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REVIEW OF FOUR FEDERAL MOTOR VEHICLE SAFETY STANDARDS: FMVSS 214, 215, 301, 208

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16. Abstract

This report covers the initial review of FMVSS 214 (Side Door Strength), FMVSS 215 (Exterior Protection), FMVSS 301 (Fuel System Integrity), and FMVSS 208 (Occupant Crash Protection). This work is the first task of the study of *Evaluation Methodology for Four Federal Motor Vehicle Safety Standards*. The review covers the objectives, requirements and timing of the four Standards. Also reviewed is the applicability of test conditions to real conditions; the relationship of the performance measures of the Standards to ultimate injury reduction; initial estimates of the effect of the Standard; and the extent and alternative methods of meeting the Standard.

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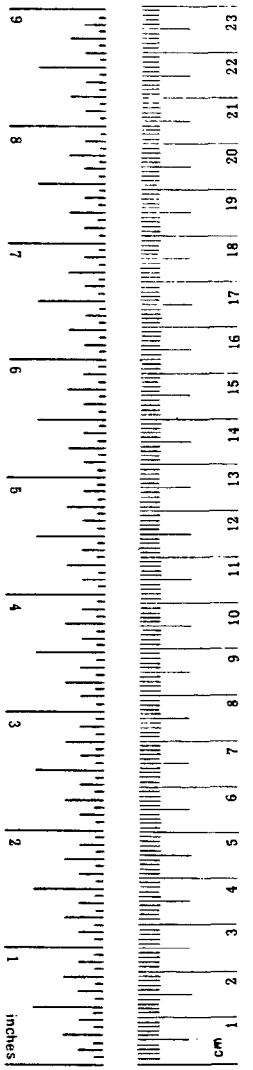
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

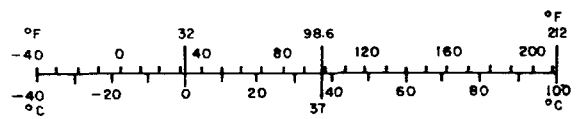
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

1.1 Background

The purpose of this study is to develop an *Evaluation Methodology for Four Federal Motor Vehicle Safety Standards*, to develop methods to estimate the effectiveness of these Standards, and to develop plans to implement these methods. The four selected Standards are:

- FMVSS 214 - Side Door Strength
- FMVSS 215 - Exterior Protection
- FMVSS 301 - Fuel System Integrity
- FMVSS 208 - Occupant Protection.

This report presents the results of Task 1 of the study--Review of the Four Selected Federal Motor Vehicle Safety Standards. The review covered the following aspects:

- The objectives of the Standard and the physical performance requirements set by the Standard.
- The crash situations and conditions under which each Standard will have (or not have) effects (both prescribed and unintentional).
- Relations between the performance measures used in a Standard's requirements, and the ultimate objective of reducing injury, death and other crash losses, where applicable.
- Initial estimates of the expected effects of the Standard, as a basis for planning statistical approaches.
- The extent to which certain existing vehicles may have satisfied a Standard prior to effective date, and what vehicles were exempted.
- Alternative methods which have been used or suggested for meeting the Standard.

In addition, our work considered the possibility that Standards have undesirable direct or indirect effects, in addition to the intended effect. For example, stronger bumpers may increase damage to other cars in angle collisions.

The information about the Standards was obtained from the annual issues of the *Code of Federal Regulations*, the *Federal Register*, and the current issue of the *Federal Motor Vehicle Safety Standards and Regulations*. Other sources were used to determine when features satisfying a Standard were introduced before they were required by the Standard, and to determine current estimates of the effects of the Standards.

This study deals primarily with passenger cars. The applicability of Standards to other vehicles will only incidentally be mentioned.

1.2 Structure of the Report

This report is divided into five sections, the introductory section and a section on each of the selected Standards. The section on each Standard will address the six points mentioned above (objectives, applicability, crash conditions, etc.). The material is presented in tabular form based on the periods during which the Standard is in effect. However, text is supplied where that format is too cumbersome, or other material is illuminating. In Section 5 on FMVSS 208 - Occupant Protection, there are three parts because the present Standard provides three options under which the Standard might be satisfied. The options are discussed in reverse order (Option 3, Option 2, Option 1) because the installation and usage follows that order. Currently, Option 3 is the lap and shoulder belt protection system with belt warning; Option 2 is the lap belt protection system with belt warning and assumes some passive system; and Option 1 is the completely passive protection system meeting the highest crash and injury criteria.

2.0 FMVSS 214 - SIDE DOOR STRENGTH

Summary

This Standard did not become effective until 1 January 1973; however, many models had side door guard beams added before then. Original estimates of the effects of the Standard are based on the observed correlations between door intrusion and occupant injury. Other studies have pointed out the potential negative effects (especially in light cars) of increased door strength and stiffness on occupant acceleration forces. Added benefits from the Standard seem to be increased axial strength which keeps doors operable in a greater frequency of crashes.

FMVSS 214 has not been changed or modified since it first became applicable; the majority of the relevant material is presented in Table 2-1. FMVSS 214 only applies to passenger cars.

TABLE 2-1

FMVSS 214 - SIDE DOOR STRENGTH

Item	Description
Effective Date	January 1, 1973
Purpose of Standard	• Specific purpose is to set strength requirements for side doors. • General purpose is to minimize the safety hazard caused by intrusion into the passenger compartment in a side impact accident.
General Requirements of Standard	Any side door that can be used for occupant egress must meet three crush resistance tests: • Initial Crush Resistance of not less than 2,250 lbs. • Intermediate Crush Resistance of not less than 3,500 lbs. • Peak Crush Resistance of not less than 7,000 lbs. or two times the curb weight of the vehicle, whichever is less.
Applicable Crash Situations	The test conditions simulate the following real crash situations: • Two car front-side collisions involving a door, especially where the striking vehicle is not at a 90° angle. • Single car oblique collisions with poles, abutments, trees and other fixed "pointed" objects. Increasing side door strength may also increase the axial, longitudinal strength of a car. Thus, the Standard may also improve compartment integrity in severe frontal collisions.

