FINAL REGULATORY EVALUATION

National Highway
Traffic Safety
Administration

INTERNATIONAL STANDARD FOR PASSENGER CAR BRAKE SYSTEMS

FMVSS NO. 135

OFFICE OF REGULATORY ANALYSIS

PLANS AND POLICY

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

JANUARY 1995

TABLE OF CONTENTS

EXECUTIVE SUMMARY

A. Final Rule Requirements

Performance requirements from U.S. Federal Motor Vehicle Safety Standard (FMVSS No. 105) and United Nations Economic Commission for Europe Regulation No. 13 (ECE R.13) have been combined and revised to produce the new, harmonized passenger car brake standard, FMVSS No. 135. This new standard has the potential to simplify the brake design and development process for the world market, resulting in reduced research and development (R&D) costs, slightly reduced compliance test costs, and further savings from economies of scale. The agency believes that the revised performance requirements carried over from FMVSS No. 105 and ECE R.13 into the new rule are either equivalent or slightly more stringent than the existing requirements, to assure the present level of vehicle safety is maintained.

B. Anticipated Benefits

The most significant improvement of FMVSS No. 135 over FMVSS No. 105 is the addition of adhesion utilization (AU) requirements, which are basically equivalent to those in ECE R.13. The inclusion of those requirements, which are evaluated by the Wheel Lock Sequence (WLS) and Torque Wheel (TW) tests, now provides a more direct requirement for vehicle directional stability during braking. A vehicle that meets the new AU requirements should have a greater accident avoidance capability than a vehicle that does not.

The AU requirements should serve to improve a limited number of make/models that currently do not exhibit adequate front brake bias, and thereby, adequate directional stability. Other minor improvements should result from the slightly more stringent requirements with respect to heat fade and recovery, partial hydraulic failure, and power boost requirements. However, the agency has no way of quantifying the benefits derived from these slight increases in stringency.

The new AU requirements may require some manufacturers to adjust the brake balance of some of their vehicle models to be slightly more front-biased. However, the corresponding design and hardware changes are expected to be quite minor. Other minor changes may also result from the slight increases in test stringency. Most cars should not need any changes in order to comply. Also, when this Rule becomes effective, ABS-equipped cars (estimated to be 100% of the 2001 MY car population) will not be required to meet the AU requirements.

C. Anticipated Costs

The revised test procedures should produce some small cost savings, around $64 direct labor per test, since slightly more testing has been eliminated than added. The total cost savings could be as much as $256 when indirect labor, labor overhead, general administration and profits are included.

D. Leadtime

Thirty days after publication of FMVSS No. 135, manufacturers may comply with either the new FMVSS No. 135 requirements or the existing FMVSS No. 105. After five years, manufacturers must comply with the FMVSS No. 135 requirements. Therefore, manufacturers should have sufficient time to redesign and verify that their vehicles meet the new requirements.

I. INTRODUCTION

In May 1985, the National Highway Traffic Safety Administration (NHTSA) issued a Notice of Proposed Rulemaking (NPRM) to establish the U.S. version of a new international passenger car brake standard (FMVSS No. 135). This proposal reflected considerable dialogue between NHTSA, its counterparts in other national governments, and foreign and domestic automobile manufacturers through the Meeting of Experts on Brakes and Running Gear (GRRF) of the United Nations Economic Commission for Europe (ECE). In developing the proposal, NHTSA tested 45 vehicles at its Vehicle Research and Test Center and published a Preliminary Regulatory Evaluation (PRE). Based on comments to the NPRM and 20 additional full scale tests of passenger cars, the agency issued a Supplemental Notice of Proposed Rulemaking (SNPRM) in January 1987. Comments to this first SNPRM were analyzed in conjunction with 19 more full scale vehicle tests and two additional series of vehicle tests which focused on adhesion utilization (a measure of the ability of the vehicle's brake system to utilize the available braking traction at each of its axles, under a broad range of road surface friction and load conditions). The agency found it necessary to issue a second SNPRM in July 1991, to further revise and refine the test conditions and performance requirements. Based on its review of the second SNPRM comments, the agency has developed a Final Rule that is approximately equal to or slightly greater in overall stringency than the existing U.S. hydraulic brake system standard (FMVSS No. 105), and this Final Rule should be appropriate for harmonization purposes.

This subject Final Regulatory Evaluation is designed to provide an overview of the events leading to the Final Rule and an assessment of the costs, benefits, and other impacts associated with that Rule.

II. THE HARMONIZATION PROCESS

The primary objective of the new FMVSS No. 135 is to eliminate any non-tariff trade barriers that have been caused by competing passenger car brake standards, specifically the U.S. standard FMVSS No. 105 and the ECE R.13. Currently, most automobiles that are built in any country for sale in both the U.S. and European markets are usually certified to both brake standards. However, a few European countries do not subscribe to R.13. A harmonized single brake standard has the potential to simplify the brake design and development process for both markets, resulting in reduced research and development (R&D) costs, reduced compliance test costs, and further savings from economies of scale.

The harmonization process essentially involved the blending of various aspects from both FMVSS No. 105 and ECE R.13. The goals of harmonization were: 1) elimination of competing brake performance requirements that are unnecessary for safety, 2) development of uniform test procedures (which reduce consumer costs), and 3) adoption of common performance levels without compromising safety. A fundamental ground rule of the harmonization process was the maintenance of equivalent levels of stringency between the current and proposed standards. Thus, any vehicle that currently met FMVSS No. 105 or ECE R.13 should not have to be significantly modified to comply with the new international standard. Thus, the agency's philosophy in setting performance criteria has been to match the stringency of proposed criteria with the existing standards. When vehicles were found to pass the current standards but too many failed to meet proposed criteria during full scale testing, the proposed criteria were adjusted accordingly. However, minor vehicle modifications were considered acceptable.

III. NHTSA's HARMONIZATION PROPOSALS AND THE FINAL RULE

A. Notice of Proposed Rulemaking (NPRM)

On May 10, 1985, NHTSA published a NPRM in the Federal Register (50 FR 19744) that proposed a new Federal Motor Vehicle Safety Standard (FMVSS) No. 135, Passenger Car Brake Systems.[1] The proposed standard would replace FMVSS No. 105, Hydraulic Brake Systems, as it applied to passenger cars. The proposed standard's purpose was to establish the U.S. version of an international braking standard for all passenger cars that are produced worldwide. At the time, the agency stated that the new standard would differ from the existing one, primarily in that it contained a revised and shortened test procedure.

