3 and 4), and severe damage occurred (VDI numbers 5 to 9). Although the damage extent code of the Collision Deformation Classification system is not interpretable as a precise measure of absolute collision severity, it is useful in this general assignment into the severity categories of this display.

As one might expect, fuel leakage is most prevalent along rear impact-force vectors, and it increases as the extent of the damage increases. One exception is in the 8 o'clock position, where no fuel leakage was noted in a total of 46 vehicles with damage resulting from 8 o'clock impact-force vectors.

FIG. 3
FUEL LEAKAGE BY FORCE IMPACT VECTOR (THE FREQUENCY OF CASES OF FUEL LEAKAGE IN ACCIDENT VEHICLES, BY PERCENT.)



SOURCE: HSRI CPIR Data File

4.2.5 CPIR Fuel Leakage by General Damage Area and Extent

When impact-force vectors and damage extent classifications were combined into a more general grouping of frontal, side, and rear impacts sustaining minor, moderate, and severe damage, this produced the findings presented in Figure 4. Figure 4 lists the number of cases of fuel leakage by accident damage area and severity, grouped within each of the nine damage area and severity classifications. It shows that fuel leakage in more severe frontal collisions is commensurate with fuel leakage in rear-impact collisions.

Figure 5 lists the number of cases of fire by accident damage area and severity, grouped within each of the nine damage area and severity classifications. It shows that the greatest number of fires occurred in severe frontal crashes. While the actual number of fires (57) in these data is small compared to the number of cases where fuel leakage was present (221), note how fire relates to fuel leakage for two damage area and extent classifications. Of the 22 cases of frontal-severe crashes where fuel leakage occurred, 19 (or 86%) of these crashes also resulted in fire. Of the 19 cases of rear-severe crashes with fuel leakage, 5 (or 26%) resulted in fire. This underscores the greater potential for fire in frontal-severe crashes as compared to rear-severe crashes.

4.2.6 The 1972 Texas Accident Data File

While findings from the CPIR File provide insight into the problems of fuel leakage and fire, they are not representative of the total accident vehicle population because of accident-selection biases in the CPIR File. That is, CPIR data are not representative of the frequency of accidents (as grouped in those classifications of frontal-severe, side-moderate, etc.) in the total national population of vehicle accidents. The proportions of fuel leakage in accidents of various types and severities within the CPIR data file have face validity, but they must be applied to the frequency of these accident types and severities in the total population of accidents to estimate the incidence of fuel leakage in the general accident population. What is needed is a representative sample of accidents with corresponding detailed information about fuel leakage. No such body of data exists. Therefore, a projection to the incidence

FIG. 4

NUMBER OF CASES OF FUEL LEAKAGE DISTRIBUTED BY VEHICLE DAMAGE AREA AND EXTENT

VEHICLE DAMAGE AREA	VEHICLE DAMAGE EXTENT: MINOR	MODERATE	SEVERE
FRONT	9	24	22
SIDE	28	48	23
REAR	20	28	19

(TOTAL FUEL LEAKAGE = 221)

SOURCE: HSRI CPIR Data File

FIG. 5

NUMBER OF CASES OF FIRES DISTRIBUTED BY VEHICLE DAMAGE AREA AND EXTENT

VEHICLE DAMAGE AREA	VEHICLE DAMAGE EXTENT: MINOR	MODERATE	SEVERE
FRONT	6	4	19
SIDE	1	7	9
REAR	3	3	5

(TOTAL FIRES = 57)

SOURCE: HSRI CPIR Data File

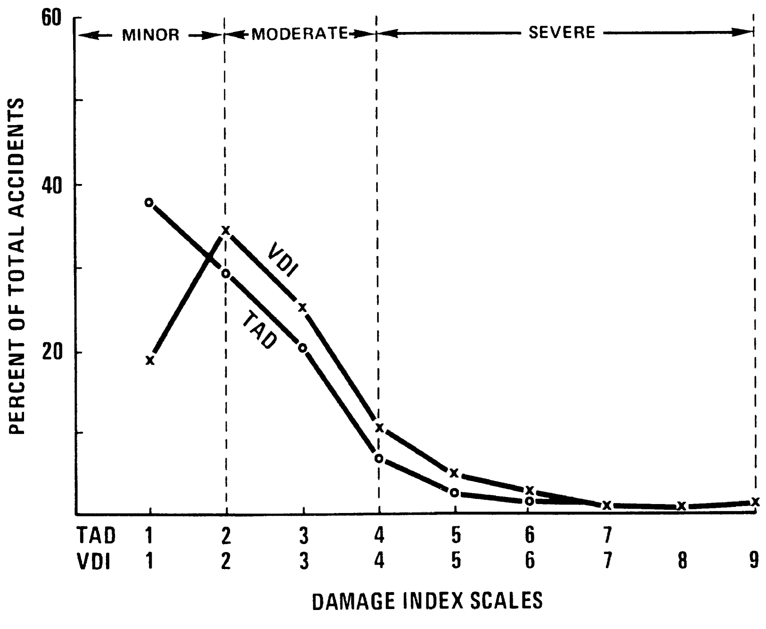
of fuel leakage in the national accident population is made here by applying the CPIR findings to the 1972 Texas Accident File, which is a reasonable representation of the national accident population. In this Texas File, accident vehicle damage area and damage extent are coded in accordance with the National Safety Council Traffic Accident Data Project, commonly called the TAD Scale. This scale was correlated with the CPIR CDC/VDI coding system so that vehicle accident data could be compared with a high level of confidence. The damage area and extent variables, grouped so as to obtain CDC/VDI and TAD Scale equivalence, are shown on the next two pages.

4.2.7 CPIR and Texas Damage Comparisons

A comparison of the CDC/VDI and TAD damage severity indices as equated on the following pages is shown in Figure 6, which plots all accidents in each data file by damage index scale. In Figure 6 the divergence between the two scales at value 1 of the damage index code results from the different accident selection criteria represented in the two files. The Texas file contains all police-reported accidents, whereas the CPIR file is biased toward more severe accidents.

FIG. 6

VDI AND TAD DAMAGE INDEX SCALE COMPARISON



SOURCES: HSRI CPIR Data File and HSRI 1972 Texas Data File

VEHICLE DAMAGE AREA CODE CORRELATION

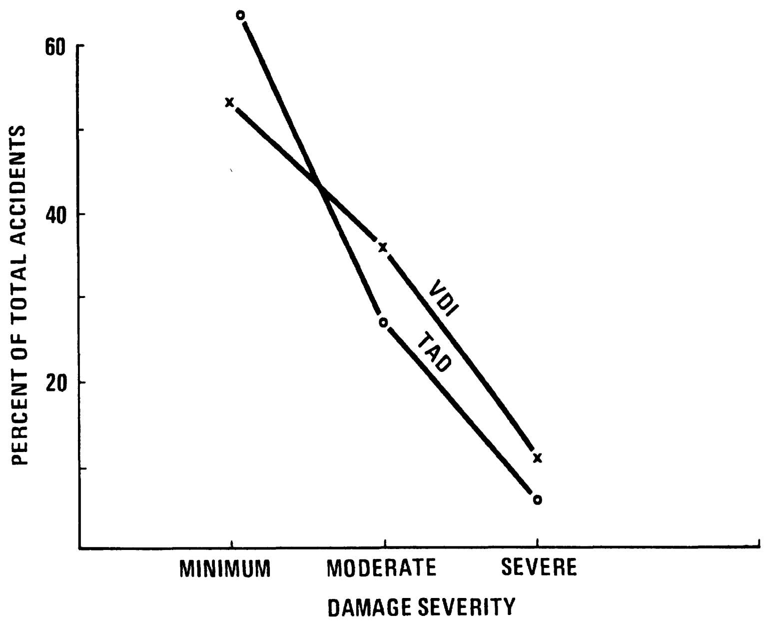
CDC/VDI	TAD
• FRONT	• FRONT
FRONT DISTRIBUTED	FRONT DISTRIBUTED
FRONT CENTER	FRONT CENTER
FRONT LEFT	FRONT LEFT
FRONT RIGHT	FRONT RIGHT
• SIDE	• SIDE
LEFT SIDE DISTRIBUTED	LEFT PASSENGER COMPARTMENT
RIGHT SIDE DISTRIBUTED	RIGHT PASSENGER COMPARTMENT
LEFT SIDE FRONT	LEFT SIDE – FRONT QUARTER
RIGHT SIDE FRONT	RIGHT SIDE – FRONT QUARTER
LEFT SIDE CENTER	LEFT SIDE – BACK QUARTER
RIGHT SIDE CENTER	RIGHT SIDE – BACK QUARTER
LEFT SIDE BACK	LEFT SIDE – DISTRIBUTED
RIGHT SIDE BACK	RIGHT SIDE – DISTRIBUTED
LEFT SIDE BACK & CENTER	LEFT SIDE AND TOP
RIGHT SIDE BACK & CENTER	RIGHT SIDE AND TOP
• REAR	• REAR
BACK – DISTRIBUTED	BACK – DISTRIBUTED
BACK – LEFT SIDE	BACK – LEFT
BACK – RIGHT SIDE	BACK – RIGHT
BACK – CENTER	
BACK – CENTER & LEFT	
BACK – CENTER & RIGHT	

VEHICLE DAMAGE EXTENT CODE CORRELATION

CDC/VDI	TAD
• MINOR	• MINOR
VDI - 1	TAD - 1
VDI - 2	TAD - 2
• MODERATE	• MODERATE
VDI - 3	TAD - 3
VDI - 4	TAD - 4
• SEVERE	• SEVERE
VDI - 5	TAD - 5
VDI - 6	TAD - 6
VDI - 7	TAD - 7
VDI - 8	
VDI - 9	

When the damage index code values 1 and 2 are combined to create the "minimum" damage classification, the difference at value 1 is reduced, as shown in Figure 7.

FIG. 7
VDI AND TAD DAMAGE CODES COMBINED INTO MINOR, MODERATE,AND SEVERE CLASSIFICATIONS



SOURCES: HSRI CPIR Data File and HSRI 1972 Texas Data File

Figure 7 illustrates the fit in equating the two grouped damage severity indices.

Use of the 1972 Texas Accident data in combination with the CPIR data allowed HSRI to estimate the incidence of fuel leakage by vehicle damage area and severity in the national accident population. However, no attempt was made to equate fire and fatalities to the Texas File because of the small number of cases of fire in the CPIR data, and because of the bias in the CPIR case selections toward severe and fatal accidents.

The 5-percent sample of the Texas accident data appears to be a reasonably good representation of the national accident population, although it must reflect some demographic and geographic characteristics peculiar to Texas. Texas has about 6 percent of the U.S.

population, in a density about the same as that of the nation. It has a mixture of large cities and rural areas. But it does not have one of the 8 largest Standard Metropolitan Sampling Areas, and it has relatively little snow and ice.

The histograms in Figures 8, 9, and 10 represent the Texas accident experience as analyzed after the CDC/VDI was equated with the TAD damage severity index. The findings suggest the incidence of fuel leakage in the national accident experience.

4.2.8 CPIR and Texas Fuel Leakage Analysis

Fuel leakage and the attendant problem of fire are not as serious a problem in minor impacts as in severe impacts. Minor-impact crashes seldom result in serious injuries even in the relatively rare instances in which such collisions result in fire.