TABLE 2-1 (concluded)

Item	Description
Inapplicable Crash Situations	The test conditions do not exactly simulate actual pole or abutment crashes because the loading device does not impact the roof line or the sill beneath the door, and it has rounded edges at top and bottom to prevent stress concentration. Seats are also removed, which reduces the realism of the test. No effect is expected in angle collisions in which the front or rear quarter panels are damaged. No effect is expected in frontal or rear impacts except possibly in extremely severe cases, in which the side beam would lessen door buckling.
Relation of Test Requirements and Injury Reduction	The test criteria are based on the assumption of a causal relationship between passenger compartment intrusion and passenger injury (Cornell Aeronautical Laboratory, Inc., *Automobile Side Impacts and Related Injuries*, Dec. 1969, [2] and others.) The action based on that assumption is correct if: (1) the hypothesis is correct, and (2) all other (crash) factors remain the same. However, preliminary calculations indicate that in light weight vehicles the stiffening of side doors increases the acceleration forces on the vehicle occupants. The Standard may also have a beneficial effect because the stiffened doors will likely absorb more energy than earlier doors.
Alternative Compliance Methods	Presently, passenger cars satisfy this Standard by adding side door beams to the door construction. Variously fabricated beams have been used or proposed--channel beams, roll formed, special high strength low weight configuration, etc.
Extent of Compliance	FMVSS 214 has been in effect for all passenger cars since January 1, 1973. However, starting in 1969, certain models had side beams or other strengthening of side doors. (Therefore, any analysis of this Standard must segregate events by this factor.)
Exemptions	See Appendix A on Temporary Exemptions.
Prior Compliance	Information we have received from the manufacturers as to when side beams were introduced, by make and model, is presented in Table 2-2 below. We do not have information on foreign manufacturers. Recent conversations with GM technical personnel revealed that the pre-side beam Nova almost met the Standard criteria.

INTRODUCTION DATES OF SIDE DOOR REINFORCEMENT BEAMS

Make	Line	Series	Model Year
AMC	Javelin	SST	1971
		Basic	1971
		AMX	1971
GM			
Buick	Buick	Electra	1969
		La Sabre	1969
		Riviera	1971
	Special/Skylark	Skylark	1970
		GS	1970
Cadillac	Cadillac	Calais	1969
		De Ville	1969
		El Dorado	1971
		Fleetwood El Dorado	1971
		Fleetwood Brougham	1969
		Fleetwood Seventy-five	1969
		Fleetwood Sixty Special	1969
Chevrolet	Chevelle	Concours	1970
		Malibu	1970
		Nomad	1970
		Greenbriar	1970
	Chevrolet	Bel Air	1969
		Biscayne	1969
		Caprice	1969
		Kingswood	1969
	Monte Carlo	Monte Carlo	1970
	Vega	Vega	1971
Oldsmobile	F-85/Cutlass	F-85	1970
	Oldsmobile	Delta 88	1969
		98	1969
	Toronado	Toronado	1971
Pontiac	Firebird	Firebird	1970
		Esprit	1970
		Formula	1970
		Trans-Am	1970
	Pontiac	Bonneville	1969
		Catalina	1969
		Executive	1969
		Grand Prix	1969
	Tempest/LeMans	Le Mans	1970
CHRYLSER			
Dodge	Challenger	Challenger	1970
		Challenger RT	1971
FORD			
Ford	Fairline/Torino	Gran Torino	1972
	Ford	Custom	1971
		Galaxie	1971
		LTD Brougham	1971
	Mustang	Mustang	1971
		Grande	1971
	Pinto	Pinto	1971
	Thunderbird	Thunderbird	1972
Lincoln	Lincoln	Continental	1971
		Continental Mark III & IV	1971
Mercury	Cougar	Cougar	1971
		Cougar XR 7	1971
	Mercury	Marquis	1971
		Marquis Brougham	1971
		Monterey	1971
	Montego	Montego	1972
		Montego MX, Brougham, & GT	1972

Current estimates of the Standard's effects on injury frequency. No thorough analysis of the effects of the Standard on injury frequency or severity appear to exist. Attempts to estimate the effectiveness are based on very limited data, and are usually based on analysis of frequency of events, rather than on planned statistical sampling and analysis.

Griffin [3] finds that in North Carolina accidents, driver injury (fatal or serious) frequency in standard size Chevrolets with damage to the left side of the passenger compartment in 1969-1971 models (with side beams) is 35% lower than in 1967-1968 models (without side beams), and 40% lower if cars with any left side damage are considered. The results reported by McLean [6] show no consistent pattern when cars are classified by size: changes range from a complete elimination of fatal or serious injuries to an increase by 76%! In the North Carolina data sample, more drivers used seat belts in cars with side beams than in cars without side beams,* which may affect the comparison. Restricting the analysis to unbelted drivers, McLean found reductions in fatal or serious injuries of 30% and 52% in standard and intermediate size cars, respectively.**

Preston and Shortridge [8] analyzed data from Denver, the MDAI, and Texas. The Denver data covered only accidents in which injury occurred; for drivers and right front passengers, they show side beam related reductions of 20% and 43%, respectively, in the frequency of fatal or serious injuries. More sophisticated analyses of the MDAI and Texas data did not show a consistent effect.

CEM attempted to estimate the effects of side beams from Texas accident data. Due to an error in instructions for decoding the data, the results were not meaningful.

Thus, no good estimates of the effects of side door beams on injuries were discovered.

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*Increased seat belt usage likely stems from improvements in belts; it does not appear to be correlated with side beam installation.

**Some of the reduction in frequency of fatal or serious injury is likely due to reduction of car occupant ejection, due to improved hinges and door latches.