NHTSA believed the new standard would ensure the same level of safety for the corresponding aspects of performance that are covered by FMVSS No. 105 (See Table III-1), while improving safety by addressing some additional safety issues. For the first time, the agency proposed adhesion utilization requirements to ensure vehicle stability during braking under all conditions of traction, including wet roads. Also, other requirements addressing additional areas of braking performance, engine-off effectiveness, and dynamic parking brake testing that were derived from the ECE R.13 were included. The agency also proposed to make a reduced burnish procedure optional and eliminate the following FMVSS No. 105

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[1] "Federal Motor Vehicle Safety Standard, Hydraulic Brake Systems, Passenger Car Brake Systems, Notice of Proposed Rulemaking", NHTSA, Office of Rulemaking, 49 CFR 571, Vol.50, No.91, pp. 19744 -19760, May 10, 1985, Docket No. 85-06; Notice 1.

Table III-1
FMVSS No. 105
Brake Test Procedure and Requirements

	Test Load*		Test	Require-
	LLVW	GVWR	Procedure	ments
1. Instrumentation check			S7.2	
2. First (preburnish) effectiveness test		X	S7.3	S5.1.1.1
3. Burnish procedure		X	S7.4	
4. Second effectiveness		X	S7.5	S5.1.1.2
5. First reburnish		X	S7.6	
6. Parking brake	X	X	S7.7	S5.2
7. Third effectiveness (lightly loaded vehicle)	X		S7.8	S5.1.1.3
8. Partial failure	X	X	S7.9	S5.1.2
9. Inoperative brake power assist units		X	S7.10	S5.1.3
10. First fade and recovery		X	S7.11	S5.1.4
11. Second reburnish		X	S7.12	
12. Second fade and recovery		X	S7.13	S5.1.4
13. Third reburnish		X	S7.14	
14. Fourth effectiveness		X	S7.15	S5.1.1.4
15. Water recovery		X	S7.16	S5.1.5
16. Spike stops		X	S7.17	S5.1.6
17. Final inspection			S7.18	S5.6
18. Moving barrier test		X	S7.19	S5.2.2.3

* (LLVR) - Lightly Loaded Vehicle Weight (GVWR) - Gross Vehicle Weight Rating

tests because it believed they were no longer necessary to ensure safety: water recovery, 30 mph effectiveness, and the optional barrier impact. The resultant proposed test sequence is presented below in Table III-2.

NHTSA stated that adoption of the proposed standard would result in a cost savings, because manufacturers would find it easier to build and test common brake systems for cars that were sold in different parts of the world. Further, compliance costs would be reduced by the shorter test procedure. Overall, it would be easier for manufacturers to build cars for the world market.

Table III-2

Notice 1 Initial Proposed FMVSS No. 135 Test Procedures

Vehicle loaded to GVWR:
- Preparation and pretest instrumentation check (10 stops)
- Preburnish effectiveness (4 stops)
- Cold effectiveness:
  - Burnish (optional; 36 stops from 80 km/h @ 3 m/sec^2)
  - Cold effectiveness
  - Reburnish (optional; 50 stops from 80 km/h @ 3 m/sec^2)
  - Cold effectiveness - retest
- Adhesion utilization: (Single Axle Method; high-friction (SN 81) road)
  - Coast-downs
  - Snubs @ 6.4 m/sec^2
  - Front brake only test
  - Rear brake only test
  - Brake pressures determination
- High speed effectiveness

Vehicle loaded to LLVW:
- Cold effectiveness
- High speed effectiveness
- Partial system failure:
  - Hydraulic circuit failure
  - Failed antilock or variable proportioning valve (if applicable)

Vehicle loaded to GVWR:
- Partial system failure:
  - Hydraulic circuit failure
  - Failed antilock or variable proportioning valve (if applicable)
  - Inoperative brake power assist or brake power unit
- Fade and recovery:
  - Heating snubs
  - Hot performance
  - Brake cooling
  - Recovery performance
- Parking brake performance:
  - Gradient hold (static, 20%)
  - Dynamic
- Spike stops
- Final effectiveness
- Final Inspection

A Preliminary Regulatory Evaluation (PRE), prepared in support of the NPRM and entitled International Braking Standard for Passenger Cars, was published in March, 1985, which addressed the technical issues, the compliance procedure cost savings, and the expected benefits from the proposed standard.[2] The Preliminary Regulatory Evaluation (PRE) identified the potential for some compliance test cost savings of $41.50 per vehicle tested.

Comments to the NPRM were submitted to Public Docket 85-06, Notice 1 by foreign and domestic automobile manufacturers, their representatives, foreign governments and safety organizations with interests in the international brake harmonization process. These included key participants from the international brake harmonization discussions that led to the proposed standard. A detailed summary of the comments has been placed in the Docket[3].

Although the commenters supported the intent of NHTSA's NPRM, they generally believed that NHTSA's proposal was more stringent than either the existing U.S. brake standard (FMVSS No. 105), the European brake standard (ECE R.13), or a proposed European version of an international brake standard (GRRF/R.88). They believed that a Supplemental NPRM would be necessary to properly align NHTSA's proposed standard with current standards.

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[2] "International Braking Standard for Passenger Cars, Preliminary Regulatory Evaluation", NHTSA, Office of Plans and Policy, March, 1985, Docket No. 85-06-N01-001.

[3] "Summary of Comments to Docket No. 85-06; Notice 1 on the Proposed FMVSS 135 for Passenger Car Brake Systems", NHTSA, Office of Rulemaking, May 20, 1986, Docket No. 85-06-N01-025.

The European community was particularly concerned about the objective measurement of brake factor data using the Single Axle Method or any other method such as the Road Transducer Plate (RTP) or Torque Wheel (TW) methods to generate data for calculating compliance with the Annex 10, Adhesion Utilization (AU) map.[4] Adhesion utilization performance is affected by a vehicle's brake balance, and the proposal is based on the desire to require automobiles to be front brake biased (i.e., the front axle locks up first during hard braking so that the vehicle tends to skid straight ahead). When rear brake biased vehicles lockup the rear wheels, the subsequent skidding tends to make the vehicle unstable causing the vehicle to spin out.

Various commenters were concerned that a practical/physical AU test would make it more difficult to meet the proposed stopping distance requirements, which were equivalent to those in FMVSS No. 105. They expressed a preference for a simpler, more practical road test. Several commenters thought the burnish procedure did not adequately prepare the vehicle for the relatively short stopping distance requirements. A few commenters also felt that dropping the pre-burnish test would make it easier to achieve shorter post-burnish stopping distance requirements. Many commenters thought that longer stopping distances were needed to accommodate any brake design changes that may be necessary to meet the adhesion utilization requirements. No commenter was opposed to eliminating the water recovery test,

[4] E/ECE/324 E/ECE/TRANS/505-Rev.1/Add.12/Rev.2 - Addendum 12: REGULATION NO.13 TO BE ANNEXED TO THE AGREEMENT Revision 2, UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES WITH REGARD TO BRAKING, incorporating the 04 series of amendments approved during the 60th session of WP29(March 1980)

the 30 mph effectiveness tests, or the optional barrier impact test.

