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Evaluation of Hydraulic Brake System Tests of Used 1973 and 1978 Vehicles

Standard 105-75 - Hydraulic Brake Systems, Passenger Cars

Plans and Programs
Office of Program Evaluation

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16. Abstract

This is the first in a series of evaluative analyses on vehicle braking systems as they relate to the requirements of Federal Motor Vehicle Safety Standard (FMVSS) 105, Hydraulic Brake Systems. It deals with the effect of aging on braking performance and that of brake maintenance. The study looks only at the standard for passenger cars and focuses on the current version of the standard, FMVSS 105-75.

The primary purpose of this study was to compare post-standard vehicles' performance on the compliance test with that of used pre-standard vehicles. In order to make these comparisons between pre- and post-105-75 cars, five 1973 (pre-standard) and five 1978 (post-standard) vehicles were chosen for study. Each of the ten vehicles was subjected to the FMVSS 105-75 compliance test "as is" and with original equipment equivalent replacement linings. Additionally, the 1978 cars were retested with an aftermarket lining. The tests were run to determine the best stopping distances obtainable.

The results indicate that used post-105-75 cars perform better than used pre-105-75 vehicles on the standard's compliance test. More importantly, the 1978's performed better than the 1973's in terms of stopping distance both when the vehicles were tested "as is" and when they were tested with replacement linings. Replacing the linings on used vehicles improved their stopping distance performance, but the improvement was not as pronounced for the 1973's as it was for the 1978's. Original equipment linings and one aftermarket lining tested were found to be equally successful in improving the stopping distance performance of used post-standard cars.

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METRIC CONVERSION FACTORS

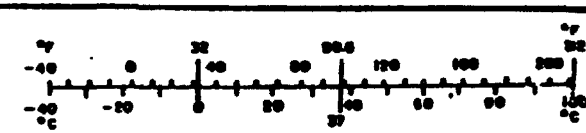
Approximate Conversions to Metric Measures

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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EXECUTIVE SUMMARY

This is the first in a series of evaluative analyses on vehicle braking systems as they relate to the requirements of Federal Motor Vehicle Safety Standard 105, Hydraulic Brake Systems. It deals with the effect of aging on braking performance. An analysis based on police accident data is presently underway, and its results will be presented in a subsequent report. Both studies look only at the brake standard for passenger cars.

This study focuses on the current version of the brake standard, Federal Motor Vehicle Safety Standard (FMVSS) 105-75. The standard evolved from a basic requirement first published in 1967, to a highly specific regulation which became effective on January 1, 1976. FMVSS 105-75 expresses requirements in terms of maximum stopping distance and number of stops at specified speeds. This version of the standard greatly expands performance requirements, including testing for partial system failure.

The primary purposes of this study were to examine post-standard vehicles' ability to continue to comply with the requirements of FMVSS 105-75 when they are no longer new and to compare their performance on the compliance test with that of used pre-standard vehicles. In order to make these comparisons between pre- and post-105-75 cars, five 1973 (pre-standard) and five 1978 (post-standard) vehicles were chosen for study.

Each of the ten vehicles was first subjected to the FMVSS 105-75 compliance test procedure "as received." Following the test, new original equipment wheel cylinders were installed on the ten vehicles. The five 1978 vehicles were then tested with an aftermarket replacement lining. Finally, all ten cars were retested with original equipment equivalent linings. Tires were replaced on all vehicles prior to the "as received" test. The compliance tests were run to determine the best stopping distance obtainable in addition to whether the vehicles passed or failed.

Findings

The results indicate that used post-105-75 cars perform better than used pre-105-75 vehicles on the standard's compliance test. While none of the 1973 cars could comply "as is", over half of the 1978's did. (Of course, the 1973's were not required to comply even when they were new.) More importantly, the 1978's performed significantly better than the 1973's in terms of stopping distance both when the vehicles were tested "as is" and when they were tested with replacement linings. Replacing the linings on the used vehicles improved their stopping distance performance, but the improvement was not as pronounced for the 1973's as it was for the 1978's. Original equipment equivalent linings and the one brand of aftermarket lining tested were found to be equally successful in improving the stopping distance performance of used post-standard cars. No pattern could be discerned from a comparison of new vehicle data from the compliance test program and the used vehicles' test data due to the differences in the testing methods used.

Certain factors should be kept in mind in using these results. First, they are only test results. A subsequent analysis, based upon vehicles' on-the-road experiences, will examine the standard's effectiveness in more detail. Second, the sample tested is not a statistically valid one and may not reflect what is true for the entire vehicle population. A third factor is that the 1973 vehicles are five years older than the 1978's. Discrepancies between the levels of performance of the two model year vehicles may in part be explained by the further deterioration of the 1973 cars. However, the used vehicles selected for testing were inspected to assure that there were: no brake fluid leaks and no indication of contamination of brake linings or pads, drums or discs; no braking or suspension components were beyond the manufacturer's recommended service limit; the vehicle had an up-to-date periodic motor vehicle inspection sticker less than one-year old; and the vehicle had sufficient brake lining to complete the 105-75 tests. In studies of brake-system component degradation (Component Degradation: Braking System, DOT-HS-801-250, November 1974) the most significant item affecting performance cited is contamination - most other items such as thin friction materials, proportioning, drum/disc wear, and imbalance are of much less importance.

1.0 Introduction

This is the first in a series of evaluative analyses on vehicle braking systems as they relate to the requirements of Federal Motor Vehicle Safety Standard 105, Hydraulic Brake Systems. It deals with the effects of aging on braking performance. An analysis based on police accident data is presently underway, and its results will be presented in a subsequent report. Both studies look only at the brake standard for passenger cars, but it is anticipated that other vehicle types, e.g., light trucks, will be included in later studies when data are available.

Two problem areas -- the effect of degradation on braking performance and that of brake maintenance -- will be examined in detail here through the use of a vehicle testing program. Previous research has been conducted on the effects of degradation of individual brake parts, but the overall effects of degradation on braking performance have not been determined.

While it is assumed that vehicles manufactured after the effective date of the standard have better braking performance than vehicles built before the standard, when both are new, little is known about how pre- and post-standard vehicles fare after they are put into use. In evaluating the effectiveness of the brake standard, it is important to compare the performance of used vehicles -- pre-standard with post-standard. If post-standard cars in everyday driving have better braking performance than pre-standard cars, it is reasonable to expect reductions in brake-involved accidents over pre-standard cars.

Braking performance of used pre- and post-standard cars was measured using standard 105-75's test procedure with which post-1975 cars must comply. Using the compliance test procedure had several advantages: it is an established method familiar to all interested parties; the test method is objective yet does not exceed the performance expectations for post-standard cars; and the test results for the used cars can be compared with compliance test results for the same make/model (post-standard) cars when new. This final advantage would yield some insight into brake performance degradation after post-standard cars are put into use (e.g., can post-standard cars on-the-road still pass standard 105-75).

Another topic that will be discussed is whether a vehicle's braking performance can be improved sufficiently to pass the FMVSS 105-75 compliance test by replacing its brake linings and wheel cylinders -- as would eventially be done in normal maintenance over the life of a car. Brake linings, both original equipment equivalent and a popular aftermarket brand, were tested to determine if there is any difference in performance.

In summary, the following questions will be addressed:

- o Can used pre-standard cars comply with FMVSS 105-75?
- o Can pre-standard vehicles with replaced brake linings and wheel cylinders comply with the standard?
- o Can used post-standard cars continue to comply with FMVSS 105-75?
- o By replacing the brake linings and wheel cylinders on a post-standard car, can its ability to comply with FMVSS 105-75 be restored?
- o How does the performance of used post-standard cars compare with that of pre-standard cars on the FMVSS 105-75 compliance test?
- o Does it make any difference whether brakes are refurbished with manufacturer replacement linings or with aftermarket linings?
- o How do used vehicles' test data compare with available data on new vehicles' performance (i.e., any Office of Safety Vehicle Complaince test results on similar models)?

In the subsequent examination of the brake standard, based on accident data, the effects of dual master cylinders and disc brakes on brake failure (as determined by accident investigators) will be measured. Multiple regression analysis will be employed to determine effects by model year, for vehicles under wet road and weather conditions, in hilly terrain, and under all weather and roadway conditions combined. In addition, the ratios of striking vs. struck vehicles in front-to-rear two-car accidents will be compared, again using regression models. Estimates will be made of the effects of dual master cylinders and disc brakes on these ratios for accidents under all, wet, and hilly conditions. While previous attempts to use accident records to measure the effectiveness of the brake standard have proven difficult, this approach is expected to surmount most of the past problems.

2.0 Development of the Brake Standard

Federal Motor Vehicle Safety Standard 105-75 evolved over a nine-year period from a basic requirement to a highly specific regulation which became effective on January 1, 1976. Extensive interactions between vehicle manufacturers and the Federal Government produced the current standard, first published under the name 105a but subsequently renamed and published as 105-75 with an effective date of September 1, 1975. The current version of the standard emerged shortly after with the January 1, 1976 effective date.

The original FMVSS 105 essentially adopted several Society of Automotive Engineers (SAE) Recommended Practices which had been in effect since 1966. In addition, FMVSS 105 required vehicles to have split braking systems for emergency braking, warning lights to indicate brake failure, and parking brakes capable of holding on a 30 percent grade.1/

There were, however, a number of differences between FMVSS 105 and 105-75, most of which involve the specification of performance requirements. FMVSS 105-75 expressed requirements in terms of maximum stopping distance and number of stops at specified speeds. This version of the standard greatly expanded performance requirements, including substantially reduced distance for partial failure tests and added requirements for failed power and spike stop tests. While Appendix V compares the performance requirements for FMVSS 105 and 105-75 in detail, the following briefly describes the two major stages of the standard:

1/Some U.S. automobile manufacturers began installing the split braking system on selected models in 1962. In 1966, about half the cars produced had the split brake system. By 1967, the split brake system was a standard item on all makes and models. Thus, this requirement of FMVSS 105 added no additional effectiveness in preventing accidents; it simply required manufacturers to continue the practice already established. Most of the pre-standard cars which had split brake systems also had brake failure warning lights.