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3.0 FMVSS 215 - EXTERIOR PROTECTION (FRONT AND REAR BUMPERS)

Summary

This Standard for front and rear bumpers has changed considerably since it first became effective on 1 September 1972. The increased crash test requirements were difficult to perform and there were numerous modifications and exemptions, especially to specialty cars (sports, vintage, etc.). Corner impact test criteria were delayed until the 1977 model year, for cars with more than 120 inch wheelbase. Smaller cars met these criteria with 1976 models. Under Title I of the Motor Vehicle Information and Cost Savings Act, a new Bumper Standard (Part 581 of Title 49) was issued in March 1976. This new Standard extends the damageability limits. Until 1 September 1978, manufacturers can comply under FMVSS 215 or Part 581; however, after that time, Part 581 is mandatory.

FMVSS 215 is a relatively straightforward Standard for front and rear bumpers, which has been significantly modified and revised because of the complexity of vehicle design and testing and non-safety related requirements for vehicle damageability. In the original 1971 version, the Standard required two levels of compliance, one effective 1 September 1972, and the second effective 1 September 1973. Unique problems involving the corner impact test (effective 30 September 1975) developed, requiring manufacturers to seek modifications of the Standard. During the same period, Title I of the Motor Vehicle Information and Cost Savings Act authorized the development of damageability Standards for bumpers (Part 581 of Title 49 of the Code of Federal Regulations). On 27 February, 1976, a new Bumper Standard (Part 581) was added, and FMVSS 215 was revoked effective 1 September 1978. FMVSS 215 emphasized damage to safety-related systems, while Part 581 includes any damage. Table 3-1 below describes the initial format of FMVSS 215 and Table 3-2 describes the new Bumper Standard (Part 581).

TABLE 3-1

FMVSS 215 - EXTERIOR PROTECTION

Item	Description	
Effective Date	September 1, 1972	September 1, 1973
Purpose of Standard	• Specific purpose: to establish requirements for impact resistance and the configuration of front and rear bumpers. • General purpose: - Prevent low-speed accidents from impairing safe operation. - Reduce the frequency of override or underride in higher speed collisions.	
General Requirements of Standard	Vehicle can impact fixed barrier at 5 mph forward or 2.5 mph in reverse and suffer limited damage, such as: - Lamps and reflectors remain unbroken. - Hood, trunk and doors remain operable. - Fuel, cooling and exhaust systems have no leaks or other damage.	Vehicle can be impacted by a pendulum-like test device followed by impacts into a fixed barrier at 5 mph in both directions,and suffer limited damage, such as: - Same items for earlier test. - Propulsion,suspension,steering, and braking systems remain in normal operati condition. - Other parts of the vehicle not impacted in the test.
(Modifications)		Until Oct.31, 1974, there was an exemption from the pendulum test for vehicles that have less than 115 in. wheelbase, or a convertible top, or no roof support between A-pillar and rear support, or no rear seating positions. Vehicles manufactured after Aug. 31,1975 were to have a corner impact test. However,vehicles or more than 120 inch wheelbase were exempted for an additional year.
Applicable Crash Situations	The test criterion reasonably simulate the following real crash situations: • Low speed, full front or full rear collisions with other bumper-like surfaces. (The pendulum test and also the corner impact test have broadened the realism.)	

TABLE 3-1 (continued)

Item	Description
Inapplicable Crash Situations	• To the extent that the rear crash is not full front or full rear, the tests are not applicable. • Until the corner impact test went into effect, corner hits did not apply. • Crashes at higher speeds than specified in the Standard are inapplicable. • A portion of collisions into the side of other vehicles may be inapplicable, due to crash conditions.
Relation of Test Requirements and Injury Reduction	The Standard requirements imply two hypotheses: (1) Impairments of safe operation of vehicle systems caused by low speed accidents will increase the probability of subsequent accidents and consequent injuries. (2) The incidence of bumper underride/override causes damage to safety-related vehicle systems needed to operate the vehicle. This may delay clearing the scene of an accident, and may thereby result in subsequent accidents. In the first case, to show that meeting the test criteria led to fewer subsequent injury accidents, one would have to conduct a detailed and extensive accident investigation. One would have to test more narrowly defined hypotheses such as whether a lamp failure, a latch failure, etc. resulted in a subsequent accident with injuries. In the second case, one would have to determine simply how many accidents occurred as a consequence of prior low speed accidents, where a vehicle is disabled.
(Secondary Effects)	The means used to comply with the Standard may have undesirable secondary effects due to the rigid, obtrusive bumpers. These bumpers may inflict more damage to other vehicles. And in the kinematics of pedestrian accidents they may act as a hinge point, flipping the person onto the hood.
Alternative Compliance Method	The basic principle used in meeting this Standard is energy adsorption. Various torsional systems, mechanical systems, or energy absorbing materials have been used: springs, pneumatic shock absorbers, plastic foams,etc. The major manufacturers have primarily used the following methods: Chrysler - rubber blocks; Ford - shear blocks; GM - hydraulic/air shocks. In order to limit damage to safety systems, soft noses and cushioned bumper surfaces have been used.

TABLE 3-1 (concluded)

Item	Description
Extent of Compliance	FMVSS 215 has been in effect for all passenger cars since September 1, 1972. Smaller vehicles with less than 115 inch wheelbase and special configuration vehicles were exempted from the Sept.1, 1973 requirements until Aug. 31, 1974. (See Gen. Rqts., above.) Some vehicles met the initial Standard without model modification. Information on prior compliance and exemptions is given below.
Exemptions	See Appendix A for Temporary Exemptions.
Prior Compliance	Crash tests conducted by IIHS show that the 1971 models met - with one trivial exception - the Standard's requirement in the 2.5 mph rear barrier crash. Even half of the tested 1969, 1970 and 1971 models met the Standard's requirements in a 5 mph rear barrier crash [1]. All six tested 1972 models met the requirement of the Standard in the 2.5 mph rear barrier crash [2].