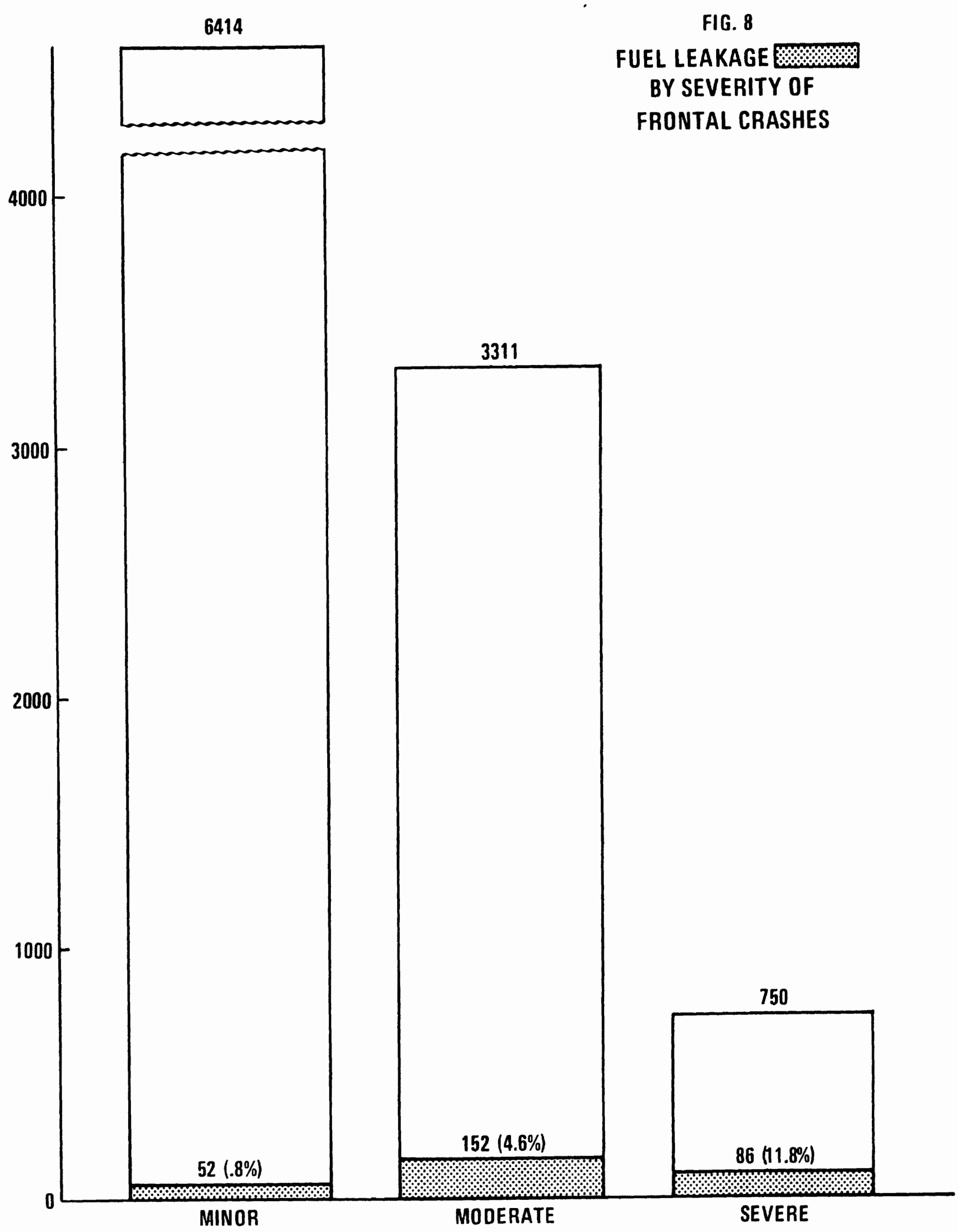
Fuel leakage in accidents is most often not accompanied by fire, but yet fuel leakage is a prerequisite for fuel-fed fires. The current amended Motor Vehicle Safety Standard #301, which specifies tests of fuel system integrity, will apply to passenger cars manufactured after September 1, 1975, and is effective for certain classes of multipurpose vehicles, trucks, and buses on September 1, 1976. In addition to specifying that fuel leakage be restricted to a maximum permissible flow rate after a front-barrier test crash, the amended Standard #301 imposes similar test conditions for rear and lateral crashes and for rollovers. The tests involving rear and lateral crashes specify minimum-speed impacts with, or into, a specified barrier at front, side, and rear crash orientations. Thus the impact speed is the criterion employed by the standard for testing the capacity of vehicles to maintain fuel system integrity in the specified frontal, side, and rear crash orientations.

4.2.9 CPIR and Texas Fuel Leakage by Damage Area and Extent

The joint analysis of the CPIR and Texas Accident File data estimated the probability of fuel leakage in frontal, side, and rear-impact crashes as a function of vehicle damage severity. To establish the probabilities of fuel leakage as a function of impact speed, HSRI equated vehicle damage areas and severities with impact speeds so as to produce findings more relatable to Motor Vehicle Safety Standard #301 requirements.

FIG. 8

FUEL LEAKAGE BY SEVERITY OF FRONTAL CRASHES



SOURCES: HSRI CPIR Data File and HSRI 1972 Texas Data File

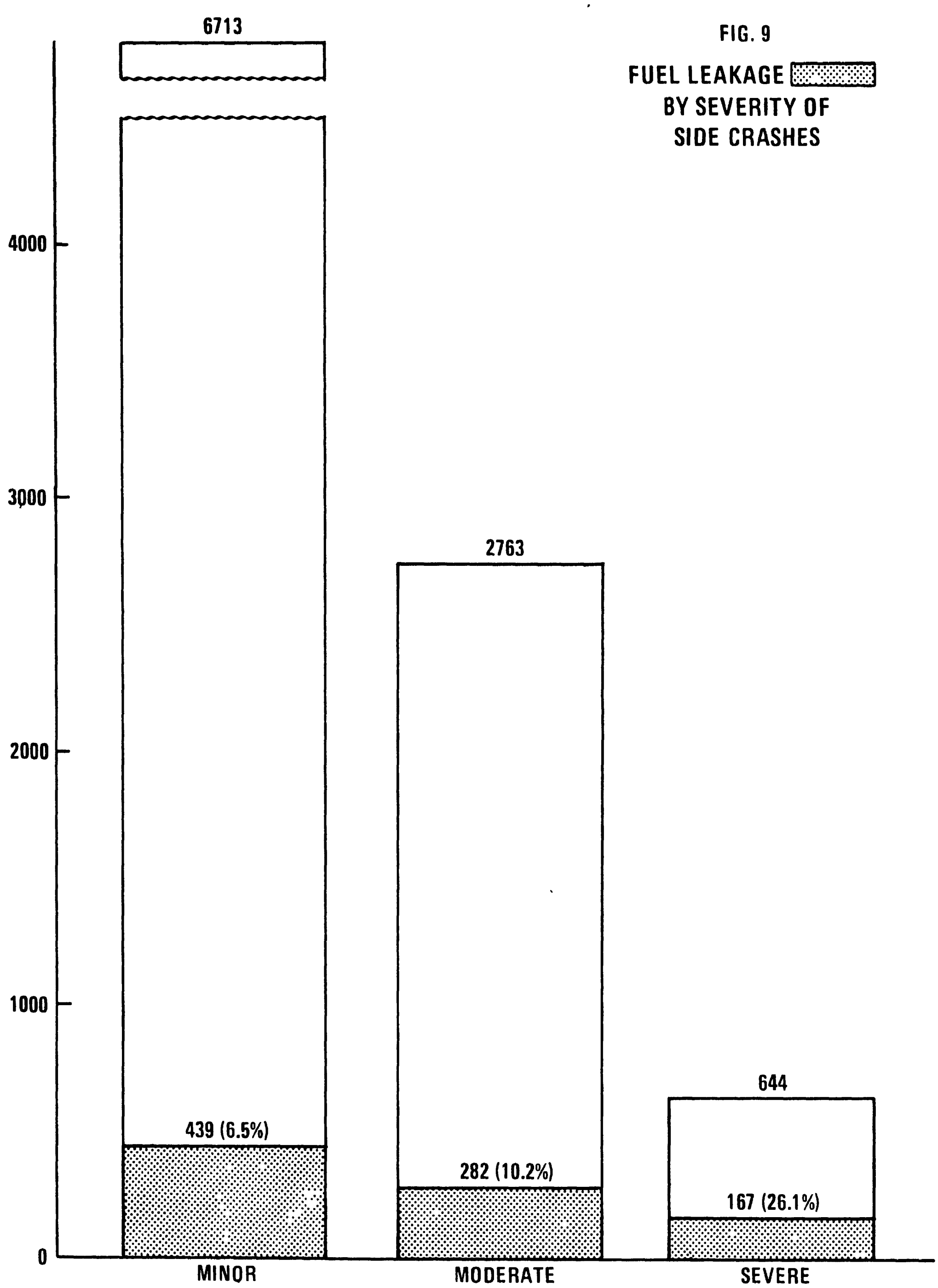
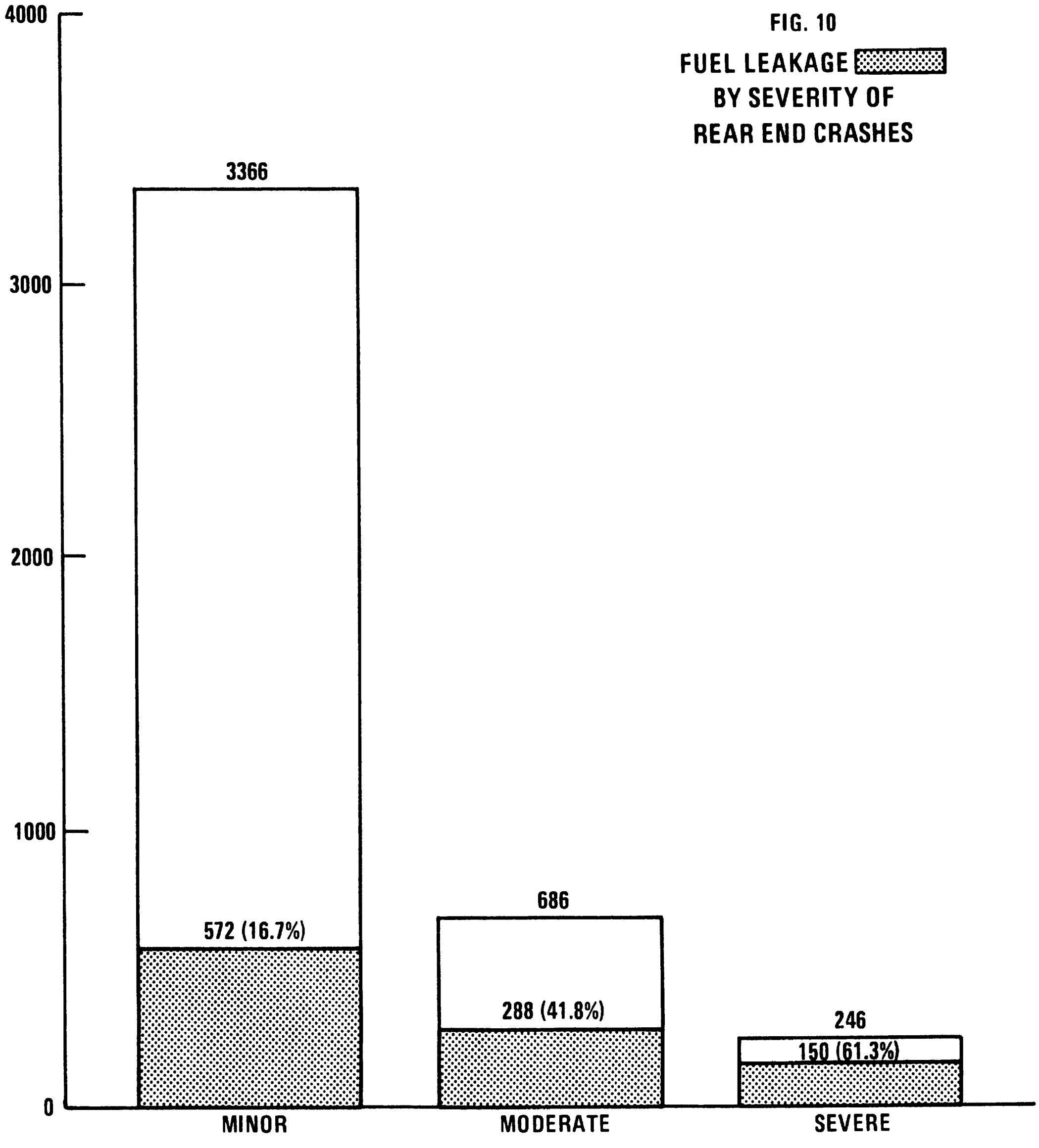


FIG. 9
FUEL LEAKAGE
BY SEVERITY OF
SIDE CRASHES

SOURCES: HSRI CPIR Data File and HSRI 1972 Texas Data File



SOURCES: HSRI CPIR Data File and HSRI 1972 Texas Data File

In controlled barrier crashes, such as those conducted by automobile manufacturers and research organizations, the impact speed of the crashed vehicle and the extent of damage, in terms of measured deformation, are accurately known, both for controlled crashes with another vehicle and controlled crashes with various fixed objects. Therefore a review was conducted of test data for such controlled crashes, along with a review of accident data on selected accidents in which speed of the vehicle(s) is accurately known. This permitted a plotting of the relationship between damage deformation (crush) and impact speed. Each crash was evaluated and plotted as a single data point. The resultant graph of impact speed relative to crush in frontal crashes is shown in Figure 11. Figure 11 shows, in addition to damage deformation or crush measurements, the CDC/VDI damage extent categories (numbers 1, 2, 3, 4). As is shown, the majority of test crashes (denoted as points on the plot) are bunched about the 30 m.p.h. impact-speed area, reflecting the preponderance of 31 m.p.h. barrier test crashes included in the data.