Standard	Effective Date	Key Requirements
105	1-1-68	Required a vehicle to pass 3 effectiveness tests at 20 fpsps deceleration, 2 fade and recovery tests, a water recovery test, a system failure test, and a parking brake test. Required brake failure warning light.
105-75	9-1-75 & 1-1-76	Required performance stopping distances in lieu of deceleration rates. Added another effectiveness test, a power assist unit test, and a post-spike effectiveness test plus a master cylinder reservoir inspection.

3.0 Methodology

3.1 Test Vehicles

The primary purposes of this study were to examine post-standard vehicles' ability to comply with the requirements of FMVSS 105-75 when they are no longer new and to compare their performance on the compliance test with that of used pre-standard vehicles. In order to make these comparisons between pre-and post-standard cars, five 1973 and five 1978 vehicles were chosen for study.

In selecting the vehicles to be tested, an attempt was made to find vehicles which would represent a large percentage of the vehicle population and manufacturers. The vehicles chosen were:

1973 Vehicles	1978 Vehicles
Chevrolet Impala	Chevrolet Impala
Ford LTD	Ford LTD
Plymouth Satellite	Plymouth Fury
Pontiac Lemans	Pontiac Lemans
Toyota Corolla	Toyota Corolla

These 10 cars represent approximately 60 and 63 percent of the market in 1978 and 1973, respectively, if body type alone is considered. With even greater specificity, including vehicles with the same manufacturer and body type or specialty body type only, the five 1978 cars still represent approximately 31 percent of total 1978 cars registered, and the 1973's represent about 33 percent.

The used vehicles for the testing program had the following characteristics when purchased:

- o No brake fluid leaks and no indication of contamination of brake linings, drums, or discs.
- o No braking or suspension components beyond the manufacturer's recommended service limit.
- o Between 15,000 and 40,000 miles on the 1978 vehicles and between 50,000 and 80,000 miles on the 1973's.
- o The 1978 vehicles' brake systems consisted of original equipment only.
- o For the 1973 vehicles, brake linings which had not been replaced in the last 10,000 miles.
- o An up-to-date periodic motor vehicle inspection sticker, not over one year old.
- o Sufficient brake lining to complete the 105-75 test.

A brief description of the features of each test vehicle follows:

1973 Chevrolet Impala Custom 2-door

- 52,352 miles at start of tests
- 5551 GVWR
- V-8
- 350 c.i.d.
- Automatic transmission
- Power steering and brakes
- 2.82 "disc caliper front,11"drum brake rear
- Air conditioning

1978 Chevrolet Impala 4-door

- 19,115 miles
- 4880 GVWR
- I-6
- 250 c.i.d.
- Automatic transmission
- Power steering and brakes
- 2.815 "disc caliper front, 9 1/2" drum brake rear
- Air conditioning

1973 Ford LTD 4-door

- 76,847 miles
- 5660 GVWR
- V-8
- 351 c.i.d.
- Power steering and brakes
- 3.115 "disc caliper front,11"drum brakes rear
- Air conditioning

1978 Ford LTD 2-door

- 33,136 miles
- 6157 GVWR
- V-8
- 351 c.i.d.
- Automatic transmission
- Power steering and brakes
- 3.075 "disc caliper front,11" drum brakes rear
- Air conditioning

1973 Plymouth Satellite Salon 4-door

- 65,947 miles
- 5310 GVWR
- V-8
- 318 c.i.d.
- Automatic transmission
- Power steering and brakes
- 2.75 "disc caliper front, 10" drum brakes rear
- Air conditioning

1978 Plymouth Fury Custom 4-door

- 28,507 miles
- 5565 GVWR
- V-8
- 318 c.i.d.
- Automatic transmission
- Power steering and brakes
- 2.75 "disc caliper front, 10" drum brakes rear
- Air conditioning

1973 Pontiac Lemans 2-door

- 55,206 miles
- 5290 GVWR
- V-8
- 350 c.i.d.
- Automatic transmission
- Power steering and brakes
- 2.828" disc caliper front, 91/2" drum brake rear
- Air conditioning

1973 Toyota Corolla 1600 Deluxe 2-door

- 69,434 miles
- 2815 GVWR
- 4 cylinders
- 96.9 c.i.d.
- Standard transmission, 4 speed
- 1.81" disc caliper front, 9" drum brake rear
- Power brakes

1978 Pontiac Grand Lemans 4-door

- 36,347 miles
- 4574 GVWR
- V-8
- 305 c.i.d.
- Automatic transmission
- Power steering and brakes
- 2.75" disc caliper front, 9 1/2 " drum brake rear
- Air conditioning

1978 Toyota Corolla 1600 2-door Liftback

- 38,650 miles
- 3100 GVWR
- 4 cylinders
- 96.9 c.i.d.
- Automatic transmission
- Power brakes
- 1.81" disc caliper front, 9" drum brake rear
- Air conditioning

3.2 Tests Performed

The existing tires on each of the ten test vehicles were replaced with original equipment equivalent tires (Goodyear tires for the domestic vehicles; Bridgestone tires for the Toyotas) and the wheel alignment and suspension were set to manufacturer's specifications prior to the start of testing. Each of the vehicles was first subjected to the FMVSS 105-75 test procedure (modified as indicated below) "as is". This test will be referred to as the "as received" or "as is" test through the remainder of the discussion.

Following the "as is" test, the hydraulic system was flushed and refilled with DOT-3 brake fluid and the system was bled. New original equipment equivalent (OEE) wheel cylinders were installed at the rear brakes and wheel alignment and suspension were checked again. The 1978 vehicles were then tested with similar quality aftermarket replacement linings of the leading producer of aftermarket linings and pads.

After this test, the 1978 vehicles once again had their wheel alignment and suspension checked and their hydraulic systems flushed, refilled with DOT-3 brake fluid, and bled. All 10 vehicles' pads and shoes were then replaced with original equipment equivalent parts and the vehicles were retested.

In summary, the tests run on the vehicles were:

<u>1973 Vehicles</u>

1. "as is" test
2. test using original equipment equivalent linings.

<u>1978 Vehicles</u>

1. "as is" test
2. test using aftermarket linings
3. test using original equipment equivalent linings

3.3 Brake System Modifications

Every attempt was made to keep vehicles as comparable as possible during the testing. However, in several instances, equipment failures or destruction during one of the first tests on a vehicle meant that parts had to be replaced before a second test. The following changes had to be made:

1978 Ford LTD -- The hub and rotor assemblies were replaced prior to the start of the test of the vehicle with original equipment equivalent linings. The right front rotor had been ruined during the Second Fade test using aftermarket linings.

1973 Plymouth Satellite -- A new master cylinder was installed during the "as is" test after a leak at the primary cup was detected. Prior to the test of the vehicle with original equipment equivalent linings, the drums were replaced after the left drum was found to be scored and 0.06" over the allowable inside diameter.

3.4 Test Procedures and Requirements

The testing program was conducted at the Daytona Speedway in Daytona Beach, Florida, by North American Testing Company, a firm experienced in hydraulic brake compliance testing. The ten used vehicles were tested according to the methodology outlined in TP-105-75-03, "Laboratory Procedures for Hydraulic Brake Systems, FMVSS 105-75" with some modifications. The procedures, which are quite lengthy, are summarized in Appendix V. Table A briefly lists the testing sequence and stopping distance requirements. Readers needing information on vehicle preparation, test and roadway conditions, instrumentation and calibration, and documentation should refer to the aforementioned document. Modifications to TP-105-75-03 for this testing program are as follows:

1. The brake test instrument was not used in the tests. All brake applications were made manually by the driver. This change was made because the instrument was not designed to control incipient skid stops used in this program.

2. No parking brake tests were run because the study was primarily concerned with the braking performance of vehicles in motion.

3. It was unclear whether the used vehicles could withstand the strain inflicted on them by the spike stop test. Thus, to ensure that the vehicles would be available throughout all the tests, the spike stop tests were conducted only at the conclusion of the final test on each vehicle, i.e., at the end of the test of vehicles refurbished with original equipment equivalent brake linings.

4. The Inoperative Brake Power Assist Units Test, all Effectiveness Tests and the Partial Failure Test were all run to determine the best stopping distance obtainable with the pedal force limited to 150 pounds and without wheel lockup of more than one wheel. This change was necessary for comparisons to be made between the stopping distances of pre- and post-105-75 vehicles. It was also felt that best stopping distance information would be more valuable than simple pass/fail data for any future uses of the test results. The restriction on lockup was more stringent than the normal test procedures which allow lockup of more than one wheel on the Inoperative Brake Power Assist Units and Partial Failure tests.

5. Because of the age of the vehicles, the maximum test speed used was 80 mph.

TABLE A

Test Sequence and Stopping Distance Requirements

Test Sequence	Stopping Distance Required (ft.)
Instrumentation Check	--
First Effectiveness at 30 mph	57
at 60 mph	216
Burnish	--
Second Effectiveness at 30 mph	54
at 60 mph	204
at 80 mph	383
First Reburnish	--
Parking Brake	--
Third Effectiveness at 60 mph	194
Partial Failure	456
Inoperative Brake Power and Power Assist Units	456
First Fade and Recovery	--
Second Reburnish	--
Second Fade and Recovery	--
Third Reburnish	--
Fourth Effectiveness at 30 mph	57
at 60 mph	216
at 80 mph	405
Water Recovery	--
Spike Stops	--
Post-Spike Effectiveness	216
Final Inspection	--
Moving Barrier Test (Parking Brake)	--

4.0 *Considerations and Limitations in Using the Data*

A discussion of several problems encountered in the testing program is crucial to the proper interpretation of the data obtained from the compliance testing program of used vehicles. These difficulties include the representativeness of the sample, comparability of the vehicles, testing problems, and anticipation of the standard. Each will be discussed below.