TABLE 3-2

BUMPER STANDARD (PART 581)

Item	Description
Effective Date	September 1, 1978
Purpose of Standard	• Specific purpose: to establish requirements for impact resistance of vehicles in low speed front and rear accidents. • General purpose: to reduce the physical damage to the front and rear ends of motor vehicles. (Injury reduction is not explicitly considered.)
General Requirements of Standard	The vehicle must undergo the pendulum impact test to both front and rear bumpers and to the corners. All the damage criteria mentioned in Table 3-1 must be met plus no visible damage (paint, surfaces, etc.) (There was a delay until August 31, 1976, for the corner impact test for vehicles with a wheelbase exceeding 120 inches.)

Current Information on the Effects of FMVSS 215

The Highway Loss Data Institute [3, 4] compared losses in collision coverage of 1972 and 1973 model year cars. The claim frequency for 1973 models was consistently lower than for 1972 models: 7% for subcompact, 14% for compact, 15% for intermediate and 11% for full-size cars. When stratified by vehicle density (registered passenger cars per square mile), 1973 cars also showed consistently fewer collision claims than 1972 cars. However, average loss per claim increased by between $7 and $57, depending on car class. Of interest is the fact that increase in loss per claim is lower in the large metropolitan areas where car density is highest. For example, the average 1973 loss per claim increased only $10 in the high density areas of Brooklyn, San Francisco, Philadelphia, and Newark. But the 1973 increase in loss per claim was $60 in the low density areas of Littleton, New Hampshire; Sutton, West Virginia; Baldview, Alabama; and Inyo County, California. This suggests that the new bumpers are effective in reducing the damage in low speed collisions which are more common in densely populated areas, whereas they do not reduce damage (and possibly increase repair cost) in higher speed crashes which are more common in low density areas.

Casassa, *et al.* [5] compared the frequency distribution of impact points in 1972, 1973 and 1974 model cars. As one would expect, the frequency of front center and rear center damage decreased from 1972 to 1973, and the frequency of rear center damage decreased further between 1973 and 1974. Replacements of front and rear face bars decreased between 1972 and 1973, and replacements of rear face bars further decreased in 1974 (when replacements of front face bars went up again). Replacements of other major parts showed no pattern.

An analysis of the relation between repair cost and front barrier impact speeds comparing 1971 and 1974 cars showed that up to approximately 14 mph, 1974 cars had lower repair cost than 1971 cars. No repair cost would have been incurred in 1971 cars in impact speeds up to 0.7 mph, in 1974 cars in impact speeds up to 4.8 mph. This pattern supports the suspicions that the new bumper reduces damage in low speed collisions, but may increase it--at least in terms of repair cost--in higher speed collisions.

Another demonstration of the effects of the Standard is given in Figure 1, which is reproduced from the IIHS *Status Report,* Vol. 10, No.5, February 1975 [2].

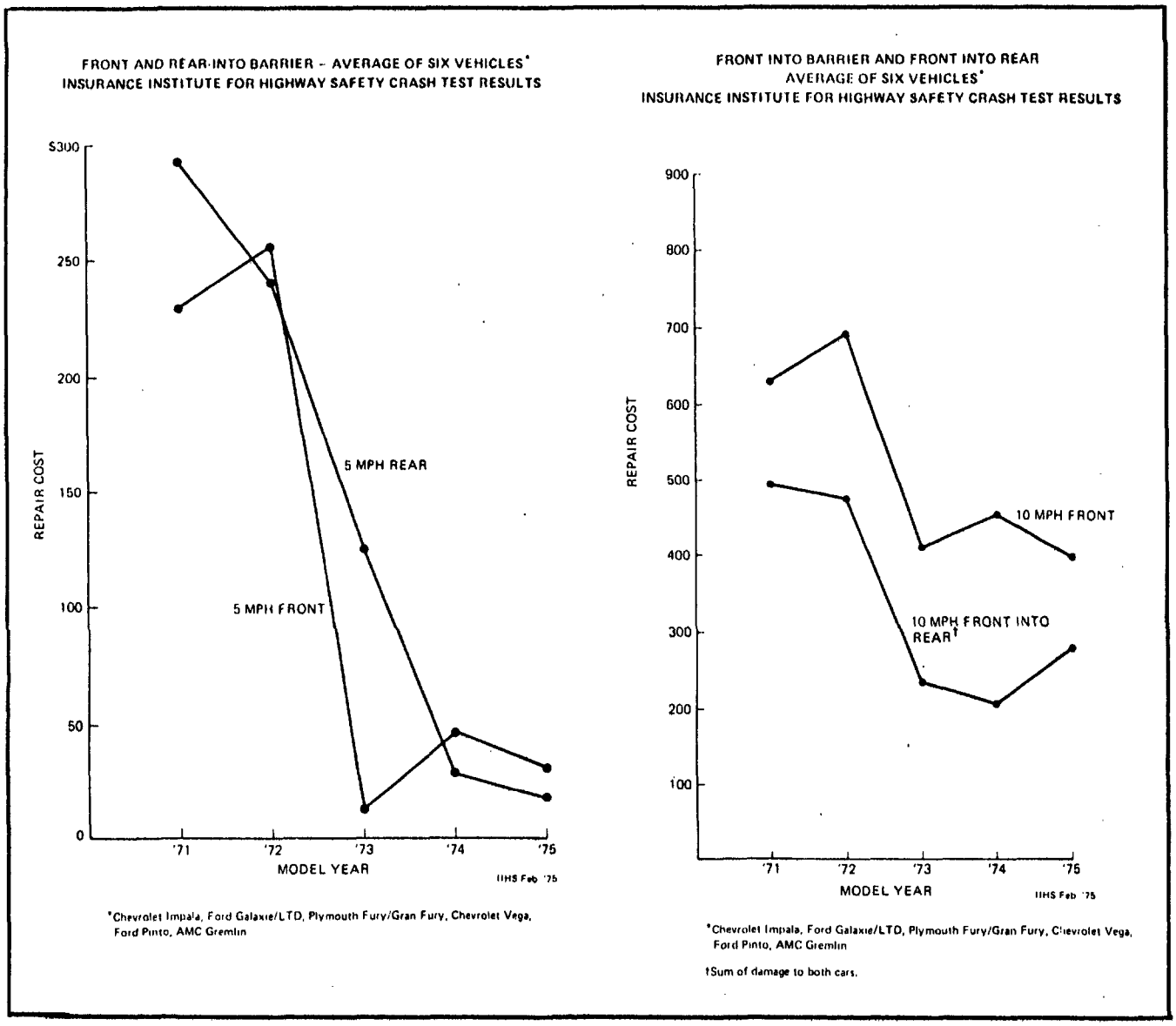

Figure 1. Effectiveness of FMVSS 215.