Similar relationships between side-impact speed and crush, and rear-impact speed and crush, are shown in Figure 12 and 13. The relationships plotted in Figure 12 and 13 are based on relatively few test crash data points. Nevertheless, they represent a representative, generalized relationship between impact speed and extent of deformation.

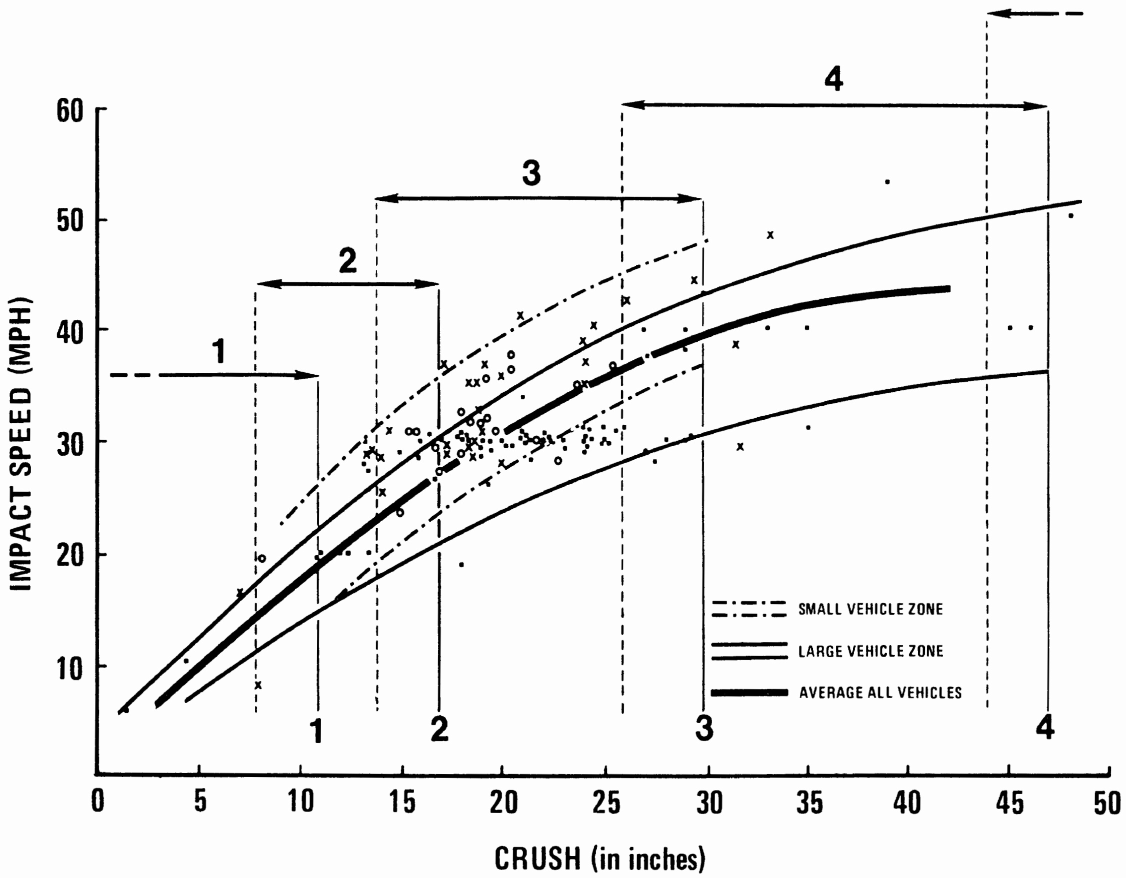
When crush was equated to fuel leakage for the same frontal, side, and rear crash orientations, this illustrated the relationships shown in Figure 14.

When damage severity was related to impact speed rather than to crush, this illustrated the relationships shown in Figure 15.

The relationship between impact speed and fuel leakage was established by using damage deformation (crush) as the dependent variable for each relationship in the frontal, side, and rear crash orientations. This estimate of the variation of fuel leakage with impact speed in crashes of passenger cars over the past several years is shown in Figure 16. The curves in Figure 16 again illustrate the susceptibility of rear-impact crashes to fuel leakage. The solid vertical line located at 30 m.p.h. and the broken vertical line located at 20 m.p.h. are included only as a reference to the fuel system integrity test crashes specified in MVSS #301. The 30

FIG. 11

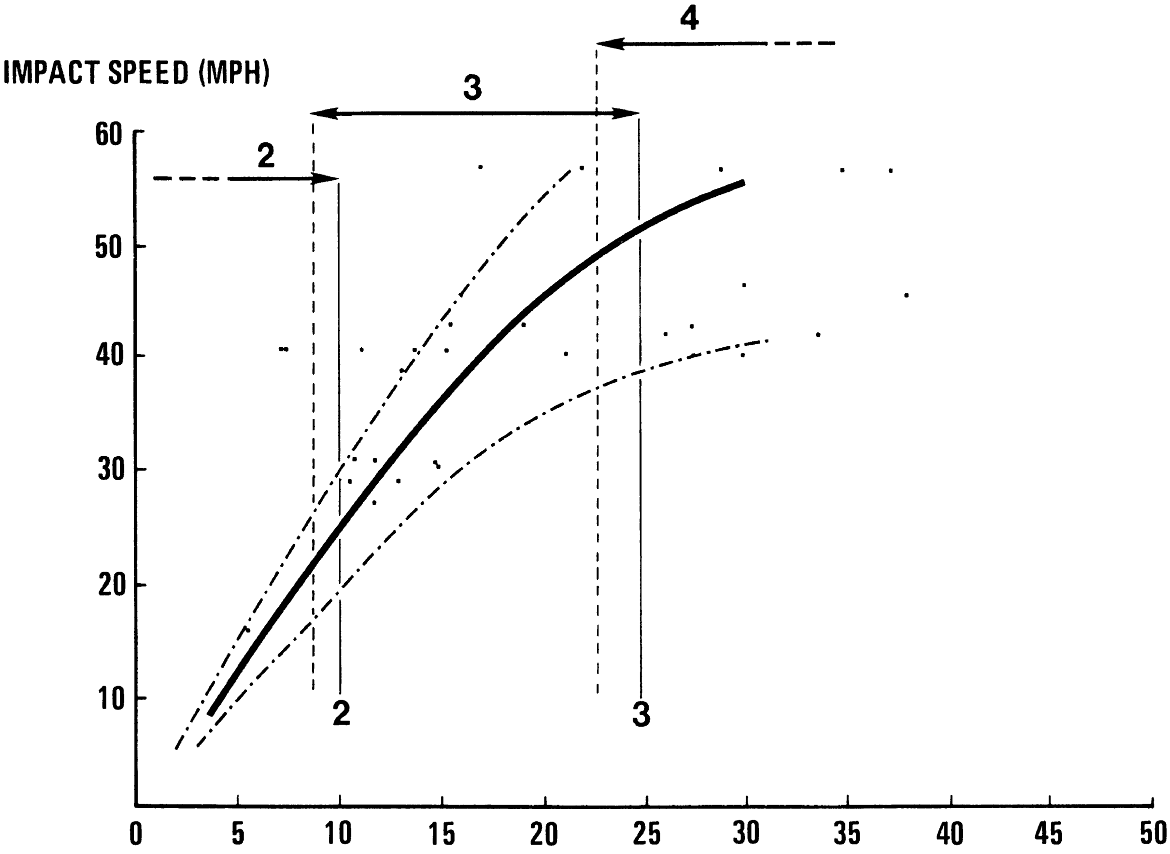
VEHICLE CRUSH RELATIVE TO IMPACT SPEED IN FRONTAL CRASHES



SOURCE: Calibrated test crashes and actual crashes where impact speed known.

FIG. 12

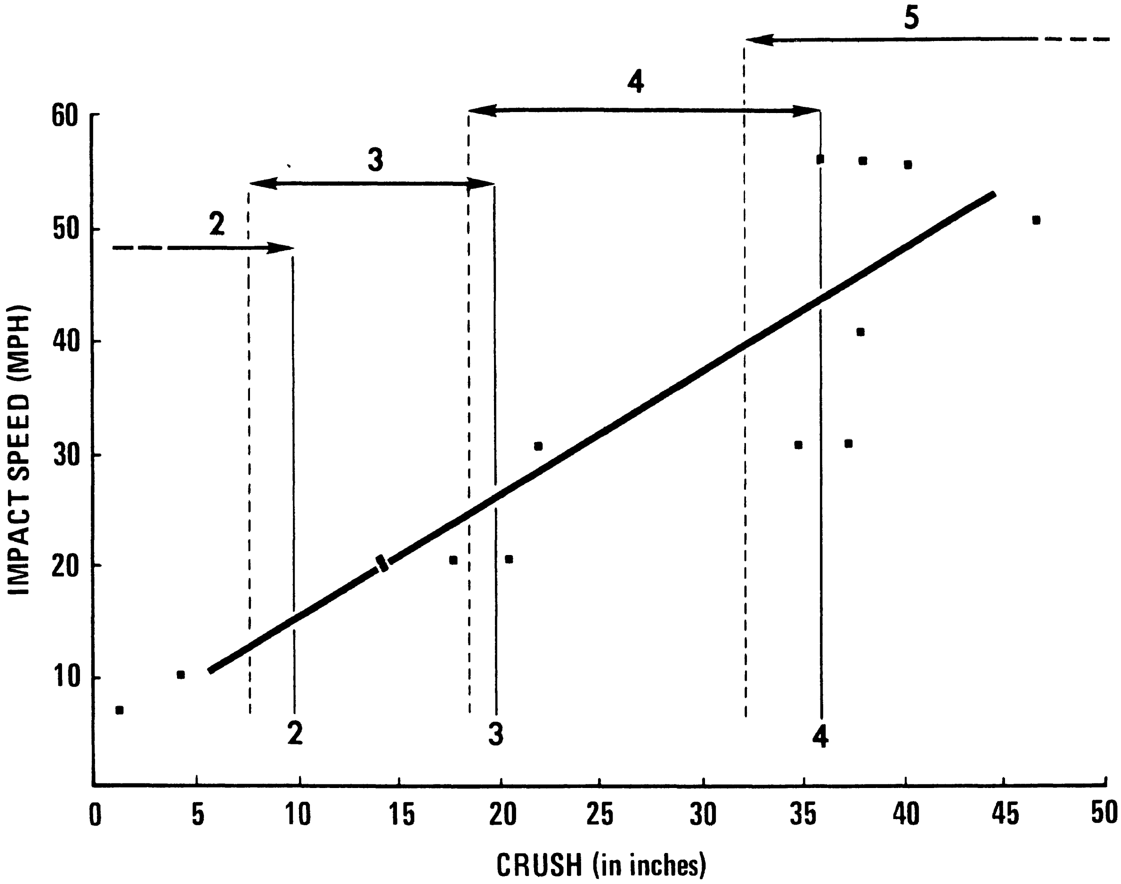
VEHICLE SPEED RELATIVE TO CRUSH IN SIDE IMPACTS



SOURCE: Calibrated test crashes and actual crashes where impact speed known.

FIG. 13

VEHICLE SPEED RELATIVE TO CRUSH IN REAR IMPACTS



SOURCES: Calibrated test crashes and actual crashes where impact speed known.