4.1 Representativeness of the Sample

As mentioned previously, the sample used represents approximately one-third of the body type and manufacturer combinations and two-thirds of the body types available for model year 1973 and 1978 cars that were initially put on the road. However, changes have occurred in these vehicles since they were new and it is impossible to know what all these changes were and whether they are typical of the used vehicle population. Variabilities between the used cars include:

- o Number of previous owners/drivers
- o Type of driving (e.g., "stop-and-go," highway)
- o Types of drivers (e.g., one who "slams on" the brakes, one who "rides" the brakes)
- o Extent of maintenance
- o Amount of driving (i.e., mileage on the vehicle)

All the 1978 vehicles were "one owner cars;" however, it is not known whether the 1973's were owned by one or many. Very little other information was available on these variables, although some information could be gleaned from the condition of several vehicles and their brakes. Mileage was known on all the cars, of course, and will be discussed in the following subsection.

All cars were purchased in or around Daytona Beach, Florida, a region which is predominantly flat with low hills and which has light to medium traffic conditions. The soil is sandy and contains a great deal of salt. The weather in the area ranges from mild winters to extremely hot summers. These climatic and traffic conditions are not typical of the rest of the Nation and thus may influence the results.

4.2 Comparability of Vehicles

Every attempt was made to keep vehicles (to be compared) as similar as possible. Options on the test vehicles, e.g., air conditioning, power steering and brakes, etc., were matched as closely as possible. Only the Toyotas' options varied significantly -- the 1978 Corolla having air conditioning and automatic transmission and the 1973 having no air conditioning and a 4-speed standard transmission. All cars had power brakes. Tires were replaced on all vehicles prior to the start of testing in an attempt to eliminate them as a variable. (Because of limited funds, skid performance tests of the replacement tires were not conducted.)

Although 1973 and 1978 cars with the same name or in the same size class were chosen for comparison, there were many changes to the vehicles in the five-year period between 1973 and 1978. The two General Motors cars tested were both downsized in that period, the 1978 Chevrolet and Pontiac weighing 671 and 716 pounds less, respectively, than their 1973 counterparts. The 1973 Chevrolet Impala engine had more cylinders and a higher displacement than the

1978 engine; the 1978 Pontiac Lemans' engine also displaced less space than the 1973.

The other three test vehicles increased in weight during the period -- the Ford by 497 pounds, the Plymouth by 255 pounds, and the Toyota by 285. The increase in weight of the Toyota may be due to the addition of automatic transmission and air conditioning on the 1978 vehicle; however, no differences in transmission type, displacement, number of cylinders, or options existed between the 1973 and 1978 Ford or Plymouth.

Ranges were set on the mileage of the used vehicles for both the 1973 and the 1978 cars. This meant that all vehicles of the same model year had odometer readings "in the same ballpark." However, the ranges did little to make the mileage differences between make/model pairs comparable. The differences in mileage between 1973 and 1978 pairs ranged from 19,000 to 44,000 miles.

4.3 Testing Problems

Despite attempts to minimize them, equipment and vehicle problems are common to brake testing programs. This project was particularly hindered by vehicle problems because the cars being tested were not new. Breakdowns on two tests completely altered the parameters of the test program since they occurred on an early test of a vehicle. The drums and master cylinder had to be replaced on one 1973 vehicle before it could be tested with original equipment equivalent (OEE) replacement linings. On one of the 1978 vehicles, the hub and rotor assemblies were ruined during the test of the vehicle with aftermarket linings and had to be replaced prior to the vehicle's final test with OEE linings. (See "Brake System Modification" for further details.) These non-standard equipment changes meant that the cars were no longer as comparable.

Equipment failures primarily slowed down the testing program. However, in some cases they also caused data to be lost. This was a minor problem since data are noted both by observers and by electronic recorders. However, equipment failures did mean that there were no "check" figures in several cases.

Another consideration in brake testing is driver error or variability. A review of statistical measures of variation of the data indicated that this was not a significant problem, probably because the contractor and test drivers used were so familiar with the FMVSS 105-75 test procedure. Also, a "demonstration" test was run prior to the start of the used car testing program to give the drivers an opportunity to try for "best stopping distances" rather than only "passing" stops.

Because of the influences mentioned in the preceding three subsections, no comparisons should be made between a single make/model pair. All the data should be grouped by test type and model year to help smooth out the effects of individual discrepancies.

4.4 Manufacturers' Actions

Another consideration in interpreting the results of the used car testing program is that manufacturers have been improving brake systems on their own or may have anticipated the implementation of FMVSS 105-75 and had already incorporated changes into their 1973 cars to meet the standard. As an example, all the 1973 vehicles tested had disc front brakes, a feature which helped manufacturers meet the requirements of the standard and which was not typically available on earlier model year cars covered by the original FMVSS 105. Thus, the differences between 1973 and 1978 vehicles are not as pronounced as what might have been observed if manufacturers had not anticipated the standard's requirements.

5.0 Test Results

The results of the 25 FMVSS 105-75 compliance tests of used vehicles are contained in individual reports available on microfiche at the NHTSA Technical Reference Division.2/ The format of these reports is the same as that used in the standard's compliance tests of new vehicles. In the section below, the results of the various tests are summarized and compared. For more detailed information on the test facility or test vehicle's braking system and performance, refer to the individual test reports.

5.1 Compliance Results

The tables in Appendix I summarize the performance of the 10 test vehicles during the 25 FMVSS 105-75 compliance tests (as modified for this program), indicating whether the vehicles passed or failed the various stages of the test. It should be noted here that none of the vehicles tested are required to comply with 105-75 now, since they are not new. The 1973 vehicles were manufactured before the requirements of FMVSS 105-75 went into effect and never had to comply with that version of the brake standard, of course. On tests in the series in which restrictions are set on the maximum pedal force and wheel lockup, a stop failed if (1) the vehicle did not stop within the required distance, (2) the pedal force exceeded 150 pounds, or (3) more than one wheel locked up.

Of the tests on 1973 vehicles, only on one did a vehicle pass all of the performance tests (i.e., the First Effectiveness through the Post-Spike Effectiveness phases). However, in addition to having had its linings refurbished with original equipment equivalent parts, this vehicle had had its master

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2/Available as Report Nos. HS-806-004 through HS-806-028, Contract No. DOT-HS-8-02025, Delivery Order No. 3.

cylinder and drums replaced after the "as is" test, equipment changes that were not performed on the other vehicles. Two additional 1973 vehicles, whose linings were refurbished with OEE parts, passed all but one of the performance tests. All the 1973 vehicles tested "as is" passed the First Effectiveness phase at both 30 and 60 miles per hour and the Partial Failure phase with the rear brakes' subsystem disabled. The 1973 vehicles equipped with original equipment parts performed better consistently, all passing the phases that the "as is" vehicles did plus eight additional performance tests.

In nine of the fifteen tests of 1978 used passenger cars, the vehicles passed every performance test run. Three 1978 vehicles passed the entire test sequence for each of the three test types -- "as is", with original equipment equivalent linings, and with aftermarket replacement linings. The 1978 vehicles equipped "as is" did particularly well since the two vehicles which did not pass the entire sequence failed on only one phase of the test each. (Refer to Appendix I for more details).

On the inspection portions of the compliance tests, i.e., the final, indicator lamp, and master cylinder reservoir inspections, 1978 vehicles passed all inspections except for one in which the vehicle failed the final inspection because its replacement linings on one wheel literally "broke into pieces" earlier in the test sequence. All the 1973's failed at least one inspection, typically the indicator lamp or master cylinder inspection. This was to be expected since the 1973 vehicles were manufactured prior to the implementation of FMVSS 105-75, which is very specific in its wording and labelling requirements for these brake system parts.

Thus, overall the 1978 vehicles performed better than the 1973's in terms of their ability to comply with the standard's requirements and test procedures.

5.2 "Best Stop" Results

Appendix II contains the "best stop" values, i.e., the shortest stopping distances, obtained with a pedal force of 150 pounds or less and lock up of no or one wheel. Non-parametric tests were used to compare these values for each of the test types (e.g., 1973 vehicles tested "as is"). Since stopping distance is not measured in the fade and recovery and water recovery portions of the test sequence, these tests were necessarily excluded from the "best stop" analysis.

5.2.1 Rank Test

First a rank test was employed. In a rank test, observations or results are arranged from smallest to largest and are given "ranks" or "scores"--"one" for the smallest, "two" for the next smallest, the mean for tied results, and so forth. These ranks can then be summed to obtain an overall score for each distribution. The distributions for the compliance tests of used vehicles were the results of individual test vehicles (e.g., the 1973 Ford LTD with OEE linings). Each of the test vehicles' "best stopping distances" were ranked from one to twenty-five (with "one" being the test vehicle which stopped in the shortest distance and "twenty-five" in the longest) for each of the 14 tests in the sequence. (The post-spike effectiveness test was not ranked since it was not run on all vehicles.) The scores were then summed for each of the test vehicles, yielding the results shown in Table B. A simple summation of these overall scores for each test type gives the following results (the lower the score, the better the stopping performance):

Test Type	Sum of Scores
1978 vehicles with original equipment equivalent linings	665
1978 vehicles with aftermarket linings	684
1978 vehicles "as is"	927
1973 vehicles with original equipment equivalent linings	1114
1973 vehicles "as is"	1159

TABLE B

Overall Scores of Test Vehicles[1/]

Test Vehicles[2/]	Sum of Scores
1978 Toyota Corolla AM	45
1978 Pontiac Lemans AM	48
1978 Toyota Corolla OEE	54
1978 Pontiac Lemans OEE	69
1978 Chevrolet Impala OEE	102
1978 Ford LTD OEE	148
1978 Chevrolet Impala AM	149
1978 Pontiac Lemans AI	150
1973 Ford LTD AI	155
1978 Chevrolet Impala AI	172
1978 Ford LTD AM	173
1978 Ford LTD AI	188
1978 Toyota Corolla AI	198
1973 Chevrolet Impala AI	202
1973 Chevrolet Impala OEE	208
1973 Plymouth Satellite OEE	211
1978 Plymouth Fury AI	218
1973 Pontiac Lemans AI	222
1973 Pontiac Lemans OEE	222
1973 Toyota Corolla OEE	234
1973 Ford LTD OEE	239
1973 Toyota Corolla AI	263
1978 Plymouth Fury AM	269
1978 Plymouth Fury OEE	292
1973 Plymouth Satellite AI	316

1/As mentioned previously, comparisons should not be made between individual vehicles or manufacturers. This table is provided purely to aid the reader in following the procedure used in the rank test.

