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Modernization of the DOT Motorcycle Helmet Standard

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ABSTRACT

The United States motorcycle helmet standard has changed minimally since its introduction 27 years ago and needs revision in order to remain relevant to modern helmet designs, international helmet standards, and in order to address problem areas that have been identified. The United States Department of Transportation motorcycle helmet standard, Federal Motor Vehicle Safety Standard No. 218, was promulgated in 1974 and was based on the 1971 American National Standards Institute Z90.1 standard. The standard has evolved over the years: in 1980 it was upgraded so that all adult helmet sizes were tested on the medium size headform, and in 1988 it was upgraded so that each helmet was tested on the appropriate size headform. A feasibility study for upgrades to several parts of the standard was completed for NHTSA in 1997. Since then, several additional studies have been completed to further explore upgrades to the impact attenuation and positional stability requirements, and manufacturing costs.

This paper reviews and summarizes these recent research efforts. The modernization of FMVSS No. 218 will probably include changes to environmental conditioning requirements, impact velocity, modified pass/fail criteria for impact attenuation, labeling and marking requirements. This paper summarizes recent compliance tests, identifies trends and problem areas, and presents recommendations for modernization. These recommendations include reduction of the allowable peak acceleration to 300g, adding positional stability (roll-off resistance) and face shield penetration resistance tests, modification of the labeling requirements, and development of a chin bar performance test.

INTRODUCTION

The Federal standard for motorcycle helmets, Federal Motor Vehicle Safety Standard No. 218 (FMVSS 218) for motorcycle helmets was promulgated in 1974. It was based on the 1971 American National Standards Institute Z90.1 standard for protective headgear (ANSI, 1971). The stated purpose of the DOT standard was to establish minimum performance requirements for helmets designed for use by motorcyclists, and the standard has been very successful in that regard (Liu, 1980, 1990).

FMVSS 218 has evolved since its introduction. In 1980 it was modified to require that all adult helmet sizes (not only medium size) be tested on a medium size headform. In 1988, the standard was modified to require that all helmets be tested on small, medium and large headforms that fit each helmet size respectively. In the ensuing years, there has been much activity in international helmet performance standards, and it was noted in 1996 that the DOT standard had not kept pace (Hurt, et al., 1996). Table 1 summarizes the testing and performance criteria for many current international motorcycle helmet standards.

This paper discusses current research toward modernization, the history of the standard, and recent compliance with FMVSS 218 requirements. In the last few years, research has been directed to explore the feasibility of changes to several aspects of the standard. A feasibility study explored many areas of proposed changes (Thom, et al., 1997), and subsequent testing and analysis has explored modifications to address impact velocity, positional stability, face shield penetration resistance, labeling, and manufacturing costs.

NHTSA has conducted extensive compliance testing of helmets from the market place over the years. These tests are briefly summarized in this paper and the prevalence and mode of FMVSS 218 failures are also described. There are additional areas of helmet performance standardization that have not been researched and those are presented as well.

Table 1
Summary of International Helmet Standards

Standard	*Year*	*Drop Test Apparatus*	*Headforms*	*Headform Sizes*	*Drop Assembly Weight*	*Anvils*	*Impact Criteria*	*Number of Impacts*	*Failure Criteria*
FMVSS No. 218	1988	Monorail	DOT	Small Medium Large	3.5 kg 5.0 kg 6.1 kg	Flat Hemi	Velocity: 6.0 m/s 5.2 m/s	Two @ each of 4 sites	< 400g 2.0 msec @ 200g 4.0 msec @ 150g
ANSI Z90.1	1992	Monorail or Guide-Wire	DOT or ISO	Small Medium Large or A,E,J,M	5.0 kg	Flat Hemi	Velocity: Flat & Hemi: 1st 6.9 m/s 2nd 6.0 m/s	Two @ each of 4 sites	$\leq$ 300g
AS 1698	1988	"Guided Fall"*	Magnesium AS 2512.1 (DOT)	A B C D	3.5 kg 4.0 kg 5.0 kg 6.0 kg	Flat Hemi	Drop Height: 1830 mm 1385 mm	Two @ each of 4 sites	$\leq$ 300g 3.0 msec @ 200g 6.0 msec @ 150g
BS 6658	1985	"Guided Fall"*	ISO	A,E,J,M	5.0 kg	Type A Flat Hemi Type B Flat Hemi	Velocity: 1st 7.5 m/s 2nd 5.3 m/s 1st 7.0 m/s 2nd 5.0 m/s 1^{st} 6.5 m/s 2nd 4.6 m/s 1st 6.0 m/s 2nd 4.3 m/s	Two (same anvil) @ each of 3 sites Two (same anvil) @ each of 3 sites	$\leq$ 300g (Multi-part shells shall remain intact)
CAN3-D230	1985	"Guided Fall"*	ISO	A,E,J,M	5.0 kg	Flat Hemi	Velocity: 1st 5.1 m/s 2nd 7.2 m/s 1st 4.3 m/s 2nd 6.1 m/s	Two @ each of 4 sites	Low Energy: $\leq$ 200g High Energy: $\leq$ 300g
Snell M-2000	2000	Monorail or Guide-Wire	ISO	A,E,J,M,O	5.0 kg	Flat Hemi Edge	Energy: Flat & Hemi 1st 150J 2nd 110J Edge 150J	Flat & Hemi: Two each @ 4 sites Edge: One impact @ one site	$\leq$ 300g
ECE 22.5	1999	Unrestrained Headform with Tri-Axial Accelerometer	ISO	A E J M O	3.1 4.1 4.7 5.6 6.0	Flat Curb	Velocity: 7.5 m/s for both anvils	4 sites per helmet in sequence with 5^{th} test @ 4 m/s or 8.5 m/s	Resultant $\leq$ 275g HIC $\leq$ 2400