B. First Supplemental Notice of Proposed Rulemaking (1st SNPRM)

On January 14, 1987, NHTSA published an SNPRM[5] that responded to the NPRM docket comments. Numerous changes were made to the agency's original proposal in response to those comments and based on further full scale testing at NHTSA's Vehicle Research and Test Center (VRTC).[6] They were as follows:

In response to NPRM comments, the SNPRM proposed a longer burnish procedure, similar to that in FMVSS No. 105, incorporating 200 stops vs. the 50 stops proposed in the NPRM, and the elimination of the pre-burnish tests. To make the burnish stops more real-world-like, the initial brake temperatures (IBT) and deceleration rates were specified at levels that were lower than those in FMVSS No. 105. Pre-test instrumentation checks were also folded into the modified burnish procedure.

Because of negative NPRM comments, the Single Axle Method of determining adhesion utilization brake factors was tabled in favor of a more simple, practical test, namely a

[5]"Federal Motor Vehicle Safety Standards, Hydraulic Brake Systems, Passenger Car Brake Systems, Supplemental Notice of Proposed Rulemaking" NHTSA, Office of Rulemaking, 49 CFR 571, Vol. 52, No. 9, pp. 1474 -1494, January 14, 1987.

[6]"Harmonization of Braking Regulations - Report Number 4: Testing to Address Issues Raised During Development of the NPRM", Flick, M.A. and Radlinski, R.W., Vehicle Research and Test Center, East Liberty, OH, July, 1985.

combination of an effectiveness test on a low coefficient of friction surface and a wheel lockup sequence test. The proposed test specified a stopping distance of less than 40 meters on an SN 20 (wet) surface at both GVWR and LLVW vehicle test weights, with no wheel lockup permitted at speeds greater than 15 km/h. This requirement would evaluate the braking efficiency on surfaces with low levels of adhesion (low coefficients of friction). The Wheel Lock Sequence (WLS) tests would require that the rear wheels do not lock up before the front wheels.

The SNPRM increased the Cold Effectiveness stopping distance from 65 m to 70 m. Because of the importance of this performance criteria, the agency continued its efforts to substantiate a stopping distance requirement that would be equivalent in overall stringency to the existing FMVSS No. 105 requirement.

The reaction time and deceleration levels that are used in formulas that establish the various stopping distance requirements throughout the proposal were also adjusted as a consequence of changing the Cold Effectiveness requirements formula. These include those that determine the High Speed Effectiveness and Recovery Performance requirements which needed to be modified since they were dependent on the Cold Effectiveness requirements. Engine failure stopping distance was decreased from 72 m to 70 m, to be consistent with the European philosophy that the engine-off performance requirement should be identical to the cold effectiveness performance, as another step toward harmonization.

The Partial System Failures stopping distance requirements for Antilock Functional Failure, Variable Proportioning Valve (VPV) Functional Failure, Hydraulic Circuit Failure and Power Assist Failure were all increased. The Hydraulic Circuit Failure and Power Assist Failure stopping distances were increased to 542 ft. (165 m) to be consistent with each other while having an equivalent stringency with FMVSS No. 105 Partial System Failure requirements.

The time interval between heat snubs was increased from 30 to 40 seconds while the hot stop requirement was reduced from 91 m to 86 m, and the tolerance band for stopping distance (but not the maximum stopping distance itself) was increased from 83%-143% to 67%-143% of the shortest stopping distance obtained during cold effectiveness testing at GVWR. The number of allowable hot stops was increased from one to two.

Comments to the first SNPRM (Docket No. 85-06; Notice 4) were received from both foreign and domestic manufacturers, manufacturers' representatives, advocacy groups and foreign governments that were involved in the international brake harmonization process, including the Group of Rapporteurs on Brakes and Running Gear (GRRF) of the United Nations' Economic Commission for Europe (ECE). A summary of the comments is contained in the Docket.[7] In support of its rulemaking activity, NHTSA conducted 19 full

[7] "Summary of Comments to Docket No. 85-06; Notice 4, on the Proposed FMVSS 135 for Passenger Car Brake Systems", NHTSA, Office of Rulemaking, August, 1988, Docket No. 85-06-N04-048.

scale vehicle tests at VRTC using the procedures that were proposed in the first SNPRM.[8] This performance data was published early in the SNPRM comment period so as to elicit commenters' views and thoughts.

C. Second Supplemental Notice of Proposed Rulemaking (2nd SNPRM)

As a result of comments received on the first SNPRM, industry tests, and tests conducted at VRTC, the agency prepared a second SNPRM. The second SNPRM continued the harmonization process of blending European and U.S. regulatory requirements toward the development of a unified brake performance standard. The agency believed the second SNPRM was close to completing that process, as substantial world-wide support had been expressed for its parts, and the proposal was fully consistent with the requirements of the National Traffic and Motor Vehicle Safety Act.

The second SNPRM continued to address the adhesion utilization (AU) issue. After considerable testing[9], analysis, consultations with the other representatives of the GRRF, and significant resources and time devoted to the above, the agency proposed a two-level testing

[8]"Harmonization of Brake Regulations - Report No. 5: Testing for Development and Evaluation of the Proposed Supplemental Notice of Proposed Rulemaking on Harmonization of Passenger Car Brake Standards", Flick, M.A. and Radlinski, R.W., Vehicle Research and Test Center, East Liberty, OH, May, 1987, Docket No. 85-06-NO4-009.

[9]"Harmonization of Braking Regulations - Report No. 7: Testing to Evaluate Wheel Lock Sequence and Torque Transducer Procedures", Flick, M.A., Vehicle Research and Test Center, East Liberty, OH, February, 1990.

method: a screening test using a simple Wheel Lockup Sequence (WLS) test procedure for qualitative spot-checks of brake balance, and contingent upon the result of that test, a possible follow-on Torque Wheel (TW) procedure. Vehicles consistently showing front brake bias during the WLS screening test would be deemed to pass the AU requirements and would not be required to undergo TW testing. It was expected that most future vehicle models needing to comply with FMVSS No. 135 would fall into this category, thus minimizing the new burden of AU compliance testing.