2/Abbreviations: AM = with aftermarket replacement linings
OEE = with original equipment equivalent linings
AI = with linings on car when purchased (as is)

This decreasing trend indicates the following:

- Braking performance can be improved by replacing the linings and wheel cylinders on a used vehicle; however, this improvement was more pronounced on the 1978 vehicles.

- There does not appear to be any great difference between the performance of used 1978 vehicles with original equipment equivalent replacement linings and those with aftermarket linings.

- The 1978 used vehicles performed consistently and substantially better than the 1973 used vehicles, particularly when the linings were refurbished.

5.2.2 Sign Test

The other non-parametric test used to analyze the "best stop" results was a sign test. In the sign test, each of the "best stop" results of the 14 tests in the sequence was compared to determine if the distance obtained in one test was greater than, the same as, or less than that of another test. Six comparisons of "best stop" values were made:

1. 1973 vehicles equipped "as is" vs. 1973 vehicles with replacement original equipment equivalent (OEE) linings.

2. 1978 vehicles tested "as received" vs. 1978 vehicles equipped with replacement OEE linings.

3. 1978 "as is" vehicles vs. 1978's with aftermarket (AM) replacement linings.

4. 1973 vs. 1978 vehicles equipped "as received".

5. 1973 vs. 1978 vehicles with replacement OEE linings.

6. 1978 vehicles with replacement OEE linings vs. 1978 cars equipped with aftermarket replacement linings.

The following results were obtained:

Sign Test Stopping Distance Comparisons

Test Condition Comparison Car A		Car B	Number of Tests Where Stopping Distance of: A > B	A < B
1. 1973 "as is"	vs.	1973 OEE	38	29
2. 1978 "as is"	vs.	1978 OEE	47	20
3. 1978 "as is"	vs.	1978 AM	46	21
4. 1973 "as is"	vs.	1978 "as is"	45	22
5. 1973 OEE	vs.	1978 OEE	55	20
6. 1978 OEE	vs.	1978 AM	36	31

Inserting these values into the sign test's equation for evaluating the "P-value", the smallest level at which the hypothesis of equivalence (between the two distributions being compared) can be rejected, the following values were obtained:

Stopping Distance Comparison	P-value	Significant at $\alpha = 0.05$?
1. 1973 "as is" vs. 1973 OEE	0.16422	not significantly different
2. 1978 "as is" vs. 1978 OEE	0.00065	OEE significantly less
3. 1978 "as is" vs. 1978 AM	0.00153	AM significantly less
4. 1973 "as is" vs. 1978 "as is"	0.00337	1978 significantly less
5. 1973 OEE vs. 1978 OEE	0.00003	1978 significantly less
6. 1978 OEE vs. 1978 AM	0.31270	not significantly different

At the $\alpha < 0.05$ level (or more exactly, at $\alpha < 0.004$), the following results, based on a sign test comparison of "best" stopping distances, were obtained:

1. The stopping distance performance of the 1973 cars was not improved significantly by replacing the linings and wheel cylinders with original equipment equivalent parts.

2. However, both original equipment equivalent and aftermarket replacements significantly improved the stopping performance of the 1978 vehicles.

3. The 1978 vehicles' "best" stopping distances were significantly shorter than those of 1973 vehicles both when the 1973 and the 1978 test vehicles were equipped "as is" and when they were refurbished with original equipment equivalent replacement linings.

4. There was no significant difference between the "best" stopping performance of 1978 vehicles equipped with aftermarket replacement linings and those outfitted with original equipment equivalent linings.

These findings parallel those of the rank test previously discussed.

6.0 Comparison of New Vs. Used Vehicle Compliance Test Results

Since FMVSS 105-75 went into effect on January 1, 1976, the NHTSA Office of Vehicle Safety Compliance has monitored vehicles' abilities to comply with the standard. Many 1978's have been tested using TP-105-75-03. Six of the new 1978's tested fall into the same size class and have the same manufacturer as the used vehicles tested in this program. These six vehicles are:

1. Chrysler LeBaron
2. Dodge Diplomat
3. Dodge Magnum XE
4. Chevrolet Malibu
5. Oldsmobile Cutlass Cruiser
6. Buick Century

All six cars fall into the intermediate size class. The first three vehicles are all Chrysler Corporation products while the final three are those of the General Motors Corporation. The Buick Century was eliminated from the comparison because it differed from the used Pontiac Lemans in that the former did not have power brakes. Although the Oldsmobile Cutlass Cruiser is a station wagon and the Pontiac Lemans is not, an inspection of the Motor Vehicle Manufacturers' Association's passenger car specifications indicated that the brake systems are comparable. The Chevrolet Malibu and Pontiac Le Mans are the only matching vehicles (based on GVWR, engine, transmission, body type, etc.) of the used and new 1978 vehicles. The Magnum XE differs from the Plymouth Fury in that it is a specialty version. Once again, however, a review of the two vehicles' specifications indicate that their braking systems are comparable.

Characteristics of interest for the five 1978 vehicles available for comparison are:

Chrysler LeBaron 4-door sedan

- o 5180 GVWR
- o V-8
- o 318 c.i.d.
- o Automatic transmission
- o 2.75" disc caliper front, 10" drum brake rear
- o Power brakes

Dodge Magnum XE 2-door hardtop

- o 5705 GVWR
- o V-8
- o 400 c.i.d.
- o Automatic transmission
- o 2.754" disc caliper front, 10" drum brake rear
- o Power brakes

Chevrolet Malibu 4-door sedan

- o 4514 GVWR
- o V-8
- o 305 c.i.d.
- o Automatic transmission
- o 2.5" disc caliper front, 9 1/2" drum brake rear
- o Power brakes

Dodge Diplomat 2-door coupe

- o 5165 GVWR
- o V-8
- o 318 c.i.d.
- o Automatic transmission
- o 2.75" disc caliper front, 10" drum brake rear
- o Power brakes

Oldsmobile Cutlass Cruiser station wagon

- o 4930 GVWR
- o V-8
- o 260 c.i.d.
- o Automatic transmission
- o 2.5" disc caliper front, 9 1/2" drum brake rear
- o Power brakes

The biggest problem in comparing the new vs. used compliance test results is that the test procedures used were different in one important respect: the new cars were tested only to see if they passed or failed the performance requirements while the used vehicles were tested both for compliance and to obtain the shortest stopping distance possible in the required number of stops. Once a new car passed the compliance test, there was no reason for the driver to "push" the car to do better. Thus, its so-called "best stop" is not necessarily the best that might have been obtained. Although a new car probably would have done better than a used car if the shortest possible stopping distance had been obtained, the used cars' stopping distances may very well be shorter than the new cars! Thus, unless the new cars' "best stops" are significantly shorter than the used cars' overall, the comparison results must be termed inconclusive.

A sign test identical to the one used on page 21 was used to compare the used with the new cars. Because of the difference in the test procedures, two sets of tests of significance were run. First, the "best stops" for both the new and the used cars were compared. (The "best stop" data for used cars is contained in Appendix II while that of new cars is in Appendix IV.) Then the "best stops" of the new vehicles (Appendix IV) were compared with the averages of the stops of used vehicles (Appendix III). The stopping distances of used cars equipped both "as is" and with OEE linings were compared with the "best stops" of new cars. As in the earlier sign tests, the fade and recovery and water recovery tests were necessarily excluded from the analysis since stopping distance is not measured in these tests.

Table C shows the sign test results. Again, the "P-value" is the smallest level at which the hypothesis of equivalence between the test results of the two vehicles can be rejected. The determination of significance was based on an α-level of 0.05.

Only one used car equipped "as is" performed significantly better than its new car comparison vehicle and only one used car refurbished with OEE linings performed significantly worse at the five percent level, certainly no trend. On the comparisons of new cars' "best stops" with used cars' average stops, more of the cars being compared performed significantly differently from one another. However, the signs of the P-values were not consistent. Some of the new cars performed better than used cars and vice versa, both when the used cars were equipped "as is" and with OEE replacements. Thus, no clear pattern can be discerned from the sign test results of Table C . As mentioned previously, due to the differences in the test procedure, it was doubtful from the start whether conclusive results could be obtained.

TABLE C

COMPARISONS OF NEW VS. USED CARS'

COMPLIANCE TEST RESULTS

Used vs. New Car Compared	Sign Test "P-values"[1/]			
	"Best Stop" Comparisons		"Best Stop" vs. Average Stop Comparisons	
	Used Car "as is"	Used Car with OEE linings	Used Car "as is"	Used Car with OEE linings
Plymouth Fury vs. Chrysler LeBaron	+0.2120 not significant	-0.2120 not significant	-0.0037 significant	-0.0037 significant
vs. Dodge Diplomat	-0.3953 not significant	-0.0065 significant	-0.0037 significant	-0.0037 significant
vs. Dodge Magnum XE	+0.2120 not significant	-0.0898 not significant	-0.0592 not significant	-0.0176 significant
Pontiac Lemans vs. Chevrolet Malibu	+0.0065 significant	+0.2120 not significant	+0.0005 significant	+0.0005 significant
vs. Oldsmobile Cutlass Cruiser	+0.3953 not significant	-0.2120 not significant	+0.0037 significant	+0.0592 not significant

1/ A "+" indicates the used car's stopping distance is shorter than the new car's.
A "-" indicates the used car's stopping distance is longer than the new car's.

2/ The determination of significance is based on $\alpha = 0.05$.

7.0 Findings and Conclusions

Using the list of questions given earlier in the "Introduction" section as an outline, the findings of the testing program and analysis will be described below:

Can used pre-standard cars comply with FMVSS 105-75?

Analysis of the compliance test results for used 1973 vehicles (pp. 17-18 and Appendix I) indicated that these pre-standard cars could not pass either the performance or the inspection portions of the test. None of the five 1973 vehicles tested "as is" passed all the performance or the inspection portions of the FMVSS 105-75 compliance test.

Can pre-standard vehicles with replaced brake linings and wheel cylinders comply with the standard?