* Apparatus not further specified

Table 2
Summary of 1997 Feasibility Study

Failure Criteria	Current Requirement:	Peak < 400g, 2.0 msec. at 200g, 4.0 msec. at 150g.
	Possible Upgrade	Peak < 300g, 2.2 msec. at 200g, no limit at 150g.
	Conclusion:	Allowable peak headform acceleration should be reduced from 400g to 300g. The effect of an increase of the dwell time limitation at 200g from 2.0 to 2.2 milliseconds is indefinite. These test data do not justify a change. The 4.0 millisecond limit at 150g can be eliminated to simplify the standard with no effect on safety.
Test Headforms	Current Requirement:	FMVSS "DOT" headforms required.
	Possible Upgrade:	Use of International Standards Organization (ISO) headforms.
	Conclusion:	ISO impact test headforms should be considered for FMVSS 218.
Test Equipment	Current Requirement:	Monorail test apparatus required.
	Possible Upgrade:	European (ECE) test apparatus.
	Conclusion:	The ECE-type test apparatus is complex but is a less severe test than the monorail currently used.
Environmental Conditioning	Current Requirement:	Ambient (room temperature), low temperature, high temperature, and water immersion for greater than 12 hours.
	Possible Upgrade:	Possibly delete water conditioning, reduce the required time in conditioning from 12 to 4 hours and add a maximum time in environmental conditioning of 24 hours.
	Conclusion:	The pre-test environmental conditioning time can be reduced to 4 hours and a maximum time should be added, e.g. 24 hours as used by other standards.
Impact Velocity	Current Requirement:	At each impact site, deliver two successive, identical impacts at 6.0 m/s (13.4 mph) onto the flat anvil and at 5.2 m/s (11.6 mph) onto the hemi anvil.
	Possible Upgrade:	At each impact site--the first impact at 6.9 m/s (15.4 mph) onto the flat anvil and at 6.0 m/s (13.4 mph) onto the hemi anvil. The second impact at each site remains unchanged from the current requirement.
	Conclusion:	Retain the current impact velocities of 6.0 m/s for the flat anvil tests, and 5.2 m/s for the hemi anvil tests.
Penetration Tests	Current Requirement:	Prevent a six kg. pointed striker dropped three meters from penetrating the helmet to contact the headform.
	Possible Upgrade:	More aggressive edge anvil in impact attenuation tests.
	Conclusion:	Retain the current penetration resistance test that is simple and effective in disqualifying inferior helmets.
Retention	Current Requirement:	Apply static, symmetrical load on retention system.
	Possible Upgrade:	Add a positional stability (roll-off) test.
	Conclusion:	Add the proposed test for positional stability.
Projections	Current Requirement:	No internal projections allowed, 5mm limit on external projections.
	Possible Upgrade:	No change expected.
	Conclusion:	No change needed regarding internal or external projections.
Labeling and Marking	Current Requirement:	Simple permanent "DOT" sticker on rear of shell.
	Possible Upgrade:	Require manufacturer identification permanently marked on each helmet. Require counterfeit-resistant "DOT" sticker on rear of shell.
	Conclusion:	Commercially available labels can be specified to reduce counterfeiting. Helmet Identification Number and manufacturer registry would provide consumer assurance of DOT compliance.
Face Shield Penetration	Current Requirement:	No requirement.
	Possible Upgrade:	Add penetration resistance test specified in the Vehicle Equipment Safety Commission No. 8 standard (VESC-8).
	Conclusion:	Add a faceshield penetration test as specified in the Vehicle Equipment Safety Commission No. 8 standard (VESC-8).