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4.0 FMVSS 301 - FUEL SYSTEM INTEGRITY

Summary

Since its promulgation in 1968, this Standard has been modified several times, increasing the difficulty of meeting the test criteria. A rollover test was added to the original criteria,which previously involved only a 30 mph frontal barrier crash. In the latest version of the Standard, the rollover test has been temporarily suspended and side and rear crash tests have been added. The rollover test was found to have particularly difficult criteria and certain vehicles, such as buses, have been given exemptions.

FMVSS 301 was one of the original Standards effective on 1 January 1968; (its full title: Fuel Tanks, Fuel Tank Filler Pipes, and Fuel Tank Connections - Passenger Cars). This Standard has had three major modifications since that time: 301a (subsequently 301) in August 1973; 301-75 (for 1977 and 1978 models) in March 1974; and 301 (revised) in October 1975. The material on FMVSS 301 will, therefore, be divided into two parts: Table 4-1 will discuss 301 as it was originally put into effect and the major revision it underwent in 1973. Table 4-2 will discuss 301-75 and the 1975 revision. The 1973 and later revisions brought other motor vehicles under the Standard; however, in these tables, only the passenger car implications are considered.

TABLE 4-1

FMVSS 301 - FUEL SYSTEM INTEGRITY
(1968 and 1973 Versions)

Item	Description	
Effective Date	January 1, 1968	September 1, 1975
Purpose of Standard	• Specific Purpose: to establish requirements for the integrity and security of fuel tanks, fuel tank filler pipes, and connections.	• Specific Purpose: to establish requirements for the integrity of motor vehicle fuel systems.
	• General Purpose: to minimize the fire hazard and resulting deaths and injuries due to fuel spillage in motor vehicle accidents.	

TABLE 4-1 (continued)

Item	Description	
General Requirements of Standard	After a full front crash with a fixed barrier, the vehicle's fuel tanks, pipes and connections will not leak at a rate greater than 1 ounce per minute and the impact itself will not cause a fluid loss of more than one ounce. Originally the speed of impact was "at least 30 mph." This was revised as of Sept. 1, 1970 to "velocity of 30 miles per hour."	The vehicle will not spill more than one ounce during the crash, or more than one ounce in the 15 minutes following the crash (crash is directly into a fixed barrier at up to 30 mph). The vehicle will not lose more than one ounce per minute as it rolls over in successive 90° increments under test conditions.
Applicable Crash Situations	The test criteria only simulates full front collisions into relatively flat objects at 30 mph or less.	The crash test only reduces the allowable leakage but does not make the test more realistic. The realism of the test is limited.
Inapplicable Crash Situations	The test criteria do not simulate the following realistic crash situations. • Rear end crashes. • Angle crashes. • Full speed rollovers (original standard: any rollover). Different vehicles have tanks and filler connections at a variety of places. Any impact at these vulnerable locations would be more realistic.	
Relation of Test Requirements and Injury Reduction	This Standard makes the very plausible assumptions that fuel spillage/leakage increases the fire hazard and that fires increase the hazard to the vehicle occupants and also to other drivers and vehicles. However, an empirical relation between the introduction of this Standard and the ultimate goal--injury reduction--may be difficult to establish. It has to be determined that occupants were killed by subsequent vehicle fire, rather than in the crash or as a consequence of the injuries suffered in the crash. In addition, other factors have to be considered, such as door integrity, door catches, flammability of interior materials, etc.	

TABLE 4-1 (concluded)

Item	Description
Alternative Compliance Method	The methods used for achieving the increased integrity of the fuel system are to provide for the strengthening and protection of vulnerable areas such as tanks, connectors, etc. Repositioning of tanks and connectors has been one successful response.
Extent of Compliance	FMVSS 301 (1968) may have been met by some manufacturers without modification of existing vehicle designs. The 1973 version which includes the rollover test was not to go into effect until the 1976 model year. Although this Standard was subsequently modified, some manufacturers might have satisfied this Standard before the 1976 model year.
Exemptions	See Appendix A on Temporary Exemptions.
Prior Compliance	Initial replies from letters to manufacturers indicate no compliance prior to the issuance of the Standard.

TABLE 4-2

FMVSS 301 - FUEL SYSTEM INTEGRITY
(1974 and 1975 Versions)

Item	Description	
Effective Date	September 1, 1975	September 1, 1975 and September 1, 1976
Purpose of Standard	Same as 1973 Version	
General Requirements of Standard	Requirements for passenger cars remain the same as the 1973 version except the fuel spillage after crash amount has been changed to 5 ounces in the first 5 minutes and not more than 1 ounce during any one minute period during the next 10 minutes after the crash. The loading of the test vehicle is also upgraded.	Requirements for passenger cars manufactured between Sept.1,1975 and Sept.1,1976 are exempted from meeting the rollover test criterion. The frontal barrier test criterion was modified to include angle crashes up to 30°, rear moving barrier crashes at 30 mph, and lateral moving barrier crashes at 20 mph. Other modifications in the Standard focus primarily on school buses with GVWR greater than 10,000 lbs.
Applicable Crash Situations	Same as 1973 Version	With upgrading of test criteria, the applicable crash situations increased to side and rear collisions with flat objects.
Inapplicable Crash Situations	Same as 1973 Version	With the temporary exemption of the rollover criterion, the performance of vehicles in that situation is no longer measured. Despite upgrading of flat barrier crashes, certain situations still remain, including crashes with: • Poles, abutments, and similar objects. • Other vehicles at oblique angles and at vulnerable fuel tank and filler positions.