FIG. 14

FUEL LEAKAGE RELATIVE TO SHEET METAL CRUSH

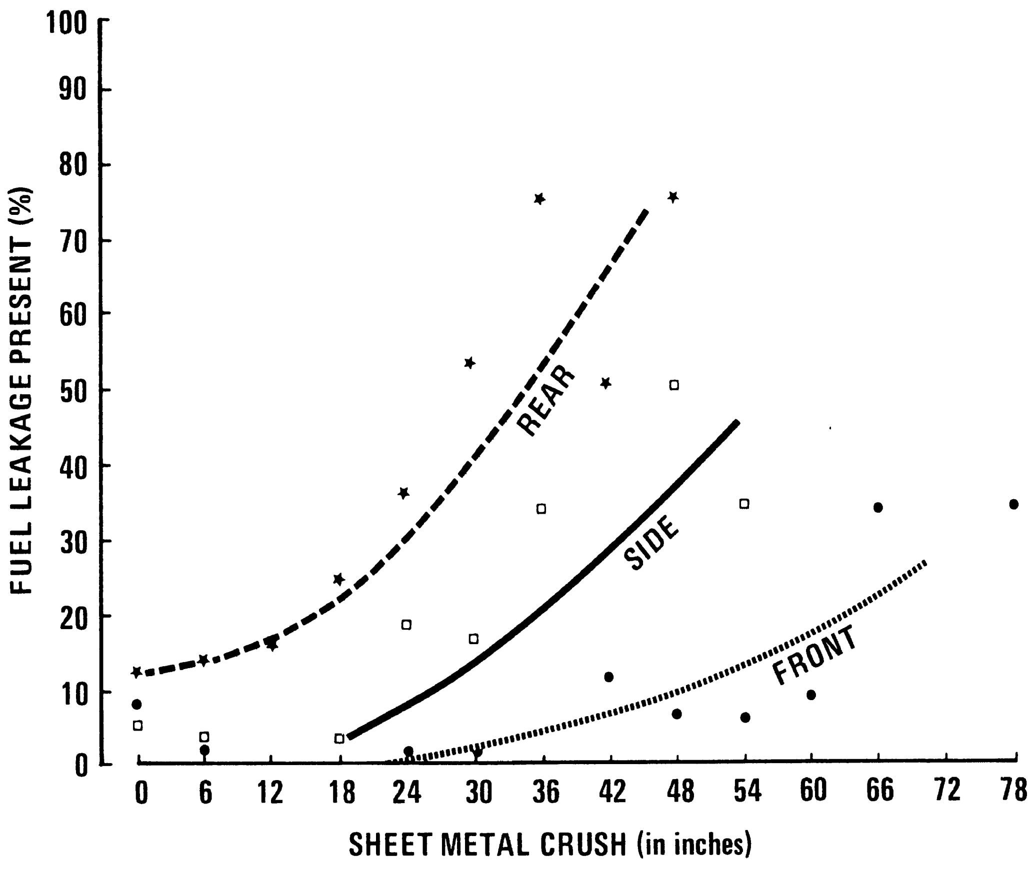


FIG. 15

FUEL LEAKAGE RELATIVE TO VEHICLE DAMAGE SEVERITY CLASSIFICATION

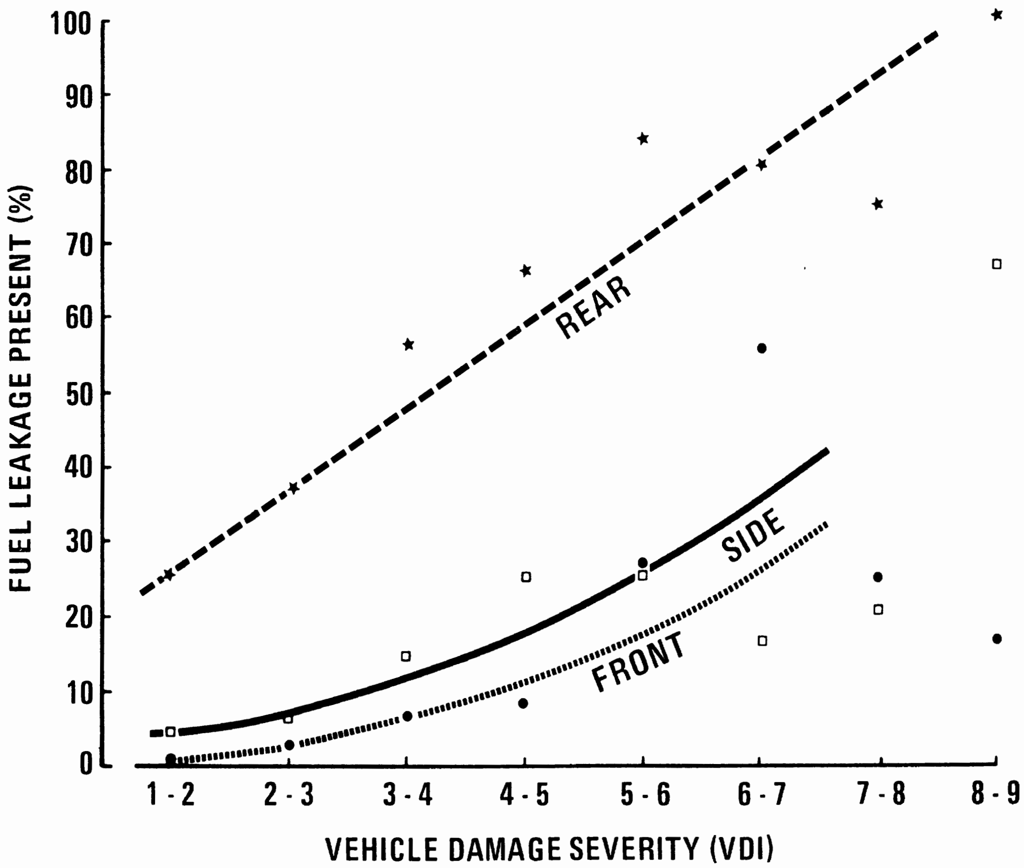
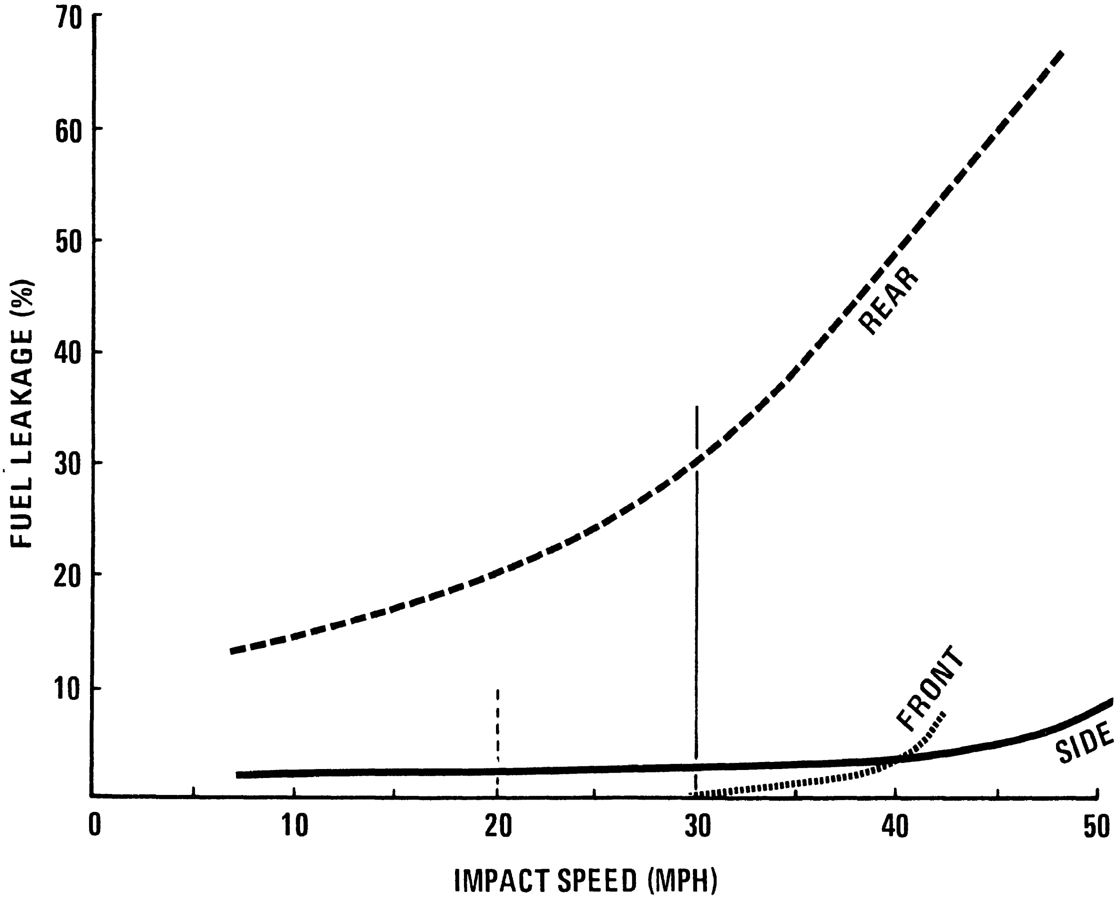


FIG. 16

FUEL LEAKAGE IN VEHICLES INVOLVED IN FRONT, SIDE, AND REAR IMPACTS RELATIVE TO IMPACT SPEED



m.p.h. line indicates that when rear-end impacts are equated with an impact speed of 30 m.p.h., approximately 30 percent of the struck vehicles may be expected to leak fuel, given that the vehicles have fuel system characteristics of recent model passenger cars. Similarly, for frontal impacts at 30 m.p.h., less than 1 percent of the struck vehicles may be expected to leak fuel. The dotted line indicates that at impact speeds of 20 m.p.h., 3 percent of the vehicles struck in the side may be expected to leak fuel.

The quantity or rate of flow of leaking fuel in those accident vehicles in the CPIR data file is unknown; those data merely indicate whether the accident investigator observed or did not observe fuel leakage from the accident-damaged vehicles.

No attempt was made to equate rollover accidents with fuel leakage. Damage in rollover accidents often occurs to frontal, side and rear areas.

The HSRI findings provide an indication of the relative magnitude of the fuel leakage problem at test-impact speeds specified in the amended fuel system integrity standards of MVSS #301 for frontal, side, and rear crash orientations. The findings reveal the magnitude of the problem manufacturers face regarding compliance with MVSS #301, particularly as it relates to fuel leakage from rear-impact crashes.

4.3 HSRI Analyses of Medical Data

An alternate approach to the problem of assessing the size of the problem of fires in vehicle accidents involves assessing hospital records, morgue records, and death certificates. In the Dunn and Halpin study (discussed in Section 4.1), a sample of national death certificate transcripts forwarded to Washington, D.C., by the various states was used to classify accidental burn deaths. However, no such national study of death certificate transcripts has been made since the 1951 Dunn and Halpin analysis of 1948 data. Data on the origin and type of motor vehicle accidents resulting in burn fatalities is not collected on any scale that would support reliable statistical inferences. The National Burn Information Exchange at The University of Michigan collects data on burn victims and the circumstances of the burn accidents. However, these data are obtained only from cooperating hospitals and are focused mainly on details of patient treatment and rehabilitative practices. Because of the limited number of cooperating hospitals, and since only those burn victims who enter a hospital are included in N.B.I.E. data, those records were only of limited value in this study.

4.3.1 Wayne County Morgue Records

In an NHTSA-sponsored research study conducted from mid-1967 to mid-1969, HSRI collected morgue pathology examination reports of fatal automobile accident victims in Wayne County, Michigan. A total of 449 "in-car" fatal accident victims were brought to the Wayne County Morgue over this two-year period. Of those, 6 victims were identified as having died as a result of burns. They represented 1.3 percent of the 449 "in-car" fatal accident victims. When that percentage is applied to the National Safety Council total of 44,800 "in-car" fatal accident victims for 1972, the resulting estimate is 590 such annual fatalities nationally. However, this estimate must be tempered by the knowledge that fatalities in this Wayne County sample were the result of accidents occurring mainly in an urban area, because most of Wayne County consists of Detroit and its suburbs. Studies by HSRI, the University of Oklahoma Research Institute, and other research organizations have shown that a higher incidence of fire-associated accident fatalities occurs in rural areas than in urban areas. Thus the percentage of 1.34 for Wayne County and the resulting projection of 590 fire-associated fatalities nationally may be conservative. However, the findings were based on pathology examinations, and those examinations often were not followed by autopsies which might have established cause of death as a result of injuries other than those resulting from fire. A further limitation in the findings is that the sample of 6 fire-associated fatalities is too small to permit much confidence in a projection to the national accident experience.

4.3.2 The Michigan Fatal Accident File

In a further effort to determine the incidence of fire in fatal accidents, HSRI examined a microfilm file of hard-copy police reports of all fatal accidents in the State of Michigan for the years 1968 through 1971. (This film record was made available by the Michigan Department of State Police.) A microfilm of 1972 fatal accident reports was not available at the time of this analysis, but will be similarly examined when it becomes available. Most of the fatal accident reports included materials provided by the investigating officers in addition to the standard police accident report form. These often included witness statements and narratives of followup investigations conducted by the police officers. Most of the cases also included a certificate of death. HSRI arrived at findings regarding the frequency and significance of fire in fatal accidents by examining those cases where fire or some appropriate indicator of fire was noted in some way in the accident, or where fire was noted as related to cause of death. The determination of whether death in these fire-associated accidents was the result of fire or of some other injuries was made by this author, based on the death certificate entries for the disease or condition directly leading to death as well as all other documents included with each fatal accident report--the policeman's confidential report, witness statements, pathologist's summary, etc. Some of the terms and phrases in the various documents that were considered in making those judgments were:

Burned	Consumed by fire
Burned up	Conflagration
Burned alive	Extensive body burns
Asphyxiated by burns (sic)	Incinerated
Asphyxiated by fire	Carbonized

Deaths associated with crash fires are actually distributed along a "causal continuum" on which deaths solely due to burns or asphyxiation are located at one pole and deaths solely due to impact trauma are located at the opposite pole. In this study of Michigan fatal accidents, fire-associated deaths were categorized in the following five ways:

(1) Deaths which were in no way the result of the fire--i.e., deaths in which the victims were not burned or asphyxiated. In one case, for example, one car in a 13-car crash caught fire and the occupant of another car died from impact injuries. In another case, there was a fire in the engine compartment of a car, but the victim (who died from impact injuries) was not burned or asphyxiated.