RECENT RESEARCH:
Feasibility Study

In 1996, the Head Protection Research Laboratory contracted with NHTSA to perform a study to examine the feasibility of upgrading FMVSS 218 (Thom, et al, 1997). The purpose of the feasibility study was to explore several areas of upgrading of FMVSS 218. Table 2 provides a summary of the areas that were considered for revision and the conclusions that were reported.

Additional Testing and Research

Tests at Increased Velocity

Several additional projects related to FMVSS 218 have been completed since the 1997 release of the feasibility study. These efforts have addressed impact velocity, positional stability, and the cost of modifying helmets to meet an upgraded standard. In 1999, NHTSA tested an additional 40 helmets for their ability to meet the proposed increase in impact velocity (HPRL, 1999 and US Testing, 1999). Both of these projects involved testing additional samples of the helmets that had been tested as part of the NHTSA compliance test program earlier in 1999, with the exception that the additional testing used the increased impact velocities first explored in the 1997 feasibility study described above. When higher impact velocities were used, 24 of the 40 helmets (60%) failed one or more of the current impact attenuation requirements. Table 3 provides details of the specific failures. Applying the proposed pass/fail criteria would change the percentage of failures somewhat; however the final total would be similar, with 21 of 40 (52.5%) failing even if the proposed impact attenuation criteria were used. See Table 4 for a summary of this data.

Table 3
Test Failures in Increased Impact Velocity Tests
at Current Pass/Fail Criteria

	Peak Acceleration (400g limit)	Dwell time at 150g (4.0 msec. limit)	Dwell time at 200g (2.0 msec. limit)
HPRL, 1999	0	12	13
UST, 1999	1	2	4
Total	1	14	17

Note that since many helmets failed more than one criterion, the total number of failures is greater than 24

Table 4
Test Failures in Increased Velocity Tests
at Proposed Pass/Fail Criteria

	Peak Acceleration (300g limit)	Dwell time at 150g (4.0 msec. limit)	Dwell time at 200g (2.2 msec. limit)
HPRL, 1999	1	10	9
UST, 1999	3	2	3
Total	4	12	12

Positional Stability (Roll-off Ejection)

Some international helmet standards have included tests of positional stability for many years. The lack of this type of test in the DOT helmet standard represents a shortcoming that should be addressed when considering any upgrades to FMVSS 218. At present, the DOT helmet standard uses a quasi-static retention system test, which requires that a helmet retention system be subjected to a 300 lb. downward pull by a mandible-like device. While this procedure effectively tests the strength of the retention system, it does not test how well the helmet remains in place when subjected to other forces.

In order to compare laboratory test procedures to human subject testing, Thom, et al., (1997) evaluated motorcycle helmets and compared the human subject test results to the laboratory test results. The laboratory test procedure employed a 10kg mass dropped 60cm to jerk the helmet forward to induce it to roll off of the DOT test headform. The human subject testing involved motorcycle riders who were asked to fasten the helmets on their heads and then attempt to pull the helmets off by rotating them forward. The test results showed a clear correlation between human testing results and the laboratory procedure results. Helmets that tended to come off easily in the laboratory test were usually rotated off easily by human test subjects, even when properly fastened. Additional human subject tests were completed and those tests again confirmed the meaningful relationship between laboratory testing and human subject performance (Hurt, et al., 1998).

This year, the Head Protection Research Laboratory (HPRL) tested 20 helmet models that had been the subject of routine NHTSA compliance testing the previous year to the proposed positional stability test procedures. The results indicated that eight of the models tested failed the positional stability test. Six of the failures were due to the design geometry of the helmet. In these instances, rotating the helmets failed to cause the chinstrap to tighten and resist further rotation. In two instances, there was a mechanical failure of strap stitching that allowed the helmets to be ejected (HPRL, 2000).