Most cars meeting FMVSS No. 105 are already predominantly front-biased. However, slight brake design modifications may be needed by some of the manufacturers to insure they comply with the new braking stability/adhesion utilization requirements. This shift toward more front-biased braking would tend to reduce the overall braking efficiency of a vehicle which would tend to increase stopping distance. Therefore, to be able to meet the adhesion utilization requirements for a given model, the necessary modifications may result in some slight increase in stopping distance for that model.

An increase in stopping distance is not desirable in itself, but a possible slight increase for some vehicles is deemed a justifiable, favorable trade-off for improved vehicle directional stability, and associated improved crash avoidance capability. Although the potential influence on accident statistics is difficult to assess, stability during braking is recognized world-wide as a very beneficial component of overall highway safety, especially on slippery road surfaces.

Another modification proposed in the second SNPRM was the use of peak friction coefficient (PFC) values rather than skid number (SN) values for the characterization of road surfaces; this was proposed because PFC has been found to be a more appropriate parameter for characterizing vehicle stopping capability for braking without wheel lockup. The PFC value for a surface is established using the E 1136 standard reference test tire and test Method F-408-81, both of the American Society for Testing and Materials (ASTM).

An additional new test, a modification of the antilock brake test from Annex 13 of ECE R.13, was also proposed in the S7.3 Antilock Brake System (ABS) Performance. However, the NHTSA proposal called for the use of split coefficient of friction surfaces, rather than requiring efficiency measurements and stopping distance performance. It was initially believed that this test could evaluate the capability of ABS to compensate for changes in surface conditions that are similar to those encountered in everyday driving conditions.

D. Final Rule

The stopping distance formulas have changed numerous times through the rulemaking process. The stopping distance formulas now specified in the Final Rule use the same reaction times as the ECE and other foreign brake regulations, and should be found acceptable to most parties. The final stopping distances are summarized in Table III-3. The stopping distance (S) requirements (in meters), are expressed in equation form; the first term represents brake reaction time, and the second term represents an assumed, mean, fully developed deceleration rate, while V represents test speed (in km/hr).

Table III-3 ADJUSTED FINAL RULE STOPPING DISTANCE REQUIREMENTS

Stopping from 100 km/h	(m)	(ft)	(S)
Cold effectiveness	70	230	$0.10V + 0.0060V^2$
High speed effectiveness *			$0.10V + 0.0067V^2$
Stops with engine off	70	230	$0.10V + 0.0060V^2$
Antilock functional failure	85	279	$0.10V + 0.0075V^2$
Variable brake proportioning valve failure	110	361	$0.10V + 0.01V^2$
Hydraulic circuit failure	168	551	$0.10V + 0.0158V^2$
Brake power assist failure (system depleted)	168	551	$0.10V + 0.0158V^2$
Hot performance	89	292	$0.10V + 0.0079V^2$
Recovery performance			**

* Test Speed 80% of V_{MAX} up to 200km/h (124.3mph) or 160km/h (99.4mph) if V_{MAX} is over 200km/h.
** Between 70-150% of the stopping distance achieved during the best GVWR cold effectiveness stop

Because several issues concerning the evaluation of ABS performance and criteria have yet to be resolved, the agency has decided to delete Section S7.3, ABS Performance, from the FMVSS No. 135 Final Rule. As required by the Highway Safety Act of 1991, Section 2507, NHTSA published an Advanced Notice of Proposed Rulemaking to consider the need for additional brake performance standards for passenger cars, including ABS (59 FR 281, January 4, 1994). This evaluation effort will include passenger cars, light trucks, and multi-purpose passenger vehicles. In light of this effort, the agency has removed Section S7.3, ABS Performance, from the Final Rule until all issues are investigated in the research program. The FMVSS No. 135 Final Rule test sequence is presented below in Table III-4. For more detailed discussion of the technical issues, see the various Notices: NPRM, 1st SNPRM, 2nd SNPRM and the Final Rule.

Table III-4

FMVSS No. 135 FINAL RULE TEST SEQUENCE

Vehicle loaded to GVWR:
- Burnish (instrument check & stops; 200 80 km/h @ 3 m/sec^2)
- Wheel Lock Sequence (Non-ABS cars, braking ratios between .15 &.8)

Vehicle loaded to LLVW:
- Wheel Lock Sequence (Non-ABS cars, braking ratios between .15 &.8)
- Torque Wheel Test (contingent on WLS result)

Vehicle loaded to GVWR:
- Torque Wheel Test (contingent on WLS result)
- Cold effectiveness
- High speed effectiveness
- Stops with engine off

Vehicle loaded to LLVW:
- Cold effectiveness
- High speed effectiveness
- Partial system failure:
  - Failed antilock (if applicable)
  - Failed variable proportioning valve (if applicable)
  - Hydraulic circuit failure

Vehicle loaded to GVWR:
- Partial system failure:
  - Hydraulic circuit failure
  - Failed antilock (if applicable)
  - Failed variable proportioning valve (if applicable)
  - Inoperative brake power assist or brake power unit
  - Static Parking brake performance (20% gradient hold)
- Fade and recovery:
  - Heating snubs
  - Hot performance
  - Brake cooling
  - Recovery performance
  - Final inspection

(PFC$\geq$0.9 road surface, unless otherwise noted)

IV. COSTS

Cost impacts that result from the adoption of FMVSS No. 135 consist of small test cost differences between the new standard and FMVSS No. 105 and some possible minor cost impacts associated with the redesign of some marginal brake systems.

Contractor cost proposals for FMVSS No. 105 compliance tests provide the baseline for NHTSA's compliance cost estimates associated with the FMVSS No. 135 Final Rule. The overall compliance test cost for the final version of FMVSS No. 135 should be slightly less than the cost for FMVSS No. 105, because slightly more testing has been eliminated than has been added. The agency does not expect the revised test surface specification used in FMVSS No. 135 to add any costs beyond those already incurred during FMVSS No. 105 testing. If TW tests are necessary, the PFC requirement of at least 0.9 is usually met by surfaces that have a Skid Number of 81, as currently already specified in FMVSS No. 105. Also, no costs should result from the use of different surfaces for the WLS testing, because, the agency believes adequate test surfaces are already available. No commenters made statements concerning the construction and maintenance of new test surfaces. The costs associated with the eliminated and additional tests are discussed below.

Compliance Test Cost Impacts of FMVSS No. 135 vs. FMVSS No. 105

The FMVSS No. 105 compliance test procedures were previously listed in Table III-1. The test sequence for the final version of FMVSS No. 135 were shown in Table III-4.