(2) Deaths which were the result of impact injuries in cases in which victims incurred minor burns which did not contribute to the fatalities.

(3) Deaths which resulted primarily from impact injuries, but in which the victims were burned sufficiently to have worsened their condition, thus leading to the conclusion that neither the impact injuries alone nor the burns alone would have caused death, but the combination of them did.

(4) Deaths which would have been assured by either the impact injuries or burn injuries (or asphyxiation).

(5) Deaths which resulted solely from burns or asphyxiation.

In this study, a distinction was made between deaths in accidents accompanied by a fire and deaths in which fire was the primary cause of death. Where both impact injuries and burns are sustained by a fatally injured occupant, ascertaining which of the two injury types directly resulted in death is difficult. Here, a judgment was made, where possible, on the relative seriousness of the two types of injury. This was attempted in those cases where death may have been assured by either type of injury. When the fatally injured occupant is extensively or completely incinerated or carbonized, it is sometimes quite difficult for even the most experienced and qualified pathologist to determine the primary cause of death. This is because of the extensive loss of soft tissue as a result of the fire, leaving only the larger or massive fractures on which to establish a judgment as to the primary cause of death. Many of these pathology examinations are not followed by autopsy. In some fire-associated fatal accidents, information needed to make these fine distinctions as to cause of death was not available. Here, the author made a judgment whether the fire in a fatal accident was a direct or major contributing cause of death, or merely associated with the accident and cause of death. In general, deaths assigned to categories 3, 4, and 5, above, were classified as deaths resulting from fire.

To compute the incidence of fire in motor vehicle accidents as a percentage of all motor vehicle accidents, HSRI examined its digital data files of all Michigan traffic deaths for the years 1968 through 1972. During those years there was a total of 9,386 traffic deaths in Michigan, representing 4.2 percent of the national total. Of those 9,386 deaths, 1,490 were pedestrians and 155 were bicyclists. Those categories of deaths were excluded from consideration, leaving a total of 7,741 fatalities in vehicle accidents where fire could have been a direct or associated cause of death. In Figure 17 those Michigan fatal accidents by year are shown in relation to the national figures and to the number of Michigan fatalities in accidents where fire was noted, or fire was listed as the cause of the fatality. Figure 17 shows that fire was noted, in one form or another, in 1.6 percent of the Michigan fatal accidents. It could have been a minor fire within the engine compartment, easily extinguished by a passerby, or a spectacular conflagration incinerating all of the vehicle occupants. Fire units are often dispatched to the scene of an accident because of fuel spillage and the potential for fire. Thus the presence of fire equipment at an accident site does not always indicate that a fire has occurred. Conversely, small fires in severe accidents are presumably often not reported. The State of Michigan Traffic Accident Report Form UD-10 does not provide any data check-off elements relating to fire, or any note that would prompt a policeman to record the occurrence of fire. Therefore, while small fires may go unrecorded, larger and potential injury-producing fires were most probably noted on those police accident report forms completed on fatal accidents.

The second row of data in Figure 17 shows how Michigan accident fatalities have remained at a fairly constant percentage of national fatalities over the five-year period. The third row shows how Michigan traffic deaths in accidents accompanied by fire have also remained fairly constant. The fourth row shows a somewhat larger variation in the numbers and percent of Michigan deaths <u>resulting from</u> fire in vehicle accidents. The fifth row shows a fairly constant number and percentage of fatal accidents accompanied by fire.

The fatal accidents in which fire occurred (row 5) can be compared with deaths resulting from fire in accidents (row 4) to produce a ratio of the four-year averaged percentage figures of 1.44 to 1. This is significantly larger than the ratio of deaths to all Michigan fatal accidents, which is 1.16, indicating the much greater

FIG. 17

MICHIGAN VEHICLE DEATHS INVOLVING FIRE

	VEHICLE DEATH AND CLASSIFICATION ACCIDENT	YEAR 1968	1969	1970	1971	1972	4 YEAR AVERAGE
1	MICHIGAN VEHICLE DEATHS	1975	2083	1794	1707	1827	1890 (1877)*
2	NATIONWIDE VEHICLE DEATHS (MICHIGAN % OF NATION)	44,172 (4.5%)	44,891 (4.6%)	43,580 (4.1%)	43,250 (3.9%)	44,800 (4.1%)	43,973 (44,138)* (4.3%) (4.3%)*
3	DEATHS IN ACCIDENTS ACCOMPANIED BY FIRE (%OF MICH. TOTAL – LINE1)	29 (1.5%)	25 (1.2%)	35 (2.0%)	32 (1.9%)	-----	30 (1.6%)
4	DEATHS IN ACCIDENTS RESULTING FROM FIRE (% OF MICH. TOTAL - LINE 1)	11 (.56%)	16 (.77%)	25 (1.4%)	22 (1.3%)	-----	19 (0.98%)
5	FATAL ACCIDENTS ACCOMPANIED BY FIRE (% OF FATAL ACCIDENTS)	21 (1.3%)	18 (.84%)	21 (1.4%)	24 (1.3%)	-----	21 (1.3%)

* 5-YEAR AVERAGE, INCLUDING 1972

SOURCE: Michigan Department of State Police, Fatal Accident Microfilm File.

severity and lethality of fatal accidents accompanied by fire, compared to all fatal accidents.

The analysis also yielded other characteristics of fatal accidents accompanied by fire. The probability of being fatally burned in a fatal accident accompanied by fire is highest in three types of collisions: head-on collisions with a fixed object (a tree, overpass abutment, etc.), rear-end impacts, and rollovers. As noted previously, these accident classifications also represent a high incidence of fuel leakage. A summary of these accident types in terms of burn deaths in Michigan accidents for the period 1968-1971 is shown in Figure 18. The last line in Figure 18 shows the percentage relationship between deaths resulting from fire and deaths from all causes. Note that this ranges from 82 percent for head-on collisions with a fixed object (at the left) down to 50 percent for intersection side-impacts (at the right). The overall percentage for all crash configurations was 70 percent, indicating that nearly 3 out of 4 deaths in fatal accidents accompanied by fire either result from fire or are ensured by fire.

A comparison of vehicle types in terms of fire-induced injury is shown in Figure 19. Full-size passenger cars were most often involved in fatal accidents accompanied by fire. One would expect this because they constitute a high proportion of the total vehicle population. Sports cars were the next most often involved type of vehicle. These were followed by pickup trucks and truck tractor-semi-trailer combinations. Two of the latter were tankers involved in fire when their flammable cargo spilled and ignited.

Deaths resulting from fire in pickup fatal-fire accidents were more numerous than deaths from other causes in pickup accidents, suggesting that pickup trucks may be more vulnerable to injury-producing fire in accidents. Of the 13 pickup trucks in fatal accidents accompanied by fire, 5 crashes were rollovers, 4 were head-on collisions with another vehicle, 3 were rear-end impacts, and one was an angle or side-impact crash. The sample size of these vehicles and accident types is small, limiting the conclusions which can be drawn from these data. As tabulated in Figure 19, a total of 12 fatal accidents with fire occurred with sports cars, resulting in 18 fatalities. Of these, 15 deaths resulted from the fire. Most of the accidents included loss of control and striking of multiple fixed

FIG. 18

MICHIGAN FATAL ACCIDENTS WITH FIRE BY CRASH TYPE

DEATH BY ALL CAUSES / DEATH BY FIRE

YEAR	HEAD-ON FIXED OBJECT	ROLL-OVER	REAR-END	HEAD-ON 2 VEHICLES	INTERSECTION SIDE IMPACT
1968	3 / 2	4 / 1	4 / 2	3 / 2	6 / 1
1969	1 / 1	5 / 3	3 / 2	6 / 3	2 / 2
1970	6 / 5	5 / 5	2 / 2	1 / 1	7 / 5
1971	7 / 6	12 / 11	2 / 2	1 / 1	1 / 0
TOTAL	17 / 14	26 / 20	11 / 8	11 / 7	16 / 8
% DEATHS BY FIRE	82%	77%	73%	58%	50%

DEATHS BY FIRE, 4 YEAR AVERAGE - 70%

SOURCE: Michigan Department of State Police Fatal Accident Microfilm File.

FIG. 19

MICHIGAN FATAL ACCIDENTS ACCOMPANIED BY FIRE

VEHICLE TYPE	FATAL ACCIDENTS WITH FIRE	DEATHS ALL CAUSES	DEATHS FROM FIRE
PASSENGER CARS:			
FULL SIZE	49	65	35
INTERMEDIATE	4	8	8
COMPACT	8	8	7
SPORTS	12	17	15
OTHERS			
VANS	2	4	4
MOTORCYCLES	3	4	4
TRUCKS:			
STRAIGHT	3	3	3
PICK–UPS	13	20	12
TRK TRACTOR–SEMI TRAILER	11	14	5

SOURCE: As in Figures 18 and 19.

objects at high speed, with occupants from 21 to 23 years of age. These were all severe crashes, which perhaps suggests that young drivers, when combined with "sports" or "high performance" vehicles, tend to operate such vehicles up to and sometimes beyond the limits of their performance. Most noteworthy in this group was the number of fatal crashes involving fire with an American sports car possessing a fiber-glass body. This sports car model was involved in 8 of the 12 fatal accidents, resulting in 14 of the fatalities in the sports car category. Here, 13 of these deaths resulted directly from fire. The "stiff" characteristics and distinctive fracture behavior of the fiber-glass body, along with the high location of its fuel tank in relation to the vehicle frame, may be responsible for exposing fuel system components to greater damage in severe crashes, which could result in fire.

Compact and intermediate-size passenger cars showed a high incidence of death by fire. In the compact category, which lists 8 accidents, 2 of those accidents involved vehicles with engines in the rear, resulting in 5 deaths from fire.

Other findings in the analysis of Michigan fatal accidents accompanied by fire showed that the group included two car-train crashes in which the drivers in the two passenger cars sustained fatal injuries from fire. Three motorcycle accidents resulted in death to the drivers as a result of fire. These were side-impact crashes which ruptured the motorcycle fuel tanks. Twelve accidents involving intoxicated and/or drugged drivers resulted in 17 deaths, with 9 of those resulting from fire.

Five accidents were classified as suicide or a combination of suicide and homicide. Official police reports indicate a reluctance on the part of investigating officers to suggest the possibility of suicide in a fatal accident. However, in cases in which a driver apparently deliberately crosses the median of a divided limited-access highway, at night without lights, and crashes head-on at high speed into a car in the oncoming stream of vehicles, the accident is most likely a vehicular suicide, even in the absence of a suicide note. Of the 9 occupants in vehicles in the five crashes classified as vehicular suicides, 8 died as a result of fire in exceptionally severe crashes.

Three fatal accidents accompanied by fire involved vehicle malfunctions. They resulted in 3 deaths, one directly from fire. One of the accidents involved a truck tractor with tanker semi-trailer containing gasoline. The steering wheel in the tractor came unmounted while the truck was in motion, resulting in the uncontrolled truck combination crossing the roadway centerline and colliding head-on with a passenger car. The tanker exploded and burned, but the driver of the passenger car died from injuries other than burns. A second truck tractor and semi-trailer combination went out of control as a result of a tire blow-out. The combination rolled over and the driver burned to death while pinned in the tractor cab. The third accident involved a 1930 Ford sedan which had been modified by a teenager into a high-performance vehicle. While the car was speeding on a Detroit freeway, its transmission exploded, resulting in a severed fuel line and fire. The driver and passenger jumped from the burning vehicle while it was still moving, and one died from injuries received from the deliberate jump.