Engineering and Cost Analysis Study

In order to further analyze the implications of the increased velocity tests, an engineering and cost analysis was performed on selected helmets that had been tested at increased impact velocity (Ludtke, 2000). The purpose of this study was to determine the failure mechanism(s) of the failed helmets, determine design changes that would be required to allow them to pass, and finally to develop variable manufacturing costs, weights and lead time estimates. Ludtke reported that the impact test performance could be related to the densities (stiffness) of both the helmet shell and energy-absorbing liner. The engineering analysis determined that a change in material to alter the density of the parts would increase the helmet weight by 0.2361 lb. (107 gm.) at a cost of $0.5841 per helmet. It was noted that two of the samples evaluated had energy-absorbing liners that were too thin and would need to be made thicker in order to pass the proposed tests. It was reported that the costs associated with this more extensive modification would be $0.045 and $0.003 to $0.006 mold cost per helmet as well as an added weight of 0.02 lb (9.1 gm). NHTSA is currently evaluating the results of this cost-benefit analysis.

Compliance Testing

The NHTSA Office of Vehicle Safety Compliance has sponsored compliance testing of helmets regularly over the years. Helmets have been tested by NHTSA each year since 1980 with the exceptions of 1982, 1983, 1987 and 1988. Some of the earlier results of this testing have been presented elsewhere (Liu, 1980, 1990). Approximately 3000 helmets have been tested since 1980. In the last six years, NHTSA contractors have tested a total of 1018 helmets (NHTSA, 2000). These tests show numerous failures of FMVSS 218 requirements, primarily of labeling requirements. However, there are performance failures also, including impact attenuation, penetration resistance and retention system strength. It should be noted that these tests did include novelty helmets that were fraudulently labeled as complying with FMVSS 218. Additional compliance test information is included in Appendix A.

DISCUSSION

Impact Attenuation

Impact Test Velocity

The original research on crash-involved helmets was conducted for DOT-NHTSA in 1981 in Los Angeles (Hurt, et al., 1981). It was reported that the damage found on 90% of all accident-involved helmets could be replicated within the six-foot drop impact test of the DOT standard. At the present time, there are no published data that demonstrate that helmets meeting standards with a higher impact test velocity provide any greater protection than helmets which meet the “minimum” requirements of FMVSS 218 (Hurt, et al., 1981). In the study noted above, it was also reported that accident-involved helmets never show two significant impacts at the same location on the helmet. This finding leads to the conclusion that two impacts may not be a necessary criteria for helmet impact testing, although historically motorcycle helmet standards have required two consecutive impacts to the same location.

Thom et al. (1992) performed single-impact direct comparison tests of helmets that met either the DOT standard or the Snell standard. The DOT standard calls for a 6.0 m/s (13.4 mph) impact with a flat anvil, whereas the Snell standard calls for an 8.0 m/s (17.9 mph) impact onto a flat anvil. When tested for a single impact, however, the DOT-qualified helmets performed better than those certified to the Snell standard. At present, there is no compelling justification for raising the impact velocity of the DOT helmet standard.

Failure Criteria: Peak Acceleration

The current limitation of 400g for the peak headform acceleration is antiquated in comparison with other standards developed over the last two decades. The ANSI Z-90.1 standard peak headform acceleration limit was changed from 400g to 300g in 1979, and essentially all other international standards currently use a peak headform acceleration limit of 300g (see Table 1). Thom et al., 1998 concluded that the DOT standard should be revised to a limit of 300g, because modern helmet technology easily provides helmets capable of meeting this more stringent requirement.

Failure Criteria: Dwell Time

The scientific community generally concurs that some relationship exists between head acceleration, time duration and the occurrence of head injury. However, the exact nature of this relationship has not been clearly quantified and remains a matter of debate. Many methods currently consolidate a mathematical relationship between head acceleration and time duration. For example, the Head Injury Criterion (HIC) is used in automobile crash testing. However, the HIC and similar Gadd Severity Index (SI) have been criticized regarding their application to head protection (Newman, 1975, 1982). Nonetheless, time duration appears to be an acceptable criterion since it does have some basis in human tolerance (Ono, 1980). However, a frequent impact attenuation failure involves slightly exceeding the 200g dwell time limit, which is currently set at 2.0 milliseconds. It is possible to increase the dwell time limit to 2.2 milliseconds, which would allow more helmets to pass the standard than at present. It is assumed that this would have a minimal effect upon the overall performance of the helmet; however, at this writing, there is simply no research that allows evaluation of the effect of such a change.

