



Inter Office

Environmental and  
Safety Engineering

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FATALITIES ASSOCIATED WITH CRASH  
INDUCED FUEL LEAKAGE AND FIRES

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PURPOSE AND BACKGROUND

The NHTSA has issued Notice 2 of Docket 70-20 and Notice 1 of Docket 73-20, both regarding fuel system integrity. In this study, information has been developed concerning two of the issues raised in the Notices: the frequency of fire-related fatalities and the distribution and likelihood of fuel spillage by impact direction and type.

CONCLUSION

The NHTSA estimate of 2000 to 3500 fatalities yearly in fire-involved motor vehicle crashes appears to overstate the seriousness of the fire problem. Examination of in-depth accident data sources indicates that most fatalities in fire-accompanied crashes die from injuries not associated with the fire itself. Thus the National Safety Council estimate of 600 to 700 fire deaths each year is probably more appropriate than the higher NHTSA figure.

The actual number of fuel leakage incidents is relatively evenly distributed into four basic crash types: frontal, side, rear, and rollover. However, the likelihood of a given crash resulting in fuel spillage is much higher for rear impacts (26 percent with spillage in the sample studied) than for other crash types, such as frontals (3.5 percent spillage).

The cost of implementing the rollover portion of the amended Standard has been calculated to be almost three times the expected benefit, even using very favorable benefit assumptions. The yearly benefits of compliance were estimated at just under \$50 million, with an associated customer cost of \$137 million. Analyses of other portions of the proposed regulation would also be expected to yield poor benefit-to-cost ratios.

## METHOD AND RESULTS

### Number of Fire Fatalities

The NHTSA states that "motor vehicle collisions accompanied by fire account for between 2000 and 3500 fatalities annually." This range is about the same as that proposed by Sliepcevich and others from the University of Oklahoma Research Institute in an NHTSA-sponsored report. (1) The National Safety Council (NSC), on the other hand, has suggested (2) a somewhat lesser number (600-700) of persons dying annually in motor-vehicle fires resulting from accidents.

One explanation for the large difference in these estimates may relate to what is actually being counted: total deaths in fire-involved motor vehicle crashes or deaths from fire in fire-involved crashes. It has been reported that, as crash severity increases, the chance of a resultant fire increases in turn. (3) Thus the set of crashes which do involve fire tends to include severe accidents which are believed to be more likely to result in fatality regardless of the occurrence of fire. It may be, therefore, that many fatalities in fire-involved crashes result from the crash forces themselves, with fire being simply a concomitant and not causal variable.

The data source available to check this proposition was the CPIR III File of in-depth accident investigations maintained by the University of Michigan Highway Safety Research Institute. This file of 3500 crash-involved vehicles. Each crash was included in the data file due to some "special-interest" feature, typically an injury in a recent-model car; thus the file essentially consists of late-model cars and light trucks (up to 10,000 lbs. GVW) in injury-producing accidents.

From this data source were selected those occupants who were fatally injured in vehicles which sustained crash-induced fires. The 24 such occupants who were found comprise about seven percent of the total of 358 fatalities in the data sample. Extending this percentage to the nationwide total of some 40,000 occupant fatalities yields an estimate of 2800 deaths in motor vehicle accidents in which a fire took place, a number in agreement with the NHTSA and Oklahoma estimate.

The complete crash history on file for each of the 24 supposed fire fatalities was examined in detail to ascertain the actual circumstances surrounding the death, and the findings are outlined in Table 1. In over half of the instances the deceased was not burned at all, and death can be attributed only to the impact injuries. In these instances the occupant was typically ejected or extracted prior to spread of the fire. In one-fourth of the fatalities, fatal injuries were attributed to both impact and burns. These occupants most likely would have died even had there been no fire -- in fact, the fire may well have burned an already-dead body. For only five of the 24 fatalities examined was fire reasonably classifiable as the clear cause of the death. Brief synopses of the crashes from which each of the 24 deaths resulted are attached in the Appendix.

Table 1

FATALLY-INJURED OCCUPANTS OF BURNED VEHICLES

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DEATH DUE TO IMPACT INJURIES NO ACCOMPANYING BURNS	WITH FATAL LEVEL IMPACT INJURIES WITH ACCOMPANYING BODY BURNS	DEATH DUE TO BURNS ONLY
<u>13</u>	<u>6</u>	<u>5</u>

The efficacy of the proposed fuel integrity regulation was examined for the five incidents in which occupants were burned to death. In three of the cases (AA-00143, ML-70003, SU-00041) a gross separation or rupture of the fuel system was reported. One of the cases (TR-01212), involving an improperly replaced gas tank was really not crash-related. The fifth fatality (AA-00155) was not fuel related at all, but involved a major post-crash passenger compartment fire. Thus, in the total data file concerning more than 5700 occupants, no burn deaths were reasonably attributable to fuel-fed fires except when accompanied by massive fuel tank or filler neck failure.