Table IV-1 provides the manpower requirements, hourly labor rates, overhead rate, and other expenses associated with a single FMVSS No. 105 compliance test sequence, as presented in the PRE and expressed in 1985 dollars. FMVSS No. 105 compliance tests cost $3,855 in 1985. In 1995 the NHTSA Office of Vehicle Safety Compliance also contracted FMVSS No. 105 compliance tests for a cost of $3,885. Since the 1985 and 1994 compliance test costs are the same the agency will continue to use the 1985 labor rates published in the PRE. All cost estimates beyond Table IV-1 will be expressed in 1995 economics.

Table IV-1
1985 FMVSS No. 105 Compliance Testing Sequence Costs

Sequence	Manpower Requirements	(Hours)	Hourly Rate	Total Direct Labor Cost
Project Initiation	Manager	- 1	13.96	$ 13.96
	Engineer	- 8	17.43	139.44
	Technician	- 1	8.93	8.93
Inspection	Mechanic	- 1	9.60	9.60
Tune-Up to Manufacturing Specs	Mechanic	- 1	9.60	9.60
Front Alignment	Mechanic	- 1	9.60	9.60
Ballast Vehicle	Technician	- 3	8.93	26.79
Begin Instrumentation Installation	Instrumentation Tech	- 2	11.03	22.06
				$239.98
Complete Instrumentation Installation	Instrumentation Tech	- 6	11.03	$ 66.18
	Special Tester	- 2	7.03	14.06
Instrumentation Check	Instrumentation Tech	- 2	11.03	22.06
	Special Tester	- 2	7.03	14.06
Brake Inspection	Mechanic	- 1	9.60	9.60
	Special Tester	- 3	7.03	21.09
First Effectiveness Test (Pre-burnish)	Special Tester	- 1	7.03	7.03
Burnish (Third Shift)	Special Tester	- 8	7.03	56.24
	Engineer	- 2	17.43	34.86
				$245.18
Brake Adjustment	Special Tester	- 1	7.03	7.03
Second Effectiveness	Special Tester	- 1	7.03	7.03
First Reburnish	Special Tester	- 1	7.03	7.03
Parking Brake	Special Tester	- 5	7.03	35.15
	Engineer	- 1	17.43	17.43
				$73.67
Third Effectiveness	Special Tester	- 1	7.03	7.03
Partial Failure	Special Tester	- 7	7.03	49.21
	Engineer	- 1	17.43	17.43
				$ 73.67
Inoperative Brake Power & Assist Units	Special Tester	- 3	7.03	$ 21.09
First Fade and Recovery	Special Tester	- 1/2	7.03	3.515
Second Reburnish	Special Tester	- 1	7.03	7.03
Second Fade and Recovery	Special Tester	- 1/2	7.03	3.515
Third Reburnish	Special Tester	- 1	7.03	7.03
Fourth Effectiveness	Special Tester	- 1	7.03	7.03
Water Recovery	Special Tester	- 1	7.03	7.03
	Engineer	- 2	17.43	34.86
				$ 91.10
Spike Stops	Special Tester	- 5	7.03	35.15
	Instrumentation tech	- 2	11.03	22.06
Final Inspection	Special Tester	- 3	7.03	21.09
	Engineer	- 2	17.43	34.86
				$113.16
Moving Barrier	Instrumentation Tech	- 2	11.03	22.06
	Engineer	- 2	17.43	34.86
				$ 56.92
Final Report	Engineer	- 8	17.43	139.44
	Manager	- 2	13.96	27.92
				$167.36
	Total Manpower;			
	Direct Labor			$1,061.04
	Total Indirect Labor			$ 466.96
	Total Labor Cost			$1,528.00
	Labor Overhead (0.70x$1,528)			$1,070.00
	General Administrative and Profit			$1,257.00
	Total Cost			$3,855.00

The first difference between the standards is the elimination of the Pre-burnish Effectiveness test which consisted of 6 stops from 30 mph followed by another 6 stops from 60 mph. Elimination of this requirement saves a Special Tester man-hour, at the rate of $7.03 per hour direct labor.

Adhesion Utilization (AU) testing represents additional testing beyond FMVSS No. 105 to assure vehicle directional stability during braking. AU testing will not be conducted on vehicles equipped with anti-lock brake systems (ABS), because ABS prevents sustained wheel lock-up in these vehicles and, therefore, these vehicles already exhibit good braking stability. Based on domestic and import light vehicle data[10], the agency determined that 40.4% of the 1993 model year (MY) U.S. passenger car fleet was equipped with ABS. Automotive News[11] also predicts 100% usage of ABS by the year 2000. Since this Final Rule has a five year leadtime, the agency anticipates that 100% of all passenger cars will be equipped with ABS by the 2001 model year effective date. Therefore, none of the 2001 MY passenger cars (non-ABS-equipped) would be required to be tested to the adhesion utilization requirements. Therefore, there would not be any non-ABS-equipped cars sold in 2001 contributing to the WLS and TW test costs in the Direct Compliance Cost Summary (See Table IV-2).

[10] Automotive News Market Data Book 1994, May 25, 1994

[11] Automotive News, March 25, 1991, pg 6i

The WLS test requires a minimum of 12 to a maximum of 24 test runs to evaluate two vehicle loading conditions and two test speeds, to ensure that lockup of both front wheels occurs either simultaneously with, or at a lower deceleration rate than, the lockup of both rear wheels. A vehicle may take as few as six runs or as many as 24 to fail the WLS. The agency estimates that WLS tests add an additional two man-hours of Special Tester time at $7.03 per hour and one-half hour of Engineer time at $17.43 per hour beyond the basic FMVSS No. 105 tests, because the vehicle has already been instrumented to perform other service brake tests. Therefore, vehicles undergoing the WLS tests incur $22.78 in additional direct labor charges [($7.03 X 2) + ($17.43 X .5)].

A vehicle may pass the AU requirements by either of two methods, a Wheel Lock Sequence (WLS) test or a Torque Wheel (TW) test. A slightly rear-biased vehicle that fails the WLS can still demonstrate safe braking directional stability by passing the Torque Wheel (TW) test. The attractive feature of the combined WLS/TW Adhesion Utilization test requirement is that, without compromising safety, the TW test will not be needed for many manufacturers' vehicles, and is expected to be only rarely needed. The agency expects the vast majority (at least 95%) of WLS-tested vehicles will meet the performance requirements. Therefore, only 5% of the vehicles tested to the WLS requirements are expected to fail that test and to contribute TW testing costs in the Direct Compliance Cost Summary.