<u>Retention</u>

Positional Stability

Regardless of the strength of a helmet's retention system, an inertial or direct force on a helmet can dislodge the helmet and cause it to rotate forward and "roll-off" unless the geometry of the helmet and retention system act to prevent this motion. Mobility of the helmet upon the head is greatly dependent on the coverage of the helmet. Partial coverage helmets have been found to be the most mobile, while full-facial coverage helmets have been found to have the greatest resistance to ejection because of the presence of the chin bar. The present DOT standard does not test for problems of positional stability. Several international helmet standards incorporate such tests. Because the roll-off susceptibility is a problem of design geometry rather than strength, the roll-off test cannot be combined with existing tests, and requires separate procedures and equipment. This need for the addition of the positional stability test is important because sales of partial coverage helmets are increasing. Current helmet sales are: partial coverage 11%, 79% full-facial (street and off-road), and open-face 9% (Motorcycle Industry Magazine, 2000).

Helmet Face Shield Penetration Resistance

The current FMVSS 218 does not specify any requirements for face shields even though all full-facial coverage street helmets, and some open-face helmet are so equipped. Only full-facial helmets for off-road use are not equipped with face shields since goggles are typically used for off-road riding.

Face shield penetration resistance was explored in the 1997 feasibility study since there are currently three standards that are applicable to motorcycle use. The Vehicle Equipment Safety Commission regulation No. 8, Minimum Requirements for Motorcyclists' Eye Protection (VESC-8, 1980) specifies both optical and mechanical requirements. VESC-8 employs a 44.2 gram (1.56 oz.) steel dart dropped in free fall from 4.27m (14 ft.) to strike the eye protection device without permanent intrusion. The Vehicle Equipment Safety Commission no longer exists, however the standard is currently referenced by most state motorcyclist eye protection use laws.

The American National Standards Institute Z-87.1 (1989) Practice for Occupational and Educational Eye and Face Protection is another widely accepted standard, although not at all specific to motorcycle use.

The American Society for Testing and Materials has recently established a sub-committee for Eye Protection for Motorcyclists (ASTM F08.57). While this standard is still in the draft stage, the ASTM is expected to develop an appropriate standard for motorcyclist eye protection.

Face shields were tested to the mechanical test of VESC-8 as part of the study completed by Thom et al., 1997 and in follow up work as well (HPRL, 2000). The integral face shields tested were all original equipment on the full-facial coverage street helmets and were nominally 2.5mm (0.10 in) thick. In all cases, the typical modern face shields were made of optical polycarbonate material and easily resisted penetration in the VESC-8 impact test.

Environmental Conditioning

Impact test data collected by the authors indicates that helmet impact attenuation failures are most common when the helmet is tested in the low and high temperature environmental conditions while water immersion seldom results in impact attenuation failure. Historically, water immersion was used to eliminate helmet materials that were rendered ineffective when wet. Modern helmet construction materials for both shells and energy-absorbing liners are not significantly affected by water immersion and therefore, consideration should be given to eliminating the water immersion requirement.

Labeling and Marking

The FMVSS 218 standard contains several requirements for labeling and marking. The requirement for an external "DOT" label on the rear of the helmet is a particular problem in two ways. The standard is very specific about the placement of the external “DOT” label. The result of that specificity is that some helmet designs cannot meet the exact “letter of the law.” On some helmets, a label simply cannot be placed where required even though the helmet otherwise meets all requirements of the FMVSS 218 standard. This type of inconsequential non-compliance sometimes results in an otherwise qualified helmet being listed as a “failure” because the helmet is listed as a “failure” whether it had performance test problems or only fails in some insignificant labeling detail. Greater flexibility for positioning the DOT sticker would help rectify this situation.

The second area where labeling is a problem is that of reference to FMVSS 218 in states with mandatory helmet use laws for motorcyclists. A problem frequently noted is the placement of a counterfeit external "DOT" label on unqualified, novelty helmets that do not meet FMVSS 218 requirements. The requirement for a one cm. high "DOT" label in a color that contrasts to the helmet shell is simple enough to be counterfeited easily at the retailer or consumer level. In order to reduce this ease of deception, a solution may be to require each manufacturer to provide a traceable manufacturer’s identification code on each helmet. This system would be similar to the identification number currently found on all truck, automobile and motorcycle tires sold in the United States.

Additional Areas Requiring Further Study

It has been suggested that the chin bar of full-facial coverage helmets should be tested to provide some minimum qualification to ensure protection (Hurt, et al., 1996). As of this writing, no research has been done in the U.S. toward the establishment of a meaningful, minimum standard for chin bar performance. At present, nearly 80% of new helmets sold are full-facial coverage, yet there is no test of facial protection performance. In the absence of a standard test with established performance criteria, facial impact protection varies widely between helmets.