In sum, the in-depth review of Michigan fatal accident reports for the period 1968-1972 showed that of the 7,559 motor vehicle deaths, 74 resulted from fire. When this .98 percent of all vehicle accident deaths is applied to the total national accident deaths for 1972 (44,800 "in-car" fatalities), this produces an estimate of 448 deaths nationally. The review also showed that a total of 121 fatalities occurred in accidents accompanied by fire (including the 74 directly resulting from fire). When this 1.6 percent of all vehicle accident deaths is applied to the 1972 national "in-car" fatality total, this results in an estimate of 718 annual fatalities in accidents accompanied by fire. The percentages of .98 for "deaths resulting from" and 1.6 for "deaths accompanied by" fall on either side of the 1.3 percent finding in the study of Wayne County death certificates on 1967-1969 victims of fatal traffic accidents, which would project a national figure of 583 for burn-associated traffic accident fatalities.

The average number of deaths per fatal accident involving fire is of particular significance. This was found to be 1.44, compared to 1.16 in all fatal accidents nationally, and 1.2 for turnpike highway fatal accidents, showing that fatal accidents involving fire are most lethal.

4.4 HSRI Analyses of State and National Fire Records

The problem of fire in motor vehicles was also approached through consideration of available reports and statistics prepared by various state and national organizations concerned with fire protection and fire losses of all kinds. This field is characterized chiefly by a lack of uniformity in terminology and accounting procedures. Even the basic definition of what constitutes a fire casualty varies considerably from organization to organization, and reliable nationwide data on motor vehicle post-crash fires is nonexistent.

Within these limitations, data from the National Fire Protection Association indicates that the number of motor vehicle fires has continued to grow annually. This is depicted in terms of a percentage of the U.S. population in Figure 20. The graph is tempered by the fact that the vehicle population has increased at a greater rate during this period than has the rate of all motor vehicle fires.

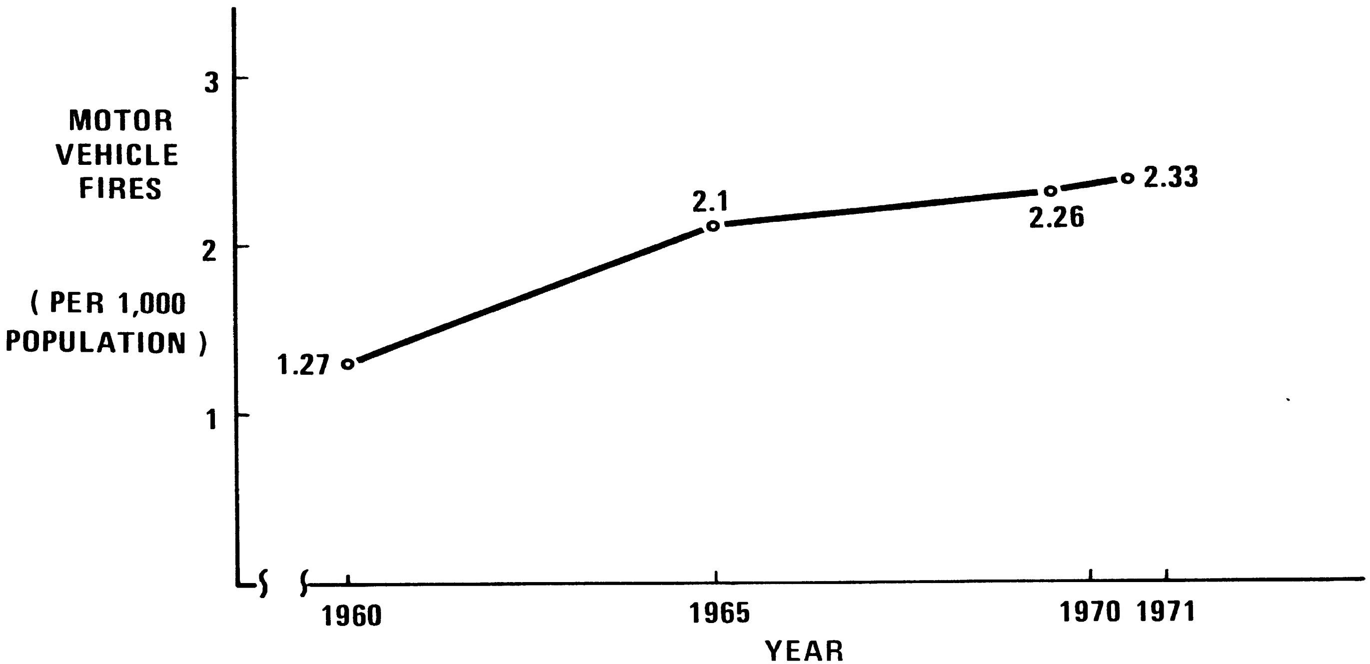
In general, organizations concerned with all types of fires (e.g., state fire marshals) use a single classification for motor vehicle fires. This would include a fire resulting from an accident, a garage fire which destroys a parked car, or a fire resulting from combustion of materials within a vehicle. Although an accurate estimate of motor vehicle post-crash fires within this gross classification is impossible, data obtained from the National Fire Prevention Association and from a few states provided some insight into the problem, particularly in the area of vehicle-accident-related burn deaths.

The National Fire Prevention Association is probably the single most effective organization engaged in developing national statistics relating to fire. Its Fire Protection Handbook (13th Edition, Revised) reports a total of 2,035 deaths associated with motor vehicles (excepting tank trucks) over a 35-year period. The NFPA estimates that these deaths are approximately 10 percent of the total estimated fire fatalities (20,350 deaths for the 35-year period 1935-1972). According to the National Safety Council, total motor vehicle deaths for that 35-year period were 1,388,915. Thus, using those figures, the average annual fatality rate of burn deaths associated with motor vehicles during that 35-year period is 1.5 percent of total motor vehicle deaths. Projecting this 1.5 percent

FIG. 20

U.S. FIRE STATISTICS

AUTO FIRES



SOURCE: National Fire Prevention Association to the 1972 "in-car" vehicle accident death total results in an estimate of 672 annual motor vehicle accident deaths associated with fire.

4.4.1 Oregon Fire Statistics

Of the various states which compile fire statistics, Oregon is one of the more progressive with regard to the detail and uniformity of its reports. The emphasis in the reporting is on fires in buildings, their causes, and resultant monetary losses. However, vehicle fires are reported in more detail than by most other states. HSRI analysis of Oregon statistics on auto fires for the period 1969-1973 resulted in the following findings:

(1) Auto fires are 12 percent of all fires in Oregon.

(2) An average of 9 deaths per year occur in fires resulting from crashes.

(3) Deaths from fire in motor vehicle accidents represent 1.25 percent of deaths in all vehicle accidents.

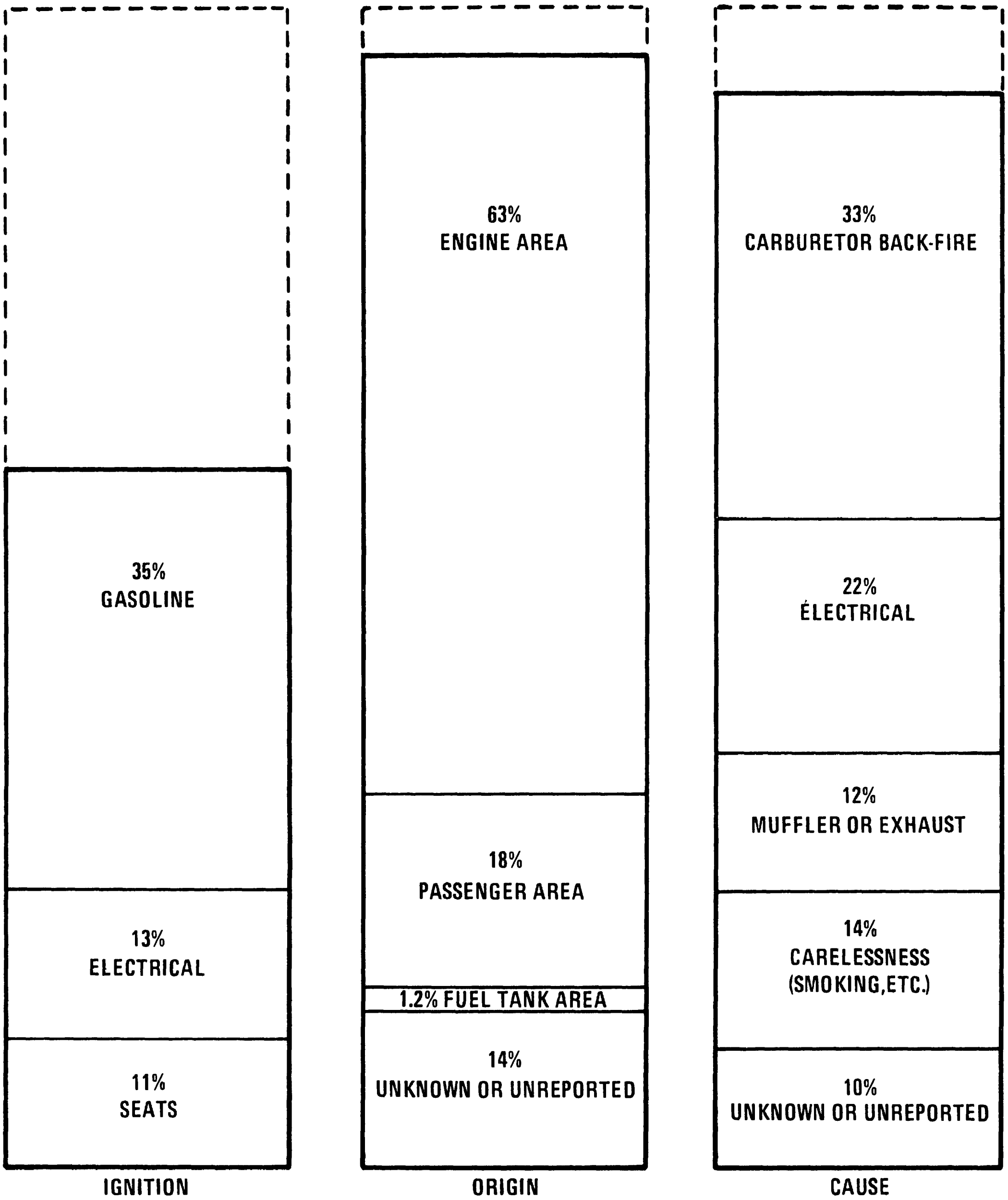
(4) The 1.25 percent applied to the 1972 "in-car" national vehicle accident fatality total results in an estimate of 560 deaths per year in vehicle crashes accompanied by fire.

The Oregon statistics on the origin and "cause" of auto fires are presented in Figure 21. This is typical of the way fire protection organizations organize statistics on vehicle fires. Note that the categories do not include traffic accidents as either origin or cause of fire. The percentages presented in Figure 21 represent all motor vehicle fires in Oregon, of which post-crash fires are but a subset. While the data shed little light on the problem of injuries and deaths from post-crash vehicle fires, they do associate gasoline, carburetor back-fire, and engine area with most (but not necessarily fatal) vehicle fires.

The total number of fatalities attributed to vehicle fires in Oregon is small. The vehicle fire fatalities are classified as "Wreck and Fire," "Suicide," "Open Flame--Non-traffic," and "Undetermined." If all victims, including those identified as suicides, are presumed to have died from burns rather than impact trauma, the four-year average of such deaths as a percentage of all Oregon traffic fatalities is 1.25.

FIG. 21

OREGON FIRE STATISTICS AUTO FIRES (1969 - 1973)



SOURCE: State of Oregon, Office of State Fire Marshall

4.4.2 Michigan Fire Statistics

Similar fire statistics of the State of Michigan for 1972 were also examined. As recorded by the Fire Marshall Division of the Michigan Department of State Police, there were 26 deaths in Michigan automobile accident fires resulting from a crash. Auto fires represented 18 percent of all fires. Eight percent of all fire-related deaths resulted from fire in autos. Deaths accompanied by fire in motor vehicle accidents represented 1.4 percent of all motor vehicle fatalities.

Application of the 1.4 percent to 1972 national motor vehicle accident fatalities results in an estimate of 627 such fatalities annually nationwide.

4.4.3 Iowa Fire Statistics

Iowa records for the years 1971 and 1972 were examined. The data include the following statistics: Auto fires in Iowa represent 20 percent of all reported fires in Iowa. An average of 12 deaths per year occurred in Iowa as a result of fires accompanying motor vehicle crashes. Sixteen percent of all fire-related deaths resulted from fire in autos. Deaths from fire in motor vehicle accidents represented 1.42 percent of all vehicle accident deaths.

Application of the 1.42 percent to the 1972 national vehicle accident fatality total (44,800) results in an estimate of 635 vehicle-fire-related fatalities annually nationwide.