Only one 1973 vehicle equipped with OEE linings passed the entire compliance test sequence. However, this vehicle also had its master cylinder and drums replaced after the "as is" test, equipment changes that were not performed on the other vehicles. Two vehicles with OEE replacement linings came close to passing with only one failure each (pp. 17-18 and Appendix I) Thus, while the 1973's compliance performance was improved by OEE linings, the vehicles still could not pass the entire sequence.

Can used post-standard cars continue to comply with FMVSS 105-75?

Over half the 1978 vehicles passed the entire compliance test sequence including the inspection phase (pp. 17-18 and Appendix I). In terms of overall compliance, the 1978 vehicles equipped "as is" did particularly well with three vehicles passing all parts and the other two failing only one of the performance tests.

By replacing the brake linings and wheel cylinders (normal maintenance over the life of a car) on a post-standard car, can we restore its ability to comply with FMVSS 105-75?

Looking only at compliance, the 1978 cars equipped with replacement linings passed fewer tests in the sequence as a group than did the same cars equipped "as received". However, in terms of the number of vehicles passing the entire test, three of the five test cars passed no matter what linings were used.

How does the performance of used post-standard cars compare with that of pre-standard cars on the FMVSS 105-75 compliance test?

Two non-parametric tests, the sign and the rank test, were used to compare the "best stop" values for each test in the sequence for which stopping distance was measured. Each test confirmed the other's findings, which were as follows:

- The stopping distance performance of the 1973 cars was not improved significantly by replacing the linings and wheel cylinders with original equipment equivalent parts.

- Both original equipment equivalent and aftermarket replacement linings significantly improve the stopping performance of the 1978 vehicles.

- The 1978 vehicles' "best" stopping distances were significantly shorter than those of 1973 vehicles both when the 1973 and the 1978 test vehicles were equipped "as is" and when they were refurbished with original equipment equivalent replacement linings.

Does it make any difference whether brakes are refurbished with manufacturer replacement linings or with aftermarket linings?

No significant difference was found between the "best" stopping performances of the 1978 vehicles equipped with aftermarket replacement linings and those outfitted with OEE linings.

How do used vehicles' test data compare with available data on new vehicles' performance (i.e., any compliance test results on similar models)?

No pattern could be discerned from the comparisons of new and used vehicles' test data probably due to the differences in the testing methods used.

In summary, this study examined the overall effects of degradation on braking performance, that is, how vehicles fare when they are no longer new. The results indicate that used post-105-75 cars perform better than used pre-105-75 vehicles on the standard's compliance test. While none of the 1973 cars could comply "as is", over half of the 1978's did. (Of course, the 1973's were not required to comply even when they were new.) More importantly, the 1978's performed significantly better than the 1973's in terms of stopping distance both when the vehicles were tested "as is" and when they were tested with replacement linings. Replacing the linings on the used vehicles improved their stopping distance performance, but the improvement was not as pronounced for the 1973's as it was for the 1978's. Original equipment equivalent linings and one aftermarket lining tested were found to be equally successful in improving the stopping distance performance of used post-standard cars.

Certain factors should be kept in mind in using these results. First, they are only test results. A subsequent analysis, based upon vehicles' on-the-road experiences, will examine the standard's effectiveness in more detail. Second, the sample tested is not a statistically valid one and may not reflect what is true for the entire vehicle population. A third factor is that the 1973 vehicles are five years older than the 1978's. Discrepancies between the levels of performance of the two model year vehicles may in part be explained by the further deterioration of the 1973 cars.

However, the used vehicles selected for testing were inspected to assure that there were: no brake fluid leaks and no indication of contamination of brake linings or pads, drums or discs; no braking or suspension components were beyond the manufacturer's recommended service limit; the vehicle had an up-to-date periodic motor vehicle inspection sticker less than one-year old; and the vehicle had sufficient brake lining to complete the 105-75 tests. In studies of brake-system component degradation (Component Degradation: Braking System, DOT-HS-801-250, November 1974) the most significant item affecting performance cited is contamination - most other items such as thin friction materials, proportioning, drum/disc wear, and imbalance are of much less importance.

Keeping these caveats in mind, the results of the tests of used vehicles indicate that it is likely that the standard improved braking performance. This implies that the subsequent analysis of accident data should allow testing of the thesis that improvements in brakes that have resulted from FMVSS 105-75 will result in a reduction in the number and/or severity of accidents in which the subject cars are the striking vehicle, i.e., the vehicle unable to stop within the required distance. This implied expectation will be analyzed in detail in the subsequent study of vehicles' on-the-road experiences.

APPENDIX I

Used Vehicle

Compliance Results

(Although the terms "pass" and "fail" are used in the following tables, none of the vehicles tested are required to comply with the requirements of Standard 105-75 since they are used vehicles.)

TABLE I(a)

USED VEHICLE COMPLIANCE RESULTS

CHEVROLET IMPALA

TEST SEQUENCE		TEST[1/]				
		1973 Impala "as is"	1973 Impala with OEE linings	1978 Impala "as is"	1978 Impala with after-market linings	1978 Impa with OEE linings
First Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
Second Effectiveness	30 mph	P	P	P	P	P
	60 mph	F	P	P	P	P
	80 mph	P	P	P	P	P
Third Effectiveness		P	P	P	P	P
Partial Failure/Lightly Loaded Vehicle	Front Failed	F	F	P	P	P
	Rear Failed	P	P	P	P	P
Partial Failure/Fully Loaded Vehicle	Rear Failed	P	P	P	P	P
	Front Failed	F	F	P	P	P
Inoperative Power Unit		F	P	P	P	P
First Fade and Recovery		P	P	P	P	P
Second Fade and Recovery		P	P	F[2/]	P	P
Fourth Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
	80 mph	P	P	P	P	P
Water Recovery		P	P	P	P	F[2/]
Post-Spike Effectiveness		NR	P	NR	NR	P
Final Inspection		P	P	P	P	P
Indicator Lamp Inspection		F	F	P	P	P
Master Cylinder Reservoir Inspection		P	P	P	P	P

[1/]"P" means "pass;" "F" means "fail;" and "NR" indicates the test was "not run." Although the terms "pass" and "fail" are used, none of the vehicles tested have to comply since they are used vehicles.

[2/]Average maximum pedal force fell below the 10 pound minimum for the baseline.

TABLE I(b)

USED VEHICLE COMPLIANCE RESULTS

FORD LTD

TEST SEQUENCE		TEST[1]				
		1973 LTD "as is"	1973 LTD with OEE linings	1978 LTD "as is"	1978 LTD with after-market linings	1978 L[…] with O[…] lining[…]
First Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
Second Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	F	P	P	P
	80 mph	P	P	P	P	P
Third Effectiveness		P	P	P	P	P
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	F	P	P	P	P
	Rear Failed	P	P	P	P	P
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	P	P	P	P	P
	Front Failed	P	P	P	P	P
Inoperative Power Unit		P	P	P	P	P
First Fade and Recovery		P	P	P	P	P
Second Fade and Recovery		P	P	P	F[3]	P
Fourth Effectiveness	30 mph	P	P	P	NR	P
	60 mph	F	P	P	NR	P
	80 mph	P	P	P	NR	P
Water Recovery		P	P	P	NR	P
Post-Spike Effectiveness		NR	P	NR	NR	P
Final Inspection		P	P	P	F	P
Indicator Lamp Inspection		F	F	P	P	P
Master Cylinder Reservoir Inspection		P	P	P	P	P

1/See Table I(a).

2/In addition to the linings, the hub and rotor assemblies were replaced prior to the start of this test.

3/Second fade and recovery test had to be terminated because of complete failure of friction material in the front right brake.

TABLE I(c)

USED VEHICLE COMPLIANCE RESULTS

PLYMOUTH SATELLITE/FURY

TEST SEQUENCE		TEST[1]				
		1973 Satellite "as is"	1973 Satellite with OEE linings[2]	1978 Fury "as is"	1978 Fury with after-market linings	1978 Fur with OEE linings
First Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	F
Second Effectiveness	30 mph	P	P	P	P	P
	60 mph	F	P	P	P	F
	80 mph	F	P	P	F	F
Third Effectiveness		F	P	P	F	F
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	F	P	P	P	P
	Rear Failed	P	P	P	P	P
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	P	P	P	P	P
	Front Failed	P	P	P	P	P
Inoperative Power Unit		F	P	P	F	P
First Fade and Recovery		F[3]	P	P	P	P
Second Fade and Recovery		NR	P	P	P	P
Fourth Effectiveness	30 mph	NR	P	P	F	F
	60 mph	NR	P	P	F	F
	80 mph	NR	P	P	F	F
Water Recovery		NR	P	P	P	P
Post-Spike Effectiveness		NR	P	NR	NR	F
Final Inspection		F	P	P	P	P
Indicator Lamp Inspection		P	P	P	P	P
Master Cylinder Reservoir Inspection		F	F	P	P	P

1/See Table I(a).

2/A new master cylinder and brake drums were installed prior to the start of this test.

3/A leak at the primary cup of the master cylinder was detected at this point. Since the remainder of the test was run with a new master cylinder, the data is not recorded here as being under "as is" conditions.

TABLE I(d)

USED VEHICLE COMPLIANCE RESULTS

PONTIAC LEMANS

TEST SEQUENCE		TEST[1]				
		1973 Lemans "as is"	1973 Lemans with OEE linings	1978 Lemans "as is"	1978 Lemans with after-market linings	1978 Lemans with OEE linings
First Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
Second Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
	80 mph	P	F	P	P	P
Third Effectiveness		F	P	P	P	P
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	P	F	P	P	P
	Rear Failed	P	P	P	P	P
Partial Failure/Fully Loaded						
	Rear Failed	P	P	P	P	P
	Front Failed	P	F	F	P	P
Inoperative Power Unit		F	F	P	P	P
First Fade and Recovery		P	P	P	P	P
Second Fade and Recovery		P	P	P	P	P
Fourth Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
	80 mph	P	P	P	P	P
Water Recovery		P	P	P	P	P
Post-Spike Effectiveness		NR	P	NR	NR	P
Final Inspection		P	P	P	P	P
Indicator Lamp Inspection		F	F	P	P	P
Master Cylinder Reservoir Inspection		F	F	P	P	P

[1] See Table I(a).