TABLE 4-2 (concluded)

Item	Description
Relation of Test Requirements and Injury Reduction	(Same as Table 4-1)
Alternative Compliance Method	(Same as Table 4-1)
Extent of Compliance	The 1973 revisions of FMVSS 301 (effective as of Sept.1, 1975) underwent considerable testing and revision because of the difficulty of certain vehicles in meeting the Standard.
Exemptions	See Appendix A on Temporary Exemptions.
Prior Compliance	(Same as Table 4-1)

Current Information on the Effects of FMVSS 301

Cooley [1] of HSRI estimates that annually there are from 720 to 1,250 fatalities in vehicle accidents which are accompanied by fire; of these, 450 to 650 fatalities might be directly related to fire. This compares to CEM's estimate [2] of 600 to 1,100 fatalities annually (which emphasizes the lower part of the range). Cooley reported that 180 to 260 of these fatalities could be eliminated if all vehicles complied with FMVSS 301 (1973 version). The incidence of fire in automobile accidents is about 0.5% [2,3], which is about 7% of all injury-producing accidents [3]. The latest amendments to the Standard (1975) add test requirements which take into account the more frequent types of collision: rear, front, rollover, and rear quarter panel.

Initial Bibliography for FMVSS 301

1. Cooley, P., *Fire in Motor Vehicle Accidents*, Highway Safety Research Institute, HIT LAB Report Volume 5, Number 1, September 1974.

2. The Center for the Environment and Man, Inc., *Evaluation of Motor Vehicle Safety Standards*, CEM Report 4135-496, September 1973.

3. Brayman, A., *Impact Intrusion Characteristics of Fuel Systems*, Cornell Aeronautical Laboratories, Inc., CAL-VJ-2839-K, April 1970.

5.0 FMVSS 208 - OCCUPANT CRASH PROTECTION

Summary

Originally promulgated in 1968, this Standard has been modified several times. The later versions gave vehicle manufacturers three options for satisfying the Standard. The two more general options include specific occupant protection criteria, while the specific lap/shoulder belt option has involved less strict criteria. The objective of this Standard is to decrease occupant injury through increased usage of active restraint systems and innovative passive restraint systems.

FMVSS 208 is another of the original Standards that became effective 1 January 1968, and required seat belt installations in "each passenger car seat position." Because of the obvious relation of occupant restraint systems and injury avoidance, the Standard has been used as a major instrument for motor vehicle injury reduction. To this end, the Standard has been modified several times, including the 1973-1974 ignition interlock system, which resulted in controversy, and was later abandoned. The major versions of the Standard are described below.

- The 1 January 1968 version is one of the original FMVSS, and was promulgated along with FMVSS 209 (Seatbelt Assemblies) and 210 (Seatbelt Assembly Anchorages). Thus, NHTSA established criteria for occupant restraint systems. Though many modifications were proposed, this Standard remained in effect until 1 January 1972.
- On 3 November 1970, the Standard was amended to upgrade the requirements of 1974 and 1975 models. This Standard still relied on the seat belt or lap and shoulder belt combination to achieve occupant restraint and injury reduction.
- Before the modifications required by the 1970 amendment went into effect,the Standard was significantly changed. As of 1 January 1972, the manufacturers were given three options for compliance under the Standard: (a) a totally passive system; (b) the existing lap/shoulder system with warning device; and (c) an intermediate system.
- During 1972, the Standard was modified further to require ignition interlocks for the lap/shoulder belt system on 1973 and subsequent models. Because of public reaction, this requirement was rescinded on 29 October 1974.
- The current version of this Standard (as of 26 August 1976), postpones the effective date of elimination of the lap/shoulder belt system until 31 August 1977. The Secretary of Transportation issued a statement on 9 June 1976, calling for additional hearings on FMVSS 208.

One critical aspect of the current status of FMVSS 208 is the three options under which the automobile manufacturers may satisfy the Standard. The essential elements of the three options originally proposed in 1971 are described below.

- Option One. Complete passive protection system where only occupant injury criteria have to be met.
- Option Two. Lap belt protection system with belt warnings. In this case less stringent injury criteria have to be met.

- Option Three. Lap and shoulder belt protection system with belt warning. In this case, there was originally no crash or injury criterion, although these have been upgraded in subsequent versions.

The material on FMVSS 208 is presented in three major tables described below.

- Table 5-1. This table discusses the original 1968 version and the major changes proposed in 1970 to take effect initially on 1 July 1973.
- Table 5-2. This table discusses the December 1971 version which was to take effect on 1 January 1972. This version has the initial description of the three compliance options.
- Table 5-3. This table discusses the major revisions to the December 1971 version.

Other tables follow, listing additional information about prior compliance, exemptions, and initial indications of the Standard's effects. The post-1968 versions of the Standard include much information on multipurpose vehicles, trucks, and buses; in this review, only passenger car effects are considered.

TABLE 5-1

FMVSS 208 - OCCUPANT CRASH PROTECTION
(Original and 1970 Version)

Item	Description	
Version	Original	November 1970
Effective Date	January 1, 1968	July 1, 1973 and July 1, 1974
Purpose of Standard	• Specific Purpose: to establish requirements for seat belt installations.	• Specific Purpose: to establish specific performance requirements for the protection of vehicle occupants in crashes.
	• General Purpose (implicit): to reduce occupant injuries in motor vehicle crashes.	
General Requirements of Standard	• Provide Type 1 (lap) or Type 2 (lap and shoulder) seat belt assembly in each passenger seat position.	• For July 1, 1973, crash tests using anthropomorphic dummies must meet specified injury criteria using Type 1 or 2 seat belt assemblies. After July 1,1974, rollover crash test is added and the vehicle must meet the protection criteria without any action required by the occupant (passive system). • The critical crash tests were: - Frontal barrier crash into fixed barrier at 30 mph and up to 30° from perpendicular.
(continued)		

TABLE 5-1 (continued)