4.4.4 Los Angeles Fire Statistics

Los Angeles City and County fire statistics were discussed previously (Section 4.1) in the evaluation of the Siegel and Nahum study. Fire statistics estimated by Siegel and Nahum and presented in their study report differ considerably from the pattern of statistics reported by the NFPA and by Oregon, Michigan, and Iowa. The discrepancy may be due to Siegel and Nahum's problems of attempting to separate the interlocking statistics kept for the City of Los Angeles and the County of Los Angeles, or it may merely reflect the idiosyncracies of Los Angeles residents, their driving behavior, and their roadway system. In any case, the findings as reported by Siegel and Nahum for the period 1966-1969 were these: Auto fires represent 19 percent of all fires. The estimated percentage of deaths per year in fires resulting from crashes is 12 percent of all traffic deaths. Deaths from fire in auto crashes represent 22 percent of all fire deaths and 2.7 percent of all deaths resulting from motor vehicle accidents. The 2.7 percent, when applied to the 1972 total "in-car" national fatality number, results in an estimate of 1,215 such fatalities per year nationwide. This estimate is approximately twice as high as estimates based on most of the other studies and records examined in this HSRI investigation. The percentage figure for the Los Angeles area may indeed by accurate. However, as previously mentioned, Los Angeles may not accurately represent traffic conditions throughout the United States. This estimate, as well as the estimate resulting from the Oklahoma study (Section 4.1.8) appears to present an upper bound on the range of estimates based on studies examined in this HSRI study.

4.4.5 Illinois Department of Public Health Mortality Statistics

Mortality records maintained by the Illinois Department of Public Health include a category of deaths resulting from fires and explosions occurring in motor vehicle accidents. This statistic is used by the National Safety Council in preparation of their annual statistical summary regarding motor vehicle accidents.

Through cooperation by the Illinois Department of Public Health and Illinois Department of Transportation, HSRI reviewed ten years of the Illinois data (1963-1972) and found 334 deaths attributed to fire and explosions occurring in motor vehicle accidents. More than one-half of those fatalities resulted from collisions involving two or more vehicles, and approximately one-third of them resulted from single-vehicle accidents. By counting all traffic fatalities in the Illinois statistics for the ten-year period, and excluding those of pedestrians and bicyclists, the 334 fire-related deaths represent 1.7 percent of the total motor vehicle fatalities in the Illinois records for the ten-year period. Projected to the national vehicle accident fatality total for 1972, the 1.7 percent results in an estimate of 762 annual fire-related traffic accident deaths nationwide.

4.5 Economic Considerations

The number of lives lost from fires in motor vehicle accidents is relatively small compared to the number of deaths resulting from other kinds of injuries in motor vehicle accidents. Nevertheless, improvements in vehicle fuel systems are needed, and the specifications for fuel system integrity in the amended Motor Vehicle Safety Standard #301 will make fuel systems more safe.

Obviously an estimate of the number of lives that can be saved by the use of vehicles that comply with the amended MVSS #301 is a starting point for computation of the costs and benefits associated with MVSS #301. The estimated number of lives that might be saved annually (see Section 5.4) is 180 to 260. However, this reduction in burn fatalities would not be achieved until all motor vehicles on U.S. roadways meet the requirements of the amended MVSS #301. This would be years away because of the introduction rate of new cars complying with the amended standard into the total vehicle population. A dollar figure assignable to each fatality, according to a recent NHTSA study report (Societal Costs of Motor Vehicle Accidents) is $200,000. Thus, apart from the intangible personal and human costs to individual victims and their families, the social or societal cost of 180 to 260 annual fatalities ranges from $36 million to $52 million.

Some critics of vehicle fuel system designs have used an estimate of 3,500 lives as the number that might be saved through compliance with MVSS #301. That estimate is greater than 10 times the estimate arrived at on the basis of this HSRI study. At $200,000 per life saved, that would mean a societal saving of $700 million, rather than $36-52 million.

The cost to the automobile industry (and eventually the auto-buying public) of compliance with MVSS #301 is unknown. If the total cost to the auto industry (for R&D, tooling, materials, etc.) were $100 million, and this were distributed over 10 million cars in one year's production, the added cost per vehicle would be $10. If total added cost were $200 million, total added cost per vehicle would be $20; and so forth.

The value judgment involved in the decision concerning what is a reasonable equation of "cost dollars" to "benefit dollars" does not necessarily depend on any assumption of equivalence or parity. That is, the decision-maker is not confined by any requirement that the expected costs be equal to or less than the expected benefits. If the benefit of compliance with MVSS #301 is estimated to be $100 million, this does not require that the costs of compliance be equal to or less than $100 million. A more effective cost-benefit comparison would involve estimating whether more lives could be saved by application of the same amount of "cost" dollars to vehicle improvements other than (or combined with) those now under specific consideration, even though dollar figures for such broader comparisons are less easy to develop.

Cost-benefit figures can be helpful, but before they can be helpful they must be accurate, and no accurate estimates of the cost of compliance with MVSS #301 have as yet been identified.

Certainly the problem of fire in motor vehicle accidents will be reduced by industry responses to MVSS #301, although a complete solution to the problem will not be achieved. Even a cursory review of contemporary vehicle designs shows that fuel systems have not been considered as a single, integrated, rupture-resistant sytem, but as a set of components adapted to a particular vehicle after its basic design has been completed. Hopefully the findings of this study, along with the impetus provided by MVSS #301, will challenge auto makers to produce improved fuel systems.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Fires Resulting from Motor Vehicle Accidents

Approximately 17,000 fires resulting from motor vehicle accidents occur each year in the U.S. Such fires occur in approximately 0.1 percent of the 17 million motor vehicle accidents occurring annually in the U.S. This finding is based on the New York State study of 1969 and the North Carolina study of 1973, which found that fire occurred in .07 and .04 percent, respectively, of all motor vehicle accidents. Because non-fatal vehicle accident fires tend to be underreported by police investigators (mainly because standard report forms often do not provide for notation of fire occurrence), the study findings of reported occurrences of fire were increased to arrive at the estimate of .1 percent.

The New York and North Carolina findings of .07 and .04 percent were supported by the findings of the Cornell Accident Causation and Injury Research study of 1964, which found that fire occurred in .45 percent of all injury accidents. In national accident statistics tabulated by the National Safety Council, injury accidents represent 12 percent of all motor vehicle accidents. Therefore, 12 percent of the Cornell .45 percent finding results in a finding of .05 percent for the Cornell data.

Fire protection organizations report that vehicle fires represent 12 to 20 percent of all reported fires. However, most of those vehicle fires result from causes other than motor vehicle accidents--from electrical malfunctions, carburetor backfires, etc.--and very rarely result in fatalities.

5.2 Fatalities Resulting from Fire in Motor Vehicle Accidents

The number of annual fatalities resulting from fire in motor vehicle accidents in the U.S. is between 450 and 650. Those figures represent from 1 to 1.5 percent of the 44,800 fatalities of vehicle occupants (excluding pedestrians and bicyclists) in 1972 U.S. motor vehicle accidents. Fatalities resulting from fire are defined as fatalities that would not have occurred had the fire not occurred. Fatalities accompanied by fire in motor vehicle accidents are defined as fatalities that include deaths resulting directly or solely from fire, as well as deaths resulting from non-fire-related injuries in accidents in which fire occurred.

5.3 Fatalities Accompanied by Fire in Motor Vehicle Accidents

The number of annual fatalities occurring in motor vehicle accidents accompanied by fire in the U.S. is between 720 and 1,250. Those figures represent from 1.7 to 2.8 percent of the 44,800 fatalities of vehicle occupants (excluding pedestrians and bicyclists) in 1972 U.S. motor vehicle accidents. This conclusion, and the above-stated conclusion regarding fatalities resulting from fire, is based on HSRI evaluations of previous research studies (discussed in Section 4.1), analyses of four different bodies of traffic accident and medical data (discussed in Sections 4.2 and 4.3), and examination of five sets of mortality records maintained by state and national fire protection organizations (discussed in Section 4.4). A graphic summary of the various findings is presented in Figure 22.

5.4 Types of Crashes, Fuel Leakage, and Fire

Conclusions based upon HSRI analyses of the relationship between types of crashes, fuel leakage, and fires are presented here in terms of general relationships, specific findings, and the effects of compliance with the amended Motor Vehicle Safety Standard #301.

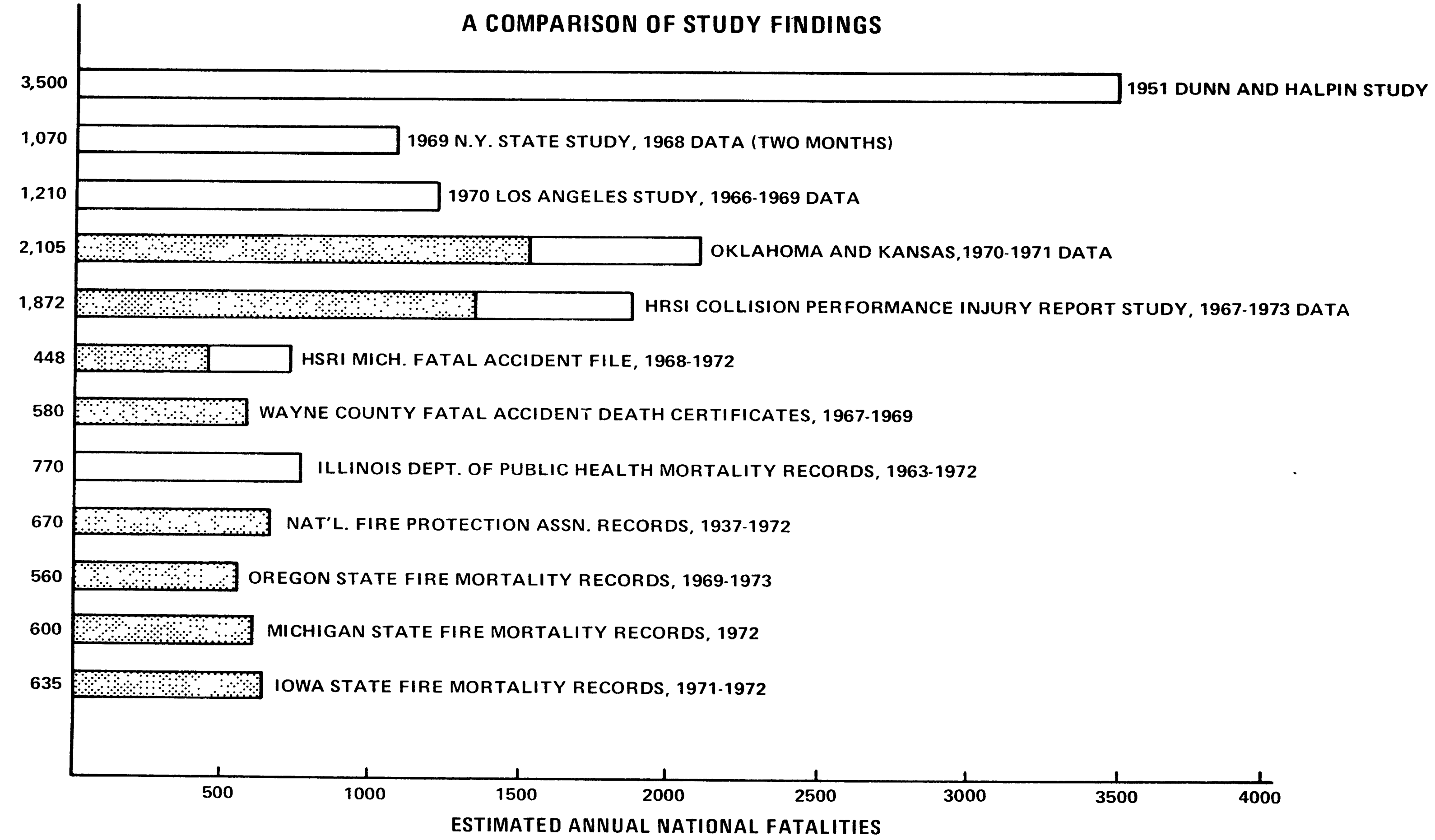
General Relationships

Fuel leakage is a prerequisite for an accident-induced fuel-fed fire, but the frequency of occurrence of fire following fuel leakage varies considerably, depending on the type and severity of the crash. Hence, from a statistical standpoint, fuel leakage is not a valid indicator of the occurrence of fire. As one would expect, fuel leakage occurs most often in rear-end impacts, and occurs more frequently as the severity of impact increases.

The type of crash that results in the greatest number of cases of fuel leakage is not the type of crash that results in the greatest number of fatalities in motor vehicle accidents accompanied by fire. Rear-end impacts result in the most cases of fuel leakage, but

FIG. 22

ESTIMATED ANNUAL
MOTOR VEHICLE ACCIDENT FATALITIES
RESULTING FROM FIRE
ACCOMPANIED BY FIRE



single-vehicle severe frontal crashes result in the greatest number of fatalities in accidents accompanied by fire.