Torque wheel measurements are used to determine the vehicle brake factor characteristics and develop the vehicle's adhesion utilization (AU) curves. From these AU curves, the directional stability of the vehicle over the full range of braking conditions can be determined. The TW test requires a total of 20 runs to plot 4 AU curves. Data reduction and analysis are highly automated. (The floppy disc from the on-board digital computer is transferred to the laboratory for further computer analysis and plotting of the AU curves.) The agency estimates TW tests require: 3.5 hours of Instrumentation Technician time at a rate of $11.03 per hour to install, calibrate and remove the torque wheels and associated equipment; plus 2 man-hours of Special Tester time at $7.03 per hour. Thus the direct labor cost of conducting a TW test is $52.67 [(3.5 X $11.03) + (2 X $7.03)].

The need to use the torque wheel procedure will involve capital equipment and facilities costs, and its use incurs some small expenditure of direct labor. A set of four torque wheels is expected to cost about $40,000, which includes adapters to accommodate varying wheel mounting bolt patterns. Each on-board digital data acquisition system for the torque wheels is estimated to cost about $15,000.

For those manufacturers who would need torque wheels, the equipment would represent a negligible cost per vehicle, and, in turn, a negligible cost to the consumer when amortized over five years of vehicle production (average torque wheel life). For example, a major manufacturer of 500,000 vehicles per year would probably buy five complete torque wheel/computer sets. This would result in a unit cost increase of $0.10 to $0.16 per car. However, many manufacturers expect no need for or already have torque wheels and will not incur any equipment cost increase.

On the other hand, type-approval authorities would be in a different situation as they are not normally budgeted for the purchase and maintenance of expensive equipment. To avoid this burden, they would probably have to require the vehicle manufacturer seeking certification approval to somehow provide the torque wheels and necessary instrumentation.

Preparation of vehicles for the TW procedure can be accomplished in the same facility where the vehicles are normally prepared for compliance testing, and the TW procedure can be performed on the same high PFC road test surface that is normally used for the various stopping distance tests.

The Final Rule states that tests, unless otherwise specified, are to be conducted on surfaces with a PFC of 0.90 or more, when tested with the E 1136 standard reference test tire; whereas FMVSS No. 105 requires that tests be conducted on surfaces with an SN of 81, when tested with the E 501 reference tire. The cost differential between the E 1136 and the E 501 tires is negligible.

The Final Rule also designates the use of the ASTM E-1337-90 test procedure, which is currently used by the industry to measure PFC values. The E-1337-90 procedure involves the use of a Traction Trailer and associated equipment and instrumentation. However, the PFC specification does not necessarily mean that manufacturers and independent test track operators would have to secure the availability of a new Traction Trailer system, if they did not already employ one, to periodically check the characteristics of their test pad surfaces. The agency believes it is not necessary to check compliance with the PFC requirement frequently; therefore, there should not be any associated cost impact.

The Cold Effectiveness and High Speed Effectiveness Tests in FMVSS No. 135 require fewer stops than the 2nd, 3rd and 4th Effectiveness Tests in FMVSS No. 105. FMVSS No. 135 has a total of 30 effectiveness and engine-off test stops as compared to 42 effectiveness test stops for FMVSS No. 105. The 12 fewer stops in the FMVSS No. 135 test sequence represents about one man-hour of Special Tester time at an hourly rate of $7.03. Therefore, FMVSS No. 135 saves about $7.03 in direct labor for effectiveness testing.

FMVSS No. 135 has added some tests to the FMVSS No. 105 Partial System Failure test sequence. These new Partial System Failure tests include: Failed Antilock (6 additional stops @ GVWR & 6 stops @ LLVW), Failed Variable Proportioning Valve (6 stops @ GVWR & 6 stops @ LLVW), 6 additional Inoperative Brake Power Assist stops @ GVWR, plus 6 stops with the engine off.

The agency estimates that the 12 Failed ABS stops would require about one man-hour of Special Tester time at an hourly rate of $7.03, thus $7.03 in direct labor. As previously mentioned, the agency anticipates that 100% of all passenger cars will be equipped with ABS in the 2001 MY. Therefore, all those vehicles equipped with ABS will impact the Failed Antilock testing costs in the Direct Compliance Cost Summary.

The agency also estimates that the 12 Failed Variable Proportioning Valve (VPV) stops would also cost about the same $7.03 in direct labor costs. However, the agency expects the number of new passenger cars equipped with variable proportioning valves will continue to be less than 1% of the total population. Since less than 1% of vehicles are equipped with VPVs, the percentage is not large enough to impact the Direct Compliance Cost Summary, and the overall cost for Failed VPV testing is assumed to be negligible.

The agency further estimates that the 6 additional Inoperative Brake Power Assist stops and 6 engine off stops would cost about $7.03 as a result of one hour of Special Tester time. While power assist is not a mandatory requirement, the agency believes that virtually all passenger cars sold in the U.S. currently in production have this feature, thus 100% of all passenger cars are affected in the Direct Compliance Cost Summary.

FMVSS No. 135 and 105 have similar static parking brake performance requirements, Fade and Recovery test requirements, and Hydraulic Circuit Failure requirements; therefore, they have about the same associated direct labor costs.

The Water Recovery Test has been eliminated from FMVSS No. 135. Elimination of this requirement saves a Special Tester man-hour, at the rate of $7.03 per hour, direct labor.

Spike Stop Testing has also been eliminated from the final version of FMVSS No. 135. Elimination of this test saves 5 Special Tester man-hours @ $7.03 per hour and 2 Instrumentation tech man-hours @ $11.03 per hour. Therefore, elimination of the spike stop testing saves about $57.21 additional direct labor charges [($7.03 X 5) + ($11.03 X 2)].

The Moving Barrier Parking Brake Test (MBPBT) has not been included in FMVSS No. 135. Elimination of this test saves 2 instrument technician man-hours @ $11.03 per hour and 2 project engineer man-hours @ $17.43 per hour. Therefore, elimination of the moving barrier test saves about $56.92 additional direct labor charges [($11.03 X 2) + ($17.43 X 2)]. However, FMVSS No. 105 does not require vehicles that have already passed the static parking brake test, to also pass the MBPBT. The NHTSA Office of Vehicle Safety Compliance reports that 0 MBPBTs were conducted during compliance tests of the 1988-94 MYs, because all the vehicles passed the static parking brake test. Informal conversations with several major manufacturer representatives also verified that it is not the industry practice to use the MBPBT, because they design their parking brake systems to pass the static test. Therefore, elimination of the MBPBT test would not result in any cost savings to the manufacturers.