Item	Description	
General Requirements of Standard (concluded)		- Lateral moving barrier crash at 20 mph. - Rollover test at 30 mph (only the first injury criteria applies). • The injury criteria were: - no occupant ejection - limited acceleration for --occupant head --occupant upper thorax - limited force transmitted through upper leg.
Applicable Crash Situations	The original Standard did not specifically test any crash situations. The use of Type 1 (lap) belt system would help in any accident situation which caused the occupant to be thrown from his seating position. The use of Type 2 (lap and shoulder) belt would be a factor in any crash where the upper torso would be accelerated. The use of seat belts in any type of collision will be a factor.	The Standard specifically sets crash and injury criteria for 1974 models: • Frontal barrier crashes • Lateral moving barrier crashes and for 1975 models, the • Rollover test. The test crashes are at moderate speeds and into flat vertical surfaces. Therefore, the most applicable crashes are of these types. However, one can expect similar effects in collisions with other approximately flat objects, though possibly only at lower speeds.
	(The usage of seat belts is the critical factor in their effectiveness.)	
Inapplicable Crash Situations	There are no crash situations in which the use of seat belts would not be a factor. However, the Type 1 (lap) belt system is less effective than the Type 2 (lap and shoulder) belt system, in frontal collisions. Little difference in effect is expected in rear end collisions.	
Relation of Test Requirements and Injury Reduction	The Standard relies on the empirical relation between injuries and the "second collision."	Explicit injury criteria are cited in the Standard.

TABLE 5-1 (concluded)

Item	Description	
Alternative Compliance Methods	No options given; seat belts required.	The 1975 model requirement (modified and postponed) allowed any method which would achieve protection without occupant action. Relatively few manufacturers have achieved that by the 1977 model year.
Extent of Compliance	As of January 1,1968,all domestic manufacturers met the Standard.	This version of the Standard was modified before its effectiveness date was reached.
Exemptions	See Appendix A on temporary exemptions.	
Prior Compliance	• Ford, Chrysler, and AMC installed two front-seat lap belts as standard equipment as of January 1,1964; GM provided this the following year. • GM, Ford, and AMC provided two rear-seat lap belts in the 1966 model year; Chrysler offered it in the last half of the 1965 model year.	

TABLE 5-2

FMVSS 208 - OCCUPANT CRASH PROTECTION
(December 1971 Version with Three Compliance Options)

Item	Description	
Option	Passive Option 1 - complete passive system. Option 2 - lap belt system with warning.	Active Option 3 - lap and shoulder belt with belt warning.
Effective Date(s)	January 1, 1972 (After August 15, 1973, Option 3 was to be eliminated, and after August 15, 1975, Option 2 was to be eliminated.)	
Purpose of Standard	• Specific Purpose: to specify vehicle crashworthiness requirements in terms of forces and accelerations on anthropomorphic dummies in test crashes, and specifying equipment requirements for active and passive restraint systems. • General Purpose: to reduce frequency of fatalities and severity of injuries in vehicle collisions.	
General Requirements of Standard	Option 1 The vehicle will provide occupant crash protection in: • Frontal barrier crashes • Lateral moving barrier crashes • Rollover (crash test criteria given in Table 5-1) and meet injury criteria for • Head acceleration • Upper body acceleration • Axial forces in upper leg. (The injury criteria cited above have been modified somewhat from the previous version.) Option 2 Meet the injury criteria only for the frontal barrier crash.	Option 3 Under test conditions for a frontal barrier crash, the vehicle should experience no complete separation of any load-bearing element of a seat belt assembly or anchorage. (After August 15, 1973, this option was to be eliminated; however, it was not.)

TABLE 5-2 (concluded)

Item	Description	
Applicable Crash Situations	Option 1 requirements meet the broadest variety of crash situations (frontal,side and rollover). Option 2 and Option 3 are specifically tested as to effectiveness only in frontal crashes. In rollovers and other crashes which potentially involve occupant displacement,lap belts obviously have beneficial effects, while other restraint systems may have lesser effectiveness.	
Inapplicable Crash Situations	Option 2. In the context of the Air Cushion Restraint System (ACRS) there is the possibility of non-deployment in low speed or angle collisions. The Volkswagen passive belt system does not suffer this restriction.	Option 3. The lap/shoulder combination has some effect in all accident configurations providing it is in use and properly adjusted. It is less effective in lateral crashes than in front or rear collision crashes.
Relation of Test Requirements and Injury Reduction	Options 1 and 2 have specific injury criteria.	Option 3 is based on the observed empirical relation between seat belt usage and reduction in fatal and serious injury.
Alternative Compliance Methods	Option 1. No effective method has been achieved. Option 2. The two systems which are used are the Air Cushion Restraint System(with lap belt and warning device) which was offered on some GM models in 1973, and the Volkswagen passive belt system which was not offered until 1976.	Option 3. Specifications preclude alternatives.
Extent of Compliance	All 1973 model cars met this Standard under Option 3: lap/shoulder belt and seatbelt warning system. No manufacturers have satisfied the Standard under Option 1.	
Exemptions	See Appendix A for Temporary Exemptions.	
Prior Compliance	Prior compliance was partial and/or "spotty." Details are being requested from manufacturers.	

TABLE 5-3

FMVSS 208 - OCCUPANT CRASH PROTECTION
(Current Status and Important Revisions)

Item	Description	
Version	Important revisions since September 1971.	Current status.
Option	Options 1, 2, and 3 the same.	Options 1, 2, and 3 the same.
Effective Dates	• From Sept.1,1973 to Oct. 29,1974 (date of announcement),an ignition interlock system was required with Option 3. • The date of elimination of Option 3 was changed from Aug.15,1973 to Aug. 15,1975 to Aug.31,1976.	• Date of elimination of Option 3 was extended to Aug. 31, 1977. • Date of elimination of Option 2 has been withdrawn.
Purpose of Standard	Same as Table 5-2.	
General Requirements of Standard	The crash criteria remain the same (see Table 5-1). However, the injury criteria were modified again, including an explicit differential equation which describes the acceleration forces on the head of an occupant. Also, Option 3 is required to meet the frontal barrier crash and injury criteria.	No change.
Remainder of items are the same as Table 5-2.		