TABLE I(e)

USED VEHICLE COMPLIANCE RESULTS

TOYOTA COROLLA

TEST SEQUENCE		TEST[1/]				
		1973 Corolla "as is"	1973 Corolla with OEE linings	1978 Corolla "as is"	1978 Corolla with after-market linings	1978 Corolla with OEE linings
First Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
Second Effectiveness	30 mph	F	P	P	P	P
	60 mph	P	P	P	P	P
	80 mph	P	P	P	P	P
Third Effectiveness		F	F	P	P	P
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	F	P	P	P	P
	Rear Failed	P	P	P	P	P
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	P	P	P	P	P
	Front Failed	F	P	P	P	P
Inoperative Power Unit		P	P	P	P	P
First Fade and Recovery		P	P	P	P	P
Second Fade and Recovery		P	P	P	P	P
Fourth Effectiveness	30 mph	P	P	P	P	P
	60 mph	P	P	P	P	P
	80 mph	P	P	P	P	P
Water Recovery		P	P	P	P	P
Post-Spike Effectiveness		NR	P	NR	NR	P
Final Inspection		P	P	P	P	P
Indicator Lamp Inspection		F	F	P	P	P
Master Cylinder Reservoir Inspection		F	F	P	P	P

1/ See Table I(a).

APPENDIX II

"BEST STOP" VALUES

TABLE II(a)

"BEST STOP" VALUES[1/]

CHEVROLET IMPALA

TEST SEQUENCE		TEST: 1973 "as is"	1973 Impala with OEE linings	1978 Impala "as is"	1978 Impala with after-market linings	1978 Impala with OEE linings
First Effectiveness	30 mph	45.4	46.5	44.2	42.6	39.3
	60 mph	175.5	189.9	187.9	177.0	165.1
Second Effectiveness	30 mph	53.8	45.4	43.8	42.2	40.1
	60 mph	206.2	172.6	188.5	178.4	171.4
	80 mph	343.0	344.5	348.2	321.3	312.4
Third Effectiveness		184.8	174.6	174.3	178.3	163.6
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	490.4	525.5	432.8	374.3	379.0
	Rear Failed	221.6	254.2	232.1	220.6	211.9
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	243.7	272.5	256.3	266.3	235.3
	Front Failed	524.9	550.7	446.2	391.2	426.6
Inoperative Power Unit		476.0	437.6	339.5	399.2	360.5
Fourth Effectiveness	30 mph	48.8	49.0	45.9	46.9	45.5
	60 mph	175.7	191.0	198.7	203.6	197.5
	80 mph	330.1	323.7	344.8	355.1	351.4
Post-Spike Effectiveness		--	178.6	--	--	185.8

[1/] The shortest stopping distance obtainable with a pedal force of 150 pounds or less and lockup of no or one wheel.

TABLE II(b)

"BEST STOP" VALUES[1/]

FORD LTD

TEST SEQUENCE		TEST				
		1973 LTD "as is"	1973 LTD with OEE linings	1978 LTD "as is"	1978 LTD with after-market linings	1978 LTD with OEE linings[2]
First Effectiveness	30 mph	48.3	50.5	49.4	49.0	47.8
	60 mph	185.8	194.8	188.7	174.2	194.7
Second Effectiveness	30 mph	42.4	51.3	49.4	48.0	45.2
	60 mph	176.2	205.2	183.7	185.1	168.2
	80 mph	304.4	357.4	320.4	306.2	296.6
Third Effectiveness		168.8	190.4	184.8	165.6	173.8
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	479.8	400.3	402.9	348.2	370.1
	Rear Failed	236.1	260.0	230.3	231.3	241.8
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	234.5	271.9	205.8	250.5	263.8
	Front Failed	361.4	335.9	422.6	352.6	402.2
Inoperative Power Unit		391.0	442.5	406.9	329.6[3/]	395.8
Fourth Effectiveness	30 mph	46.6	48.6	46.7	--	47.2
	60 mph	220.3	202.1	201.0	--	188.0
	80 mph	365.5	351.9	361.0	--	331.9
Post-Spike Effectiveness		--	182.1	--	--	192.5

[1/]See Table II(a).

[2/]The hub and rotor assemblies were replaced prior to the start of this test in addition to the linings.

[3/]Test had to be terminated due to failure of the friction material.

TABLE II(c)

"BEST STOP" VALUES[1]

PLYMOUTH SATELLITE/FURY

TEST SEQUENCE		TEST				
		1973 Satellite "as is"	1973 Satellite with OEE[2] linings	1978 Fury "as is"	1978 Fury with after-market linings	1978 Fur with OE linings
First Effectiveness	30 mph	52.2	45.8	46.9	45.4	51.9
	60 mph	211.7	198.8	189.7	189.0	225.0
Second Effectiveness	30 mph	48.3	44.2	43.3	49.4	51.9
	60 mph	205.4	181.9	189.4	194.6	216.3
	80 mph	425.4	367.8	366.8	412.3	402.6
Third Effectiveness		220.6	177.2	177.6	207.2	198.9
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	472.8	371.0	376.4	390.0	392.0
	Rear Failed	297.7	251.3	269.4	288.0	295.6
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	312.4	263.9	284.8	303.8	302.3
	Front Failed	400.9	383.1	407.3	377.8	361.9
Inoperative Power Unit		520.4	433.9	432.4	538.0	449.7
Fourth Effectiveness	30 mph	--[3]	49.3	48.9	66.2	59.4
	60 mph	--	210.0	203.3	242.6	236.0
	80 mph	--	370.0	367.2	433.9	467.0
Post-Spike Effectiveness		--	194.0	--	--	229.8

[1] See Table II(a).

[2] A new master cylinder and brake drums were installed prior to the start of this test.

[3] The master cylinder had to be replaced before the fourth effectiveness test could be run.

TABLE II(d)

"BEST STOP" VALUES[1/]

PONTIAC LEMANS

TEST SEQUENCE		TEST				
		1973 LEmans "as is"	1973 Lemans with OEE linings	1978 Lemans "as is"	1978 Lemans with after-market linings	1978 Lema with OEE linings
First Effectiveness	30 mph	47.5	42.4	44.0	40.1	42.7
	60 mph	196.5	188.0	177.6	167.6	167.4
Second Effectiveness	30 mph	44.0	43.8	46.3	42.5	42.9
	60 mph	188.0	181.3	177.3	159.1	170.9
	80 mph	370.8	391.5	343.9	328.9	310.8
Third Effectiveness		210.7	184.8	172.9	165.3	155.9
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	433.2	587.6	389.8	241.1	293.1
	Rear Failed	259.9	250.3	214.8	196.0	219.8
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	295.6	269.2	260.6	216.7	219.8
	Front Failed	431.6	588.7	485.9	273.4	329.4
Inoperative Power Unit		462.4	465.6	437.3	302.4	403.4
Fourth Effectiveness	30 mph	44.9	49.0	45.4	40.3	42.9
	60 mph	186.7	194.1	170.6	164.9	163.2
	80 mph	326.5	350.9	348.6	304.6	343.2
Post-Spike Effectiveness		--	186.8	--	--	166.7

[1/]See Table II(a).

TABLE II(e)

"BEST STOP" VALUES[1/]

TOYOTA COROLLA

TEST SEQUENCE		TEST				
		1973 Corolla "as is"	1973 Corolla with OEE linings	1978 Corolla "as is"	1978 Corolla with after-market linings	1978 Corolla with OEE linings
First Effectiveness	30 mph	53.4	50.8	52.9	39.6	40.2
	60 mph	208.8	195.0	200.8	155.3	166.6
Second Effectiveness	30 mph	55.6	50.5	49.3	39.8	39.5
	60 mph	188.9	194.8	196.1	159.0	165.2
	80 mph	352.0	377.7	334.7	289.3	294.1
Third Effectiveness		208.0	197.7	185.5	165.2	159.0
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	633.3	416.0	386.6	393.3	356.9
	Rear Failed	320.7	246.0	245.0	207.5	230.8
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	291.4	290.3	243.8	204.9	228.4
	Front Failed	681.3	439.5	392.9	365.6	348.7
Inoperative Power Unit		293.1	256.2	251.8	231.4	235.7
Fourth Effectiveness	30 mph	47.3	51.9	50.5	45.0	46.1
	60 mph	185.8	184.8	181.8	168.6	169.9
	80 mph	344.2	334.2	341.7	289.1	320.2
Post-Spike Effectiveness		--	197.5	--	--	173.7

[1/] See Table II(a).

APPENDIX III

AVERAGE STOPPING DISTANCES

TABLE III(a)

AVERAGE STOPPING DISTANCES[1/]

CHEVROLET IMPALA

TEST SEQUENCE		TEST				
		1973 Impala "as is"	1973 Impala with OEE linings	1978 Impala "as is"	1978 Impala with after-market linings	1978 Impa with OEE linings
First Effectiveness	30 mph	48.7	47.4	45.8	49.2	41.4
	60 mph	189.0	198.8	199.1	185.2	175.2
Second Effectiveness	30 mph	55.7	46.1	45.6	45.2	42.6
	60 mph	218.4	184.0	194.6	189.7	175.1
	80 mph	345.6	351.5	359.6	341.1	327.7
Third Effectiveness		198.7	181.5	176.0	189.2	167.2
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	512.4	543.0	471.2	416.3	392.6
	Rear Failed	237.0	267.1	240.8	226.1	216.8
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	249.2	274.4	268.7	270.9	253.0
	Front Failed	534.4	596.1	476.5	418.0	447.7
Inoperative Power Unit		500.0	453.6	370.1	427.1	390.2
Fourth Effectiveness	30 mph	50.5	52.0	47.7	48.8	48.8
	60 mph	186.4	199.6	210.9	215.7	209.4
	80 mph	334.8	342.0	356.6	366.8	367.4
Post-Spike Effectiveness		--	194.7	--	--	203.7

[1/]The mean stopping distance for all trial stops obtained with a pedal force of 150 pounds or less and lockup of no or one wheel.