Direct Compliance Test Cost Summary

To summarize, the agency has estimated the net compliance test cost savings by comparing the direct labor cost of FMVSS No. 105 with the estimated cost of FMVSS No. 135 test requirements multiplied by the percentage of vehicles that require testing. These net compliance test costs are presented in Table IV-2.

Table IV-2 Direct Compliance Test Cost Summary

Eliminate the Pre-burnish Effectiveness test	- $ 7.03
Add Adhesion Utilization Testing (Wheel Lock Sequence)	+ $22.78 x 0%*
Add Adhesion Utilization Testing (Torque Wheel)	+ $52.67 x 0%* X 5%**
Reduced Effectiveness Testing	- $ 7.03
Additional Failed Antilock Tests	+ $ 7.03
Additional Inoperative Brake Power Assist & Engine Off Tests	+ $ 7.03
Eliminate Water Recovery Test	- $ 7.03
Eliminate Spike Stop Testing	- $57.21
Eliminate Moving Barrier Parking Brake Test (MBPBT)	- $56.92 X 0%***

Net testing cost decrease	$64.24

* The agency anticipates all 2001 MY cars will be equipped with ABS, thus not requiring WLS and TW testing.

** The agency assumes 5% of the test vehicles will not Pass the WLS test

*** The MBPBT provides an alternative way to pass parking brake performance requirements. However, the agency believes that no vehicles were actually tested by this method during the 1988-93 by either the government or manufacturers. Therefore, eliminating the optional tests does not create any actual cost savings.

The above table estimates that the direct labor cost of the FMVSS No. 135 compliance test sequence will be $64.24 less than FMVSS No. 105. The total compliance test cost includes: indirect labor, labor overhead, general administrative costs and profit, which can be up to 3 times the actual direct labor cost. Therefore, the total FMVSS No. 135 cost savings could be as much as $256 = ($64 x 4). However, since some of these overhead, administrative and other costs are fixed costs, which do not vary depending upon hours of testing, the $256 is higher than the total potential cost savings. The agency will use $256 as the upper end of the range of cost savings, because the agency does not know the breakout between fixed and variable costs.

Actual FMVSS 135 test sequences conducted at VRTC resulted in about an eight man-hour time savings compared to the FMVSS 105 test sequence, which compares favorably with the savings in Table IV-2. In summary, the agency believes that the proposed full test procedure will take slightly less time and therefore cost slightly less to complete as compared to FMVSS No. 105. Since manufacturers need only conduct specified series of tests once for a given make/model and brake system specification, the average savings per vehicle are negligible.

In addition to the above test and facilities expenses, which directly affect a few test vehicles but amortize over a very large number of production vehicles, manufacturers may also incur some other minor costs. First, manufacturers may incur some limited hardware expenses; however, the agency believes that these limited expenses will not impose any significant cost impacts. The new adhesion utilization requirements may require some manufacturers to adjust the brake balance of some of their vehicle models to be slightly more front-biased. For example, some manufactures may change the brake balance by altering the existing brake proportioning, or increasing the front brake torque capability via slightly larger brakes or more aggressive front brake pads. However, the agency expects any corresponding design and hardware changes to be quite minor. In any case, the substantial leadtime proposed for mandatory compliance with the new requirement, should enable manufacturers to incorporate necessary changes as part of routine model changes. The impacts on manufacturers as well as smaller supplier and user entities have, therefore, been minimized.

The increase in stringency for the performance of hand applied parking brake systems and the stopping distance for a partial failure of the service brake system were identified and discussed in the PRE. The agency expects that some engineering and redesign costs may result from these requirement changes. Hand brake design and engineering changes would probably be limited to lengthening the lever arm to gain a greater mechanical advantage. Design and engineering changes related to improved partial failure of the brake system stopping distance might include increasing the mechanical advantage of the base brake system. However, the agency does not expect that these will result in significant cost increases since manufacturers will have five years of leadtime, and any changes can typically be incorporated in the normal model changeover cycle.

The agency has analyzed the adopted, new Federal Motor Vehicle Safety Standard No. 135 and has determined that it is neither "significant" within the meaning of Executive Order 12866 nor within the meaning of DOT regulatory policies and procedures. However, the new standard should aid efforts to harmonize vehicle safety standards worldwide.

V. BENEFITS

The primary objective of FMVSS No. 135 is to eliminate any non-tariff trade barriers that have been caused by differing passenger car brake standards in the U.S. and other countries. The harmonization process essentially involved the blending of various aspects from FMVSS No. 105 and ECE R.13, while maintaining equivalent levels of stringency between new and current standards. Thus, any vehicle that would meet FMVSS No. 105 and ECE R.13 should not have to be significantly modified to comply with the new international standard.

This harmonized brake standard has the potential to simplify the brake design/development of world market passenger cars, thereby lowering research and compliance test costs, while providing further savings from economies of scale. Most of the possible benefits were already identified in the Preliminary Regulatory Evaluation (PRE)[2]. The PRE acknowledges how FMVSS No. 105 has been successful in substantially upgrading brake performance and improving vehicle accident prevention capability. Accordingly, the performance requirements carried over from FMVSS No. 105 into the new rule are either equivalent or slightly more stringent, to assure the present level of vehicle safety is maintained.

The most significant improvement of FMVSS No. 135 over FMVSS No. 105 is the addition of the adhesion utilization requirements. The Wheel Lock Sequence (WLS) and Torque Wheel (TW) tests now provide a requirement for vehicle directional stability during braking. Braking directional stability is minimally addressed by current FMVSS No. 105 on high coefficient of friction surfaces, in that the vehicle must remain within a 12 foot wide lane during the braking effectiveness tests. However, such a requirement does not totally insure against rear bias even on high coefficient of friction surfaces, and does not even attempt to evaluate front versus rear bias on low coefficient of friction surfaces, since no tests are conducted on those surfaces. The adhesion performance requirements in FMVSS No. 135 are basically equivalent to those in ECE R13. A vehicle that meets the new AU requirements should have a greater accident avoidance capability than a vehicle that does not, but the agency has no way of quantifying how much the capability would be enhanced by implementing such requirements. It is believed that most passenger cars have and will continue to possess adequate front bias. Thus, the AU requirements should only serve to improve a limited number of make/models that do not exhibit adequate front bias.

Heat fade and recovery tests provide assurance that the brake systems can endure the high temperatures caused by severe and prolonged use and still function adequately. Both FMVSS Nos. 105 and 135 have heat fade and recovery performance requirements. However, FMVSS No. 135 includes an additional hot stopping distance requirement. The first of two hot stops is based on the average pedal force recorded during the shortest GVWR cold effectiveness stop, and the second stop is performed with a pedal force no greater than 112.4 lbs (500 N). This additional requirement might be perceived as slightly more stringent than FMVSS No. 105. As such, the additional requirement may provide some benefit by further insuring adequate resistance to brake fade, but the agency has no way of quantifying the benefit derived from this slight increase in stringency.