Current Estimates of the Standard's Effects on Injury Frequency

The most complete study of the effects of FMVSS 208 is NHTSA's *Safety Belt Usage: A Review of Effectiveness Studies* (August 1976) [1]. Table 4-1 is taken from the Public Notice of 9 June 1976 [8] issued by the Office of the Secretary of Transportation; it presents restraint system effectiveness estimates based on a variety of studies. The critical aspect of all effectiveness studies is the reliability of the estimates on seat belt usage [2]. The recent Restraint Systems Effectiveness Program is exemplary in its careful treatment of both seat belt usage and injury scaling questions.

TABLE 4-1

OCCUPANT CRASH PROTECTION SYSTEM EFFECTIVENESS ESTIMATES [8]

AIS Injury Level	Lap Belt*	Lap and Shoulder Belt*	Air Cushion**	Air Cushion and Lap Belt**	Passive Belt and Knee Bolster+	Knee Bolster+
1	0.15	0.60	0	0.15	0.20	0.10
2	0.22	0.57	0.22	0.33	0.40	0.15
3	0.30	0.59	0.30	0.45	0.45	0.20
4-6	0.40	0.60	0.40	0.60	0.50	0.25

*RSEP Study [3].

**NHTSA Staff analysis [5].

+Source unknown.

The Restraint Systems Effectiveness Program (RSEP) Study [3] provides the latest and most definitive estimates of the effectiveness of lap belts and lap/shoulder belt combinations. Reinfurt, Silver and Hochberg studied 15,818 occupants in towaway accidents, for whom there was complete information on belt usage, AIS injury level, age, crash configuration, vehicle weight, and damage severity. These data were collected by NHTSA-sponsored teams in five geographic regions.

Other studies have estimated the effect of other occupant crash restraint systems (air cushion restraint system, passive belt and knee bolster, etc.) [3,5]. However, the effectiveness estimates for these systems, though high, are less certain, due to the limited number of field accident data [1]. GM has sold less than 10,000 air bag-equipped vehicles, and VW less than 30,000 specially equipped Rabbits. Therefore, the estimates are based on laboratory tests and limited field data. There have been 82 accidents in air bag-equipped cars [4].

The effectiveness of the seat belt systems and passive systems is constrained by their utilization. For seat belts, many studies have pointed out the low usage rate for the more effective lap and shoulder belt system [3,5,6]; for passive systems, there will be a considerable lag between the requirement for the system and their existence in the entire car population [7].

The NHTSA review [1] contains a lengthy list of seat belt effectiveness studies, ending with the most recent RSEP study [3]. D. Mela's [2] article emphasizes the criticalness of the seat belt usage factor in estimating the ultimate results (reduction of injury) of restraint systems. This aspect, combined with the "fuzzy" injury scaling used in most earlier studies, suggests estimates of the effectiveness of all restraint systems need further refinement.

Initial Bibliography for FMVSS 208

1. NHTSA, *Safety Belt Usage: A Review of Effectiveness Studies*. August 1976.
2. Mela, D., "How Accurate are Seat Belt Statistics?" *Highway Safety Highlights*, Highway Safety Research Center, April 1974.
3. Reinfurt, D., C. Silva and A. Seila, *A Statistical Analysis of Seat Belt Effectiveness in 1973-1975 Model Cars Involved in Towaway Crashes*, The Highway Safety Research Center, May 1976.
4. All State Insurance Companies.
5. Westefield, A. and B. Phillips, *Safety Belt Usage: Survey of Cars in the Traffic Population*, Opinion Research Corporation, March 1976.
6. Robertson, L.S., *Motor Vehicle Occupant Restraint Use and Effectiveness in Real-World Crashes*, Insurance Institute for Highway Safety, July 1975.
7. NHTSA, *Analysis of Effects of Proposed Changes to Passenger Car Requirements of MVSS 208*, Motor Vehicle Programs (NHTSA) and Transportation Systems Center, August 1974 (and amendment December 1974).
8. Office of the Secretary of Transportation, "Occupant Crash Protection: Highway Safety Program Standards," *Federal Register*, Vol. 41, No. 115, 14 June 1976. Pages 24070 - 24078.

APPENDIX A. TEMPORARY EXEMPTIONS FROM FEDERAL MOTOR VEHICLE SAFETY STANDARDS*

Docket No.	Company	Standard	Dates
EX 72-1	Lotus Cars	214	
EX 72-2	General Motors Corporation	208	
EX 73-5	Intermechanica Automobilae	203, 301	
EX 73-7	Albany Motor Carriage Co.	All	
EX 73-8	Avanti	208, 215	
EX 73-9	Sebring Vanguard	208	
EX 74-1	Stutts Motor Car of American, Inc.	215	
EX 74-2	Carrozzeria Zagato		
EX 74-3	ISO Motor Car Co.		
EX 74-4	A. M. General Corporation		
EX 74-5	Aston Martin Lagonda Ltd.	215	
EX 74-6	Vintage Reproductions	All	
EX 75-1	Automobili Lamborghini	215	
EX 75-2	Executive Industries	215	
EX 75-4	C. H. Waterman Industries		
EX 75-16	Sebring Vanguard		
EX 75-23	Sbarro Replica BMW 328		
EX 75-24	Lafer Motor		
EX 75-25	Automobili Lamborghini	215	
EX 75-26	Lotus Cars	215	Thru 9/1/76
EX 75-28	TVR Engineering Ltd.	215	Thru 10/1/78
EX 76-1	Jet Industries		
EX 76-2	Panther West Winds Ltd.	214	Thru 1/1/78
EX 76-3	Wayne Corp.	301	Thru 9/1/77

*From Mr. Taylor Vinson, Chief Counsel's Office, NHTSA - telephone conversation 20 October 1976.