TABLE III(b)

AVERAGE STOPPING DISTANCES[1/]

FORD LTD

TEST SEQUENCE		TEST				
		1973 LTD "as is"	1973 LTD with OEE linings	1978 LTD "as is"	1978 LTD with after-market linings	1978 LTD with OEE linings[2/]
First Effectiveness	30 mph	54.2	53.1	52.3	52.1	49.9
	60 mph	197.2	210.1	198.8	186.0	200.9
Second Effectiveness	30 mph	46.6	52.7	51.5	51.3	48.7
	60 mph	183.6	210.6	191.8	195.5	180.6
	80 mph	317.0	387.7	334.5	327.2	312.2
Third Effectiveness		177.8	197.4	193.0	173.4	181.7
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	492.0	412.2	410.2	367.1	374.2
	Rear Failed	256.5	268.6	243.2	245.0	253.7
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	255.2	282.2	246.5	278.0	268.7
	Front Failed	394.3	393.6	444.5	368.2[3/]	415.0
Inoperative Power Unit		421.2	477.4	432.4	358.2[3/]	407.3
Fourth Effectiveness	30 mph	49.1	50.9	50.9	--	50.1
	60 mph	230.3	212.2	209.6	--	196.0
	80 mph	388.3	366.8	370.6	--	356.5
Post-Spike Effectiveness		--	188.7	--	--	199.6

[1/] See Table III(a).

[2/] See Table II(c).

[3/] See Table II(b)

TABLE III(c)

AVERAGE STOPPING DISTANCES[1/]

PLYMOUTH SATELLITE/FURY

TEST SEQUENCE		TEST				
		1973 "as is"	1973 with OEE linings[2/]	1978 Fury "as is"	1978 Fury with after-market linings	1978 Fury with OEE linings
First Effectiveness	30 mph	54.6	48.0	48.7	47.4	53.9
	60 mph	220.0	205.7	196.6	196.6	231.9
Second Effectiveness	30 mph	51.2	46.8	49.8	51.4	53.3
	60 mph	216.4	190.9	196.1	211.3	223.3
	80 mph	449.6	373.8	379.2	423.9	429.4
Third Effectiveness		234.6	185.0	190.7	218.1	209.2
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	504.2	406.0	395.1	395.9	397.6
	Rear Failed	311.0	258.9	282.0	319.0	298.4
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	320.2	273.8	290.3	319.2	310.1
	Front Failed	510.2	414.5	431.0	411.0	386.0
Inoperative Power Unit		584.5	468.4	498.8	559.2	480.0
Fourth Effectiveness	30 mph	--[3/]	50.5	49.9	68.6	60.5
	60 mph	--	226.8	211.3	257.4	250.9
	80 mph	--	391.5	382.9	453.4	498.7
Post-Spike Effectiveness		--	200.0	--	--	243.6

[1/]See Table III(a).

[2/]See Table II(c).

[3/]See Table II(c).

TABLE III(d)

AVERAGE STOPPING DISTANCES[1/]

PONTIAC LEMANS

TEST SEQUENCE		TEST				
		1973 Lemans "as is"	1973 Lemans with OEE linings	1978 Lemans "as is"	1978 Lemans with after-market linings	1978 Lema with OEE linings
First Effectiveness	30 mph	48.9	43.4	46.9	46.3	45.9
	60 mph	198.9	190.8	186.6	177.1	173.1
Second Effectiveness	30 mph	45.4	45.3	48.0	44.4	44.6
	60 mph	192.0	191.2	181.7	168.0	177.6
	80 mph	395.8	393.1	347.2	335.3	324.5
Third Effectiveness		216.2	191.2	181.0	168.4	161.9
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	451.7	592.2	397.3	268.6	315.3
	Rear Failed	263.6	255.5	230.8	209.1	222.8
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	298.2	280.2	274.4	226.6	236.1
	Front Failed	469.6	619.9	559.4	353.3	334.9
Inoperative Power Unit		476.3	479.9	487.7	324.8	419.6
Fourth Effectiveness	30 mph	47.6	51.2	46.4	42.8	45.7
	60 mph	190.4	202.8	180.1	171.6	178.3
	80 mph	336.8	360.7	354.7	319.1	351.2
Post-Spike Effectiveness		--	196.4	--	--	172.4

1/See Table III(a).

TABLE III(e)

AVERAGE STOPPING DISTANCES[1/]

TOYOTA COROLLA

TEST SEQUENCE		TEST				
		1973 Corolla "as is"	1973 Corolla with OEE linings	1978 Corolla "as is"	1978 Corolla with after-market linings	1978 Corolla with OE linings
First Effectiveness	30 mph	55.0	53.6	55.5	42.9	42.2
	60 mph	213.2	200.0	211.1	158.8	174.9
Second Effectiveness	30 mph	57.0	52.0	53.4	42.8	43.0
	60 mph	197.0	197.7	205.6	168.7	172.6
	80 mph	363.4	382.9	351.4	312.0	305.4
Third Effectiveness		220.3	203.2	193.7	170.2	164.9
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	732.5	430.1	410.5	397.8	364.0
	Rear Failed	333.9	254.2	249.3	215.8	235.7
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	314.0	293.9	263.7	222.0	242.5
	Front Failed	729.7	465.4	400.6	379.4	368.6
Inoperative Power Unit		320.1	268.7	277.5	270.0	260.7
Fourth Effectiveness	30 mph	49.2	53.9	54.9	48.9	47.2
	60 mph	192.8	189.1	187.7	184.0	175.1
	80 mph	353.4	343.1	351.0	311.8	332.0
Post-Spike Effectiveness		--	199.5	--	--	189.0

[1/] See Table III(a).

APPENDIX IV

NEW VEHICLE COMPLIANCE RESULTS

TABLE IV

1978 NEW VEHICLE "BEST STOP" VALUES 1/

TEST SEQUENCE		NEW VEHICLES				
		Chrysler LeBaron	Dodge Diplomat	Dodge Magnum XE	Chevrolet Malibu	Oldsmobil Cutlass Cruiser
First Effectiveness	30 mph	49.9	48.1	47.6	50.8	46.5
	60 mph	187.4	187.8	182.1	184.7	186.5
Second Effectiveness	30 mph	46.5	46.3	49.3	49.9	46.6
	60 mph	180.0	176.7	179.9	178.7	173.3
	80 mph	351.0	352.6	318.6	353.3	322.8
Third Effectiveness		186.3	183.3	179.2	186.0	169.9
Partial Failure/Lightly Loaded Vehicle						
	Front Failed	435.3	418.9	430.2	434.9	410.6
	Rear Failed	279.8	254.5	315.1	236.8	371.9
Partial Failure/Fully Loaded Vehicle						
	Rear Failed	268.4	250.3	305.2	262.2	366.9
	Front Failed	454.9	402.9	416.7	420.5	401.3
Inoperative Power Unit		333.2	319.6	339.5	267.2	308.9
Fourth Effectiveness	30 mph	51.2	49.6	50.9	51.4	49.6
	60 mph	204.8	192.7	179.0	184.2	181.1
	80 mph	394.4	388.0	370.6	362.7	337.7
Post-Spike Effectiveness		207.9	196.7	194.8	189.3	186.7

1/Once a new car passed the compliance test, there was no reason for the driver to "push" the car to do better. Thus, the so-called "best stop" is not necessarily the best that might have been obtained.

APPENDIX V

Comparison of Performance Requirements

of FMVSS 105-75, 105a, and 105

TABLE V

COMPARISON OF PERFORMANCE REQUIREMENTS
OF FMVSS 105-75, 105a, and 105

FMVSS 105-75 Effective January 1, 1976	FMVSS 105a Effective September 1, 1975	FMVSS 105 (SAE J843a, J937) Effective January 1, 1968
First Effectiveness Test:		
• Six stops from 30 mph within 57 ft. • Six stops from 60 mph within 216 ft.	• Same as 105-75.	• Stop from 30 mph at 20 fpsps deceleration with pedal force between 15 and 100 lbs.
Burnish:		
• 200 stops from 40 mph at 12 fpsps deceleration (150 lb maximum pedal force not applicable). • Time between brake application either to reduce initial brake temperature to 230°F to 270°F or one mile, whichever occurs first. • Adjust brakes.	• Same as 105-75.	• Same as 105-75 except time between application either to reduce initial brake temperature to 250°F or one mile, whichever occurs first.
Second Effectiveness Test:		
• Six stops from 30 mph within 54 ft. • Six stops from 60 mph within 204 ft. • If vehicle can attain or exceed 84 mph in 2 miles, then 4 stops from 80 mph within 383 ft.	• Same as 105-75.	• Same as First Effectiveness Test, except add: - Stop from 80 mph at 20 fpsps deceleration with pedal force between 20 and 150 lbs.
First Reburnish:		
• Same as Burnish except 35 stops instead of 200.	• Same as 105-75.	• Same as 105-75 except time between applications either to reduce initial brake temperature to 250°F or one mile, whichever occurs first.
Parking Brake Test:		
• Vehicle loaded to GVWR must remain stationary in both forward and reverse orientation on a 30% grade for 5 minutes with a maximum force of 125 lbs for foot operated and 90 lbs for hand operated parking brake systems.	• Same as 105-75.	• Vehicle loaded to manufacturer's recommended test loading must be held stationary on a 30% grade in both forward and reverse orientation.

TABLE V (continued)

FMVSS 105-75	FMVSS 105a	FMVSS 105
Parking Brake Test (continued):		
• At the option of the manufacturers, if the vehicle has a transmission which incorporates a parking mechanism that must be engaged before the ignition key can be removed, the vehicle may meet the following instead of the above: - Same as above except both parking brake and parking mechanism engaged. - With only parking brake engaged, the vehicle must remain stationary in both forward and reverse orientation for 5 minutes on a 20% grade. - With only the parking mechanism engaged, it must not disengage or fracture, permitting vehicle movement when impacted at each end on a level surface by a barrier moving at 2.5 mph. • Repeat above, as applicable, except with vehicle at lightly loaded weight.	• Same as 105-75.	
Third Effectiveness Test:		
• Six stops from 60 mph within 194 ft, vehicle at lightly loaded weight.	• Same as 105-75.	• Same as Second Effectiveness
Partial Failure Test:		
• In a vehicle with a split service system, it must make 4 stops from 60 mph within 456 ft with each of the subsystems rendered inoperative, one at a time, due to a leakage or rupture type of failure. • Vehicles without a split system must make 10 consecutive stops from 60 mph within 456 ft with a rupture or leakage type of failure. • Above repeated at both lightly loaded and GVWR loaded conditions	• Same as 105-75, except no requirement for vehicles without split systems. This Standard requires a split system.	• In the event of a system or leakage type failure or insufficient fluid level causing loss of pressure in a pressure component, the vehicle must stop from within 646 ft from 60 mph.