Results from this rather small sample of fatalities taken from a specialized data source perhaps cannot be considered definitive, in terms of predicting exact numbers. The analysis does indicate, however, that the NSC estimate of 600 to 700 yearly motor vehicle fire fatalities is certainly within reason. In addition, the detailed evaluation shows that, while the higher NHTSA estimate of deaths in cars with fire may be correct, most of these occupants in fact sustain fatal injuries not at all related to the associated fire.

The results discussed here refer to the types of vehicles in service at the present time. In future cars, with improved ejection-prevention and injury-mitigation properties, fewer occupants may sustain impact-induced fatal injuries. This would brighten the overall fatality and injury picture, of course, but might increase occupant exposure to situations in which fire would be the only hazard. On the other hand, occupants sustaining lesser injuries might be better able to cope with and escape from fire impacts which do occur, thereby reducing the risk of serious burns. Thus the influence vehicle improvements will have on the relative risk associated with fire is not clear, and cannot be practicably quantified with the limited data available.

Fuel Spillage

An NHTSA-sponsored study (4) conducted by Brayman at Calspan, Inc. contains data concerning fuel leakage for different impact directions. The source for these data was the Automotive Crash Injury Research (ACIR) accident file maintained by Calspan. The ACIR data con-

cern rural, injury-producing accidents.. Accident cases analyzed by Calspan between June 1968 and May 1969 were used by Brayman as the data sample for his study.

Table 2 shows some information developed from the Brayman study. It indicates that fuel leaks themselves are relatively evenly split among four basic crash types: frontal, side (mostly to rear half of car), rear and rollover. Thus no particular crash type is especially outstanding with regard to its contribution to any fuel spillage problem.

Certain crash types have a much greater likelihood of producing fuel spillage, however. Among 933 frontal impacts in the sample, 33, or 3.5 percent, resulted in fuel spillage. In contrast, over one-fourth of all rear impacts produced fuel leakage. Other crash types had intermediate likelihoods of leaking fuel. Thus it is clear that different crash types have widely varying propensities for resulting in fuel leaks.

It is noteworthy that, while seven percent of the cars in the Brayman (4) sample developed fuel leaks, fires (both fuel-fed and otherwise) were reported for .5 percent of the cars in this ACIR data file (3). Thus it appears as though less than seven percent of cars which develop fuel leaks subsequently burn.

#### COST/BENEFIT ANALYSIS OF STATIC ROLLOVER REQUIREMENT

The analysis discussed below concerns the static rollover requirement proposed for FMVSS 301. This discussion represents an attempt to outline an approach which can be used to address this and similar problems. While the benefit analysis is not meant to be definitive and beyond criticism, it is based on assumptions and derivations believed to be quite representative of an upper bound on the possible benefits accruing from compliance with the requirement.

Table 3 outlines the pertinent benefit and cost. The relevant benefits are those associated with the consequences of reduction in the frequency of fires in rollovers, while the presented costs relate to the incremental cost associated with meeting the specific static rollover aspects of the Standard.

#### Benefits

The appropriateness of the estimate of 700 burn deaths each year resulting from motor vehicle crashes has been discussed in the main text of this study. Data from both the Calspan fire study (3) and the Oklahoma analysis (1) of a New York State fire study (5) suggest that when occupants are burned, the injuries tend to be quite serious, and about half of the casualties sustain fatal injuries. Thus the 700 fatalities should be complemented by another 700 non-fatally (though seriously) injured occupants. Given the NSC estimate (2) of 10,000 yearly crash induced vehicle fires, about 8,500 of these fire crashes occur with no resultant occupant burns each year. Benefits from FMVSS 301 compliance based on these numbers represent an overestimate, since some undetermined number of these instances relate to large trucks not covered by the proposed Standard.

Table 2

DISTRIBUTION AND LIKELIHOOD BY IMPACT TYPE  
OF IMPACT-INDUCED FUEL SPILLAGE FOR  
PASSENGER CARS IN RURAL INJURY-PRODUCING ACCIDENTS

<u>IMPACT DIRECTION</u>	<u>NUMBER OF FUEL LEAKS</u>	<u>PERCENT OF FUEL LEAKS</u>	<u>LIKELIHOOD OF FUEL LEAK</u>
FRONT	33	25.8	33/933 = 3.5%
SIDE, FRONT HALF OF CAR	8	6.2	8/169 = 4.7%
SIDE, REAR HALF OF CAR	23	18.0	23/160 = 14.8%
REAR	37	28.9	37/140 = 26.4%
ROLLOVER	27	21.1	27/333 = 8.1%
<u>TOTAL</u>	128	100.0	128/1735 = 7.3%

SOURCE: CALSPAN REPORT NO. VJ-2839-K, DATED APRIL, 1970.

Note: Accident cases in this file are significantly biased toward high severity collisions; they are all rural, and to qualify for filing, an injury had to occur. But injuries are not nearly so frequent in rear-end crashes, in general. As a result, the proportion of fuel leaks in rear-end crashes reported here, 29%, cannot be the nationwide average. Rather, in 29% of rural rear-end collisions sufficiently severe to cause an injury, fuel leaks occur.