Specific Findings

Analyses of fuel leakage in accident dâta contained in the HSRI Collision Performance and Injury Report (CPIR) File and applied to the 1972 Texas Accident File showed that the probability of occurrence of fuel leakage in minimum, moderate, and severe rear-end impacts is 16.7 percent, 41.8 percent, and 61.3 percent, respectively. The probability of occurrence of fuel leakage in minimum, moderate, and severe frontal impacts is 2.8 percent, 4.6 percent, and 11.8 percent, respectively. These findings underscore the significant difference in the probabilities of fuel leakage in rear-end and frontal impacts.

Analyses of the incidence of fire in accidents contained in the HSRI CPIR File were not similarly applied to the 1972 Texas Accident File because of an (as yet) insufficient number of fire-accompanied accidents in the CPIR data. The low number of such cases and the emphasis on fatal accidents made the projection of such findings to the Texas accident experience unreliable. However, the number of cases in the CPIR File in which fire occurred in frontal severe crashes is significant. Of the 57 cases of reported fire in the CPIR File, 19 of them (one-third) occurred in frontal-severe accidents. This suggests that the problem of fire in traffic accidents can be regarded in many respects as the problem of fire in frontal-severe accidents. That consideration is supported by the analysis (Figure 18) of Michigan fatal accidents accompanied by fire. Over a four-year period (1968-1971), 28 deaths occurred in "head-on" crashes and 11 occurred in rear-end crashes.

Effects of Compliance with MVSS #301

The objective of Motor Vehicle Safety Standard #301 is to minimize the hazard of fire resulting from collisions. The standard specifies requirements for the integrity and security of fuel tanks, fuel tank filler pipes, and fuel line connections when vehicles are subjected to certain specified crash tests.

One question that needs answering is how many lives will be saved annually by industry compliance with the amended MVSS #301, which takes effect September 1, 1975. The question can be examined in terms of the effects of compliance on the incidence of fires associated with various types of crashes.

First, with respect to frontal crashes, compliance is unlikely to affect the incidence of fires, because the amended standard does not include any new test requirements relative to frontal crashes. In this HSRI study, correlation of fuel leakage with impact speed (Figure 16) indicates that at impact speeds of 30 m.p.h., less than 1 percent of the crashed vehicles leaked fuel.

Second, with respect to side-impact crashes, based on the same analysis, less than 3 percent of vehicles crashed at 20 m.p.h. leaked fuel.

Third, with respect to rear-impact crashes, again based on the same analysis, approximately 30 percent of vehicles crashed at 30 m.p.h. leaked fuel, and 26 percent of those types of crashes resulting in fuel leakage resulted in fire. This is obviously the type of crash that will be most affected by compliance with MVSS #301.

An estimate of the number of fire-accompanied fatalities that might be eliminated through compliance with MVSS #301 can be made by using the distribution of Texas accidents by frontal, side, and rear impacts, as analyzed through application of the CPIR findings (Figures 8, 9, 10). The estimate is based on the following assumptions:

(1) That all fatalities in accidents accompanied by fire occur in the same distribution as accidents with fire;

(2) That there will be no change in the number of fatalities in frontal accidents accompanied by fire;

(3) That all fatalities resulting from fire in side impacts in moderate crashes, and one-half the number of fatalities resulting from fire in side impacts in severe crashes, are eliminated in vehicles complying with the MVSS #301 specifications for rear impacts.

(4) That all fatalities resulting from fire in rear impacts in moderate crashes, and one-half the fatalities resulting from fire in rear impacts in severe crashes, are eliminated in vehicles complying with the MVSS #301 specifications of rear impacts.

(5) That fatalities from fire in rollover accidents are included in the frontal, side, and rear accident classifications (since, in rollover accidents, the vehicle is impacted in these areas).

Based on the above assumptions, which are liberal in estimating the effects of compliance with MVSS #301, approximately 40 percent of the fatalities which now result from fire in accidents might be eliminated (in a vehicle population in which all vehicles comply with the MVSS #301). This means that of the estimated 450 to 650 fatalities per year resulting from fire in accidents, 180 to 260 of those fatalities might be eliminated. Of course, the full realization of this benefit would still be years away. If new vehicles complying with MVSS #301 are introduced into the total vehicle population at the rate of 10 percent per year (i.e., 10 million new cars in a vehicle population of 100 million cars), this reduction in fire fatalities might be achieved by 1984. The dollar cost to industry and auto buyers for compliance has evidently not yet been fully computed, nor have cost-benefit comparisons that would match compliance with MVSS #301 against other life-saving vehicle improvements. Reliable figures for use in such comparative cost-benefit estimates can be produced, but probably only through close cooperation of the NHTSA and the auto industry.

5.5 Recommendations

As evidenced by the limited and diverse data sources employed in this HSRI research study, no single body of data exists with which to accurately assess the national problem of fires in motor vehicle accidents. Neither police organizations nor such agencies as state fire marshal divisions generate adequate records.

Much research has produced a better understanding of the mechanisms and effects of fires in such areas as fuel ignition, materials flammability, vehicle fuel system design, and occupant entrapment. However, progress in these areas has permitted only narrow portions of the problem to be accurately dimensioned and evaluated. Here actual tests can be defined and conducted with considerable precision. Models can often be constructed and observed as conditions are varied. However, such is not the case with data concerning the frequency and severity of various accident types, and the frequency and severity of injuries sustained by vehicle occupants in accidents in which fire occurs.

The National Commission on Fire Prevention and Control, which consisted of a select group of nationally known and concerned legislators and specialists in the field of fire prevention, studied the national problem of fire for almost two years. In their report, America Burns, they recommended that a comprehensive national fire data system be developed which could help to establish priorities for research and action. This author agrees with that recommendation and further recommends that such a system be designed to ensure that the data collected accurately represent the national accident population in areas of motor vehicle accidents. He also recommends that data of sufficient detail and accuracy be collected to permit statistically valid studies into the causes and effects of fires in motor vehicle accidents.

The development of a national data base for modeling all types of motor vehicle accidents--including accidents accompanied by fire--is urgently needed. Policy decisions regarding the administration, funding, operational management, and uses of the data from such a collection system must be careful and deliberate. Whether the data system is administered and operated by a governmental agency, a national safety institution, or an institute within the research community, these policy decisions must be made so as to ensure the successful implementation of a national data collection system.

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September 23, 1974

MEMO TO: File

FROM: P. Cooley

SUBJECT: Study by Robert R. Nathan Associates on the Public Cost of Motor Vehicle Fires.

I have reviewed the study titled, "The Public Cost of of Motor Vehicle Fires in 1973: A Study in Fire Department Cost Allocation", recently completed by Robert R. Nathan Associates, Inc. and sponsored by the Insurance Institute for Highway Safety. It is an interesting study, but lacks the actual data on which the authors based their conclusions. Our knowledge of the costs to society from motor vehicle fires is presently sparse and inadequate. This study has attempted to add to that knowledge.

Omitting the survey data on which the study was based injects some doubt as to the accuracy and validity of their findings. Nevertheless, the study does provide some interesting numbers regarding costs of motor vehicle fires.

The authors considered two approaches to arrive at costs of motor vehicle fires in their study. One approach they termed "incremental", considered the added costs of motor vehicle fires to fixed costs relating to fire departments (facilities, salaries, etc.) which are primarily based on structural fire prevention. The rationale for this approach is that location and manpower requirements of fire stations are determined by structural fire insurance criteria (lower premimums) with fires other than structural fires accommodated by the system.

The "incremental" costing approach was discarded in favor of a "fully distributed" costing approach, since the former tends to discount the "multiple societal benefits" generated by fire department operations. The distributed approach, which was employed in the study, attempts to apportion both fixed and variable costs across the spectrum of fire services provided. Thus in considering motor vehicle fires and related incidents, man-hours expended in regard to such fires and related incidents was established as the key variable. The percentage of such man-hours, to man-hours expended for all fires, was given as 11.48%. The 11.4% was obtained from a survey titled <u>1973 National Survey of Motor Vehicle Fires</u>. I've, unsuccessfully, attempted to obtain a copy of this companion survey, which served as the basis for the numbers in this study.* This 11.4% was used in estimating costs of emergency service time associated with motor vehicle fires. Costs of fire suppression for this category in 1973 was given as $7.7 million. However, it was also used to similarly apportion overhead costs for fire suppression of motor vehicle fires and related incidents. This was given as $271 million, the single largest cost item attributable to motor vehicle fires and related incidents. Using this approach, the authors concluded that such services cost $348.8 million for 1973, or 11% of the $3.2 billion estimated for all 1973 fire department expenditures.

Cost categories other than fire suppression had their costs apportioned to motor vehicle fires and related incidents as follows:

Administration, Communications, and Maintenance	14%	$37M
Fire Prevention	1%	$1.2M
Training	1.4%	$0.7M
Heavy Apparatus Depreciation		
Paid & Mixed FDs	17.8%	$6.2M
Volunteer FDs	9.7%	$3.9M

*A telephone conversation with one of the authors brought out the intention of the authors to release the results of this study in the January, 1975 Fire Journal. A request was made for a pre-publication copy of their article.

Various formulas were employed in arriving at these costs. Training for example did include special problems posed by truck transportation of hazardous cargos. Heavy apparatus depreciation was based on the frequency of equipment responses to motor vehicle fires and related incidents. For this, the authors used an allocation of 33% of 1973 engine depreciation ($6.1M) and 1.5% of 1973 ladder truck depreciation ($0.12M). How the frequency of response of such equipment to motor vehicle fires (and related incidents) was determined was not explained, nor was any data presented. Presumably the back-up for these figures in contained in the 1973 survey which was not included in the study report.

Some comments on methods and findings in the study are given here.

(1) The study stated that more fire department responses (fire runs) are made to "incidents in which there was a threat of vehicle fire" than to actual motor vehicle fires, but then proceeded to consider only motor vehicle fires combined with such fire-related incidents. Yet, the title of the study implies that it specifically dealt with motor vehicle fires. The "related incidents" actually includes any and all reasons for a fire department response to a motor vehicle accident. These could include fuel or other leaked fluid "washdowns", debris clean-up, first-aid, occupant extrication, routine stand-by in case of fire, precautionary response where hazardous cargos may be involved, traffic assistance at an emergency scene, and even aerial photography from a ladder truck.

(2) The entire study was based on 1973 fire experience. Total U.S. building fires and motor vehicle fires are compiled yearly by the National Fire Protection Association, but only through 1972. An estimate was made for 1973 by the authors as an extrapolation of the increase of such fires (by NFPA estimates) from 1971 to 1972. My experience with NFPA data is that it lacks the accuracy to make reliable estimates of motor vehicle fires.

(3) The estimated expenditure by volunteer fire departments allocated to motor vehicle fires and related incidents is of particular interest. This was given as 11.1% of all volunteer fire department costs (including administration, prevention, training, etc.) and 9.7% of heavy apparatus depreciation. This 11.1% compares closely with the 11.44% apportionment given to fully paid and mixed fire departments for fire suppression. It is difficult to see how they could compare so closely. Paid fire departments are representative of cities and urban areas, while volunteer fire departments tend to represent rural and sparsely populated areas. In Ann Arbor for example, a fire department response is almost always made to an accident of moderate or greater severity. This is usually to stand-by in case a fire may occur, or to wash down spilled fuel or other fluids leaked by accident damaged vehicles. In addition, the fire department will almost routinely dispatch its' "fire-rescue" unit to accidents where there is moderate or greater injury to vehicle occupants, to provide for occupant extrication (if needed) and/or first aid. This is hardly the case with the more rural oriented volunteer fire departments which take more time to respond to emergencies.

(4) The method of allocating fire department costs to motor vehicle fires and related incidents was in proportion to the man-hours of firefighter's time involved in such activity. However, this same apportionment ratio was applied to all overhead man-hours. That is, costs for the time fire personnel are <u>not</u> actually providing emergency services. This single factor accounts for 78% of the total costs attributable to vehicle fires and related incidents. Since fire departments are basically located, equipped and staffed for responding to structual fires, with lower fire insurance premiums as a guide to such planning, it seems that the allocation for such a substantial portion of the cost of overhead to vehicle fires and related incidents would tend to be inequitable.

While the comments above are critical of the study, what is most significant is the omission of data on which the findings in the study were based. Without these data, the costs presented in the report cannot be evaluated. Failure to release these supportive back-up data at a time when the study is most "newsworthy" does create a suspicion as to the credibility of the entire study.

PC:plw