TABLE V (continued)

FMVSS 105-75	FMVSS 105a	FMVSS 105
Inoperative Brake Power or Power Assist Unit Test:		
One of the following requirements must be met, at the option of the manufacturers, for vehicles equipped with one or more power assist or power units: • Stop from 60 mph within 456 ft with one power assist or power unit inoperative and depleted of all reserve capability. • For vehicles equipped with backup systems, 15 consecutive stops from 60 mph at an average deceleration not lower than 12 fpsps with one power assist or power unit inoperative and only a backup system operating in the failed subsystem. • For vehicles equipped with power assist units, 6 consecutive stops from 60 mph at decelerations not lower than 16,12,10, 9.8, and 7.5 fpsps, respectively, without the inoperative unit initially depleted of all reserve capability. A seventh stop at an average deceleration not less than 7 fpsps with all reserve capability depleted. • For vehicles equipped with power units, 10 consecutive stops from 60 mph at decelerations not lower than 16,13,12,11,10, 9.5,9.0,8.5,8.0, and 7.5 fpsps respectively, without the unit initially depleted of all reserve capability. An 11th stop at an average deceleration not less than 7 fpsps with all reserve capability depleted.	• Same as 105-75 except power unit and backup system requirements are combined. Also, deceleration requirements are different, as follows: - Power units: 10 stops at 16,15,14,13,12,11,10,9,8, and 7.5 fpsps plus the eleventh stop within 554 ft with all reserve capability depleted. - Power assist units: Six stops at 16,14,12,10,8,and 7.5 fpsps plus the seventh stop within 554 ft with all reserve capability depleted.	• No requirements.
First Fade and Recovery Test:		
• Baseline pedal force established by making three stops from 30 mph at 10 fpsps, initial brake temperature 150° to 200°F. Baseline pedal force is average of the three maximums and must be between 10 and 60 lbs.	• Same as 105-75 except baseline pedal force must be between 15 and 60 lbs.	• No requirements for baseline pedal force but procedure is same as 105-75 except initial brake temperature 200°F before each stop.

TABLE V (continued)

FMVSS 105-75	FMVSS 105a	FMVSS 105
First Fade and Recovery Test (continued):		
• With initial brake temperature between 130 and 150°F, five fade stops from 60 mph at a minimum deceleration of 15 fpsps followed by five more at the maximum deceleration attainable from 5 to 15 fpsps. • After one mile at 30 mph following the fade stops, make five recovery stops from 30 mph at 10 fpsps with a pedal force that falls within the following limits: - Maximum: 150 lbs for first four stops and baseline force plus 20 lbs for fifth stop. - Minimum: Baseline force minus 10 lbs or 60% of baseline force, whichever is lower, in no case lower than five lbs.		• With initial brake temperature 150°F, 10 fade stops from 60 mph at 15 fpsps or maximum attainable with 200 lb pedal force. First four stops must be achieved with less than 200 lb pedal force. • After one mile at 40 mph following the fade stops, make minimum of 12 recovery stops from 30 mph at 10 fpsps or maximum attainable at 200 lb pedal force. Minimum deceleration must be five fpsps at a maximum pedal force of 200 lbs for the first five stops and pedal force must be below 150 lb by stop six.
First Effectiveness Spot Check:		
• No requirement.	• No requirement.	• Two stops from 60 mph at 15 fpsps.
Second Reburnish:		
• Same as First Reburnish.	• Same as First Reburnish.	• Same as First Reburnish.
Second Fade and Recovery Test:		
• Same as First Fade and Recovery Test except 15 fade stops instead of 10.	• Same as First Fade and Recovery Test except 15 fade stops instead of 10.	• Same as First Fade and Recovery Test except first eight stops must be achieved with less than 200 lb pedal force.
Second Effectiveness Spot Check:		
• No requirement.	• No requirement.	• Same as First Effectiveness Spot Check.
Third Reburnish:		
• Same as Second Reburnish.	• Same as Second Reburnish.	• No requirement.
Fourth Effectiveness Test:		
• Six stops from 30 mph within 57 ft. • Six stops from 60 mph within 216 ft.	• Same as 105-75.	• No requirement.

TABLE V (continued)

FMVSS 105-75	FMVSS 105a	FMVSS 105
Fourth Effectiveness Test (continued):		
• Four stops from 80 mph within 405 ft if the speed attainable in two miles is 84 mph or greater. • Four stops from 95 mph within 607 ft if the speed attainable in two miles is 99 to 104 mph. • Four stops from 100 mph within 673 ft if the speed attainable in two miles is 104 mph or greater.	• Same as 105-75.	• No requirement.
Water Recovery Test:		
• Baseline pedal force established by making three stops from 30 mph at 10 fpsps. Baseline pedal force is average of the three maximums and must be between 10 and 60 lbs. • After driving for two minutes at 5 mph in a trough of water six in. deep in any combination of forward or reverse direction, make five recovery stops from 30 mph at 10 fpsps with a pedal force that falls within the following limit: - <u>Maximum</u>: 150 lbs for first four stops and baseline force plus 45 lbs (but not more than 90 lbs) for the fifth stop. - <u>Minimum</u>: Baseline force minus 10 lbs or 60% of baseline force, whichever is lower, but in no case less than 5 lbs. • For the fifth stop, in the case of vehicles manufactured before Sept. 1, 1976, the maximum pedal force must be no more than baseline force plus 60 lbs (but not more than 110 lbs).	• Same as 105-75 except baseline pedal force must be between 15 and 60 lbs. Also, no pedal force requirement for the first four recovery stops but a pedal force for the fifth stop within baseline plus 30 lbs and baseline minus 10 lbs or 60% of baseline, whichever is lower.	• With initial brake temperature of 150°F, baseline pedal force established by making three stops from 30 mph at 8 fpsps. • After wetting all brakes for two minutes by slowly driving through a trough or other suitable method, make 15 stops from 25 mph at 8 fpsps or maximum obtainable at 200 lb pedal force. Pedal force to be within 60% and 120% of baseline by stop 15 or within 60% of baseline and baseline + 20 lbs by stop 10.

TABLE V (continued)

FMVSS 105-75	FMVSS 105a	FMVSS 105
Spike Stops:		
• Ten successive spike stops from 30 mph by applying 200 lbs of pedal force until vehicle is stopped. • After 10 spike stops, six effectiveness stops from 60 mph, at least one of which is within 216 ft.	• Same as 105-75.	• No requirement.
Final Inspection:		
• All performance requirements must be completed without: - Detachment or fracture of any component of the braking system. - Any visible brake fluid or lubricant on the friction surface of the brake or leakage of the master cylinder or brake power unit reservoir cover, seal and filler openings. • All mechanical components of the braking system must be intact and functional. Friction facing tearout must not exceed 10% of the lining on any single frictional element.	• Same as 105-75.	• Linings must be firmly attached and intact on shoes. • All mechanical components of the brake system must be intact and functional. • All hydraulic components of the brake system must be free of leaks.
Indicator Lamp Requirements:		
• As a functional check, each lamp must be activited without the engine running and with the ignition switch in the "on" position or in a position between "on" and "start" that is designated by the manufacturer as a check position. • An indicator lamp must be activated whenever a gross loss of pressure occurs due to one of the following conditions. <u>Split Systems</u> (chosen at the option of the manufacturer): - Before or upon application of a differential pressure of 225 lb/in^2 maximum between the active and failed systems.	• Same as 105-75 except whenever gross loss of pressure occurs in any part of system, lamp must be activated before or upon application of a line pressure of 200 lb/in^2 maximum instead of 225 lb/in^2 differential. No provision is made for vehicles without split systems.	• An electrically-operated red light shall be illuminated before or upon application of the brakes in the event of a hydraulic type complete failure of a partial system.

TABLE V (continued)

FMVSS 105-75	FMVSS 105a	FMVSS 105
Indicator Lamp Requirements (continued):		
- Before or upon application of 50 lbs maximum pedal force on a fully manual system. - Before or upon application of 25 lbs maximum pedal force on a power assist system. - When the supply pressure in a power unit system drops to a minimum level of one half of normal pressure. Without Split System: - When the supply pressure in a power unit system drops to a minimum level of one half of normal pressure. • An indicator lamp must be activated whenever the level of brake fluid in any reservoir drops to less than the recommended safe level specified by the manufacturer or one-fourth of its capacity, whichever is greater. (This applies only to vehicles manufactured on or after Sept. 1, 1976.) • An indicator lamp must be activated whenever a total functional electrical failure in an antilock or variable proportioning system occurs. • An indicator lamp must be activated by application of the parking brake. • Indicator lamps must remain activated as long as the condition exists and the ignition key is on. In addition, they must operate as follows. Split Systems: They may be steady burning or flashing. Without Split Systems: They must activate an audible signal and flash a light displaying "STOP-BRAKE FAILURE" in the event of a rupture or leakage failure.		

TABLE V (concluded)

FMVSS 105-75	FMVSS 105a	FMVSS 105
Fluid Reservoir Requirements:		
• Reservoirs must have a total minimum capacity equivalent to the fluid displacement resulting when all the wheel cylinders or caliper pistons serviced by the reservoir move from a new lining, fully retracted position to a fully worn, fully applied position. Power units must have an additional capacity equivalent to the fluid required to charge the pistons or accumulators to normal operating pressure. • Reservoirs must have separate compartments or partial compartments for each subsystem with a minimum volume of fluid equal to the volume displaced during a full strike of the piston servicing the subsystem.	• Same as 105-75.	• No requirement.