Both FMVSS No. 105 and 135 have partial hydraulic failure requirements. FMVSS No. 105 requires a vehicle to be able to stop in not more than 456 ft. (139 m) from an initial speed of 60 mph with a partial circuit failure, at both GVWR and LLVW, and within 4 stops for split brake systems and 10 stops for non-split brake systems. FMVSS No. 135 requires the vehicle to be able to stop from 62.1 mph (100 km/h) in 551 ft. (168 m) with a partial circuit failure at both load conditions, within 4 stops for split brake systems and 10 stops for non-split brake systems. FMVSS No. 105 allows a pedal force of 150 lbs. (667 N) versus a FMVSS No. 135 pedal force of 112.4 lbs (500 N). The agency believes the new FMVSS test speed and pedal force represents a justified slight increase in stringency. The partial hydraulic failure requirement continues to assure vehicle drivers that they can still stop the vehicle, although at a longer distance, after a hydraulic failure. However, the agency has no way of quantifying the benefit derived from this possibly overall slight increase in stringency.

Both FMVSS No. 105 and 135 have power boost failure requirements. Power boost failures can be either the power boost mechanism or the source of power to the booster. FMVSS No. 105 has requirements for the power boost mechanism, while FMVSS No. 135 has requirements for both the mechanism and the power source. FMVSS No. 105 requires a vehicle to be able to stop in not more than 456 ft. (139 m) from an initial speed of 60 mph with a failed power booster at GVWR, within 6 stops. FMVSS No. 135 requires the vehicle to be able to stop from 62.1mph (100 km/h) in 551 ft. (168 m) with a failed power booster at GVWR, within 6 stops. FMVSS No. 105 allows a pedal force of 150 lbs. (667 N) versus a FMVSS No. 135 pedal force of 112.4 lbs (500 N). FMVSS No. 135 also adds the test requirement that the vehicle be capable of stopping in 230 ft. (70 m) from 62.1mph (100 km/hr) with the engine not running. The agency believes the new requirements represent a justified slight increase in stringency.

The power boost failure requirement continues to assure vehicle drivers that they can still stop the vehicle if the power boost mechanism fails or loses power. The agency also believes that the addition of the engine-off test is reasonable and necessary for safe vehicle operation, since engine stalling is a fairly common occurrence. However, the agency has no way of quantifying the benefit derived from this slight increase in stringency or from the additional engine off test requirement.

VI. LEADTIME

The agency is specifying an effective date for the new Final Rule of five years after it is published. Manufacturers have the option of complying with the Final Rule, instead of FMVSS No. 105, thirty days after its published. With five years of leadtime, manufacturers should have sufficient time to redesign and verify that their vehicles meet the requirements.

The new adhesion utilization requirements might require some manufacturers to adjust the brake balance of some of their vehicle models to be slightly more front-biased. However, the corresponding design and hardware changes are expected to be quite minor. But, as noted in the cost section, the agency anticipates all passenger cars will be ABS-equipped by the 2001 model year, and therefore will not be required to meet the adhesion utilization requirements.

In any case, the substantial five year leadtime specified for implementing all changes, if any are necessary, should enable manufacturers to schedule them as part of routine model changes. Thus, manufacturers as well as smaller supplier and user entities have substantial leadtime.

VII. SMALL BUSINESS IMPACTS

The Regulatory Flexibility Act of 1980 (Public Law 96-354) requires agencies to evaluate the potential effects of their proposed and final rules on small businesses, small organizations, and small governmental jurisdictions.

Business entities are defined as small by the Standard Industrial Classification (SIC) for purposes of receiving Small Business Administration assistance. One of the criteria for determining size is stated in 13 CFR 121.601 (as of January 1994) is the number of employees in the firm. For passenger vehicle/brake manufacturers (SIC 3711), the firm must have fewer than 1,000 employees to be considered a small business. The agency has checked the size of several passenger vehicle/brake manufacturers and found them to have more than 1,000 employees; thus they are not considered small businesses.

In accordance with the Regulatory Flexibility Act, NHTSA has evaluated the possible effects of FMVSS No. 135, and it has determined that it would not likely have a significant impact on a substantial number of small entities.

REFERENCES

1./ "Federal Motor Vehicle Safety Standard, Hydraulic Brake Systems, Passenger Car Brake Systems, Notice of Proposed Rulemaking", NHTSA, Office of Rulemaking, 49 CFR 571, Vol.50, No.91, pp. 19744 -19760, May 10, 1985, Docket No. 85-06; Notice 1.

2./ "International Braking Standard for Passenger Cars, Preliminary Regulatory Evaluation", NHTSA, Office of Plans and Policy, March, 1985, Docket No. 85-06-N01-001.

3./ "Summary of Comments to Docket No. 85-06; Notice 1 on the Proposed FMVSS 135 for Passenger Car Brake Systems", NHTSA, Office of Rulemaking, May 20, 1986, Docket No. 85-06-N01-025.

4./ "E/ECE/324 E/ECE/TRANS/505 - Rev.1/Add.12/Rev.2 - Addendum 12 (March 1980)"

5./ "Federal Motor Vehicle Safety Standards, Hydraulic Brake Systems, Passenger Car Brake Systems, Supplemental Notice of Proposed Rulemaking", NHTSA, Office of Rulemaking, 49 CFR 571, Vol. 52, No. 9, pp. 1474 -1494, January 14, 1987, Docket No. 85-06; Notice 4.

6./ "Harmonization of Braking Regulations - Report Number 4: Testing to Address Issues Raised During Development of the NPRM", Flick, M.A. and Radlinski, R.W., Vehicle Research and Test Center, East Liberty, OH, July, 1985.

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8./ "Harmonization of Brake Regulations - Report No. 5: Testing for Development and Evaluation of the Proposed Supplemental Notice of Proposed Rulemaking on Harmonization of Passenger Car Brake Standards", Flick, M.A. and Radlinski, R.W., Vehicle Research and Test Center, East Liberty, OH, May, 1987, Docket No. 85-06-NO4-009.

9./ "Harmonization of Braking Regulations - Report No. 7: Testing to Evaluate Wheel Lock Sequence and Torque Transducer Procedures", Flick, M.A., Vehicle Research and Test Center, East Liberty, OH, February, 1990.

10./ "Automotive News Market Data Book 1994," May 25, 1994.

11./ "Automotive News," March 25, 1991, pg 6i.