Another area that should be studied is that of helmet friction against the roadway. A typical motorcycle helmet has a hard and rigid outer surface that has very low friction coefficient. Recently, helmets are being sold with fabric and leather outer coverings that are likely to affect friction. The effects of this design relative to the risk of head injury are currently unknown and should be evaluated.

RECOMMENDATIONS

In summary, the previous research has led to the development of the following recommendations:

1. Peak headform acceleration should be reduced from 400g to 300g.
2. The effect of an increase of the dwell time limitation at 200g from 2.0 to 2.2 milliseconds is indefinite. Helmets can more easily pass the standard, but it is unclear if head injuries would increase, decrease, or remain unchanged.
3. The 4.0 millisecond limit at 150g can be eliminated to simplify the standard with no adverse effect on safety.
4. Retain the current pre- and post-test systems check procedure for within-laboratory systems checking.
5. Adopt the ASTM calibration sphere to allow inter-laboratory systems comparisons.
6. The pre-test environmental conditioning time should specify a minimum of 4 hours and a maximum of 24 hours.
7. Retain the current impact velocity of 6.0 m/s (13.4 mph) for the flat anvil tests, and 5.2 m/s (11.6 mph) for the hemispherical anvil tests.
8. Retain the current penetration resistance test, which is simple and effective.
9. Add the developed test for positional stability ("roll-off") test.
10. Commercially available labels can be specified to reduce counterfeiting. Helmet Identification Number and manufacturer registry would provide consumer assurance of DOT compliance.
11. Allow greater flexibility in the placement of the "DOT" sticker on the helmet exterior.
12. Add a face shield penetration test as specified in VESC-8.
13. Research and develop a meaningful qualification for impact attenuation by chin bars on full-facial coverage helmets

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Appendix A

The NHTSA Office of Vehicle Safety Compliance has tested helmets for FMVSS 218 compliance each year since 1980 with the exceptions of 1982, 1983, 1987 and 1988. Liu has presented his analyses of these tests previously (Liu, 1980, 1990). Approximately 3000 helmets have been tested by NHTSA since 1980. In the last six years, NHTSA contractors have tested a total of 1018 helmets. Recent compliance tests can be divided into two groups. The most recent testing from 1997 through 1999 has been performed according to the full requirements of environmental conditioning: one helmet in each of four conditioning environments for a total of four samples per make and model. This methodology results in complete test data for a smaller number of helmet makes and models. Because a limited number of helmets can be tested each year, the full environmental conditioning testing means that fewer makes and models are tested. A total of 484 helmets were tested using this methodology. An additional 160 helmets were tested in the year 2000 but those results are not yet available.

During 1994 through 1996, tests were conducted on the widest possible number of different helmet makes and models. This was accomplished by partial testing among the four environmental conditions specified by the standard: ambient, high temperature, low temperature and water immersion. In other words, one or more of the four possible conditions was chosen for each test. This allowed testing of more makes and models of helmets, although the tests were not complete. A total of 534 helmets were tested with this methodology. These data are summarized in Table A1.

Because of these differing methodologies, the summary data cannot be directly compared between the two groups. For example, a test failure on a given make/model helmet in 1994 would be reported as a failure for the single tested helmet, while an identical single helmet failure in 1999 would be reported as a failure of the entire test group of four helmets. This is the explanation for the inconsistencies between the groups of years. It is important to note that the majority of failures reported during these recent tests are due to labeling problems, not actual test performance failures.

Table A1
Summary of FMVSS No. 218 tests
1994-1999

Year	Helmets tested	Pass	Fail Labeling	Fail Performance	Fail Labeling and Performance
1994	199	52 (26%)	124 (62%)	28 (14%)	5 (2.5%)
1995	168	42 (25%)	104 (62%)	26 (15%)	5 (2.9%)
1996	167	53 (32%)	106 (63%)	24 (14%)	16 (9.6%)
1997	164*	88 (54%)	44 (27%)	52 (32%)	20 (12%)
1998	160*	84 (53%)	44 (28%)	40 (25%)	12 (7.5%)
1999	160*	96 (60%)	40 (25%)	36 (23%)	12 (7.5%)
Total	1018	415 (41%)	462 (45%)	206 (20%)	70 (6.9%)

*Tested in sets of 4 helmets