The proportion of fuel leaks which occur in rollovers is indicated in Table 2 to be slightly less than one-fourth\*. If this proportion is applied to the fire numbers themselves, the consequences of fire in rollovers can be estimated as 180 deaths, 180 non-fatal injuries, and 2100 other fire crashes. These values are predicated upon two postulations: rollover fuel leaks result in fire just as often as other fuel leaks, and rollover fires are just as likely to result in burns as other fires.

Table 3

BENEFITS AND COSTS RELATING TO FUEL LEAKAGE ASSOCIATED WITH THE STATIC ROLLOVER TEST PORTION OF FMVSS 208

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BENEFITS:

Savings - 180 burn deaths, 180 serious burn injuries, 2100 burned vehicles.

Unit Cost - \$200,000 per death, \$67,000 per injury, \$700 per vehicle.

Total Benefit -  $180 \times (\$200,000) + 180 \times (\$67,000) + 2100 \times (\$700) = \underline{\$49.5 \text{ million}}$ .

COSTS:

Sales - 11 million cars, 1.5 million light trucks.

Unit Cost - \$11 per car, \$11 per truck.

Total Cost -  $11,000,000 \times (\$11) + 1,500,000 \times (\$11) = \underline{\$137 \text{ million}}$ .

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This analysis assumes that all these fires and the resultant casualties can be eliminated entirely through compliance with the rollover requirement. In addition, it is assumed that vehicle modifications designed to ensure compliance with non-rollover portions of the Standard will not reduce at all the number of rollover fires. The extent to which either of these assumptions is not completely accurate represents a measure of the extent to which benefits derived here are overestimates of the true values.

To compare the benefits of eliminating the consequences of these rollover fires with the requisite costs, the benefits and costs must be expressed in terms of some common measure. The measure typically chosen is dollars; this requires, then, converting the casualty losses to this metric. The casualty to dollars conversion factors used in this study were the societal cost values prepared by the NHTSA (6). These values are generally higher than similarly-defined costs from other sources, and their use does not signify that Ford accepts or concurs in the values. Rather, the NHTSA figures are used only to be consistent with the attempt not to understate the relevant benefits.

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\* That is, the 21.1% associated with rollovers from Table 2. In this and subsequent calculations, figures have been rounded upward. In that way, not only are the statistical assumptions in a conservative direction, but also the arithmetic.

The NHTSA has calculated a value of \$200,000 for each fatality. While the major portion of this amount relates to lost future wages, the total also includes some consideration for property damage. The NHTSA average loss for all injuries was about \$7000. Burn injuries which do occur tend to be quite serious, however, as discussed above. Thus a higher value of \$67,000, which is the NHTSA estimate of partial disability injuries, was used for each of the 180 non-fatal burn injuries. The \$700 property damage per vehicle is the NHTSA estimate of vehicle property damage costs in non-disabling injury crashes.

#### Costs

The Retail Price Equivalent (the customer sticker price with no provision for Ford profit) of vehicle modifications necessary to assure compliance with the static rollover portion of the proposed Standard has been determined by Ford to be an average of \$11 per passenger car and \$11 per light truck. While these are Ford costs, they have been applied across the industry in this analysis. Total yearly sales estimates of 11 million passenger cars and 1.5 million light trucks (under 6,000 lbs GVW) were used in conjunction with the unit cost determinations.

#### Benefit and Cost Comparison

The total benefit is shown in Table 3 to be just under \$50 million, while the associated cost is \$137 million. Thus the cost is almost three times the benefits, even using a number of highly favorable benefit assumptions. As better estimates of the parameters used in the benefit analysis become available, they could be inserted into the general analysis framework. It does not appear likely, however, that such alternate estimates could lead to the substantial benefit estimate increase which would be required to make compliance with the rollover requirement cost effective.

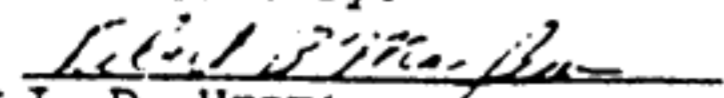
#### Benefits and Costs For Other Impact Modes

The analysis discussed above concerns only rollover consequences and costs. Similar analysis for other impact modes would be expected to yield comparable results, with the implementation costs far outweighing the expected benefits.

  
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REFERENCES

1. Sliepcevich, C. M., et al, Escape Worthiness of Vehicles and Occupant Survival, University of Oklahoma Research Institute, NHTSA Contract No. FH-11-7303, PB 198 772, December 1970.
2. National Safety Council, Accident Facts, 1968 Edition.
3. Robinson, S. J., Observation On Fire In Automobile Accidents, CAL Report No. VJ-1823-R14, February 1965.
4. Brayman, A. F., Impact Intrusion Characteristics of Fuel Systems CAL Report No. VJ-2839-K, NHTSA Contract No. FH-11-7309, April 1970.
5. Moore, J. O., and Negri, D. B., Fire In Automobile Accidents, New York State Department of Motor Vehicles, Research Report 1969-2, October 1969.
6. National Highway Traffic Safety Administration, Societal Costs of Motor Vehicle Accidents, Preliminary Report, April 1972.