VEHICLE-IN-USE LIMIT PERFORMANCE AND TIRE FACTORS

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UM-HSRI-PF-75-1-1

VEHICLE-IN-USE LIMIT PERFORMANCE AND TIRE FACTORS

SUMMARY REPORT

CONTRACT NUMBER DOT-HS-031-3-693

THE TIRE IN USE

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JANUARY 31, 1975

PREPARED FOR:

THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
U.S. DEPARTMENT OF TRANSPORTATION
WASHINGTON, D.C. 20590

BIBLIOGRAPHIC DATA SHEET

1. Report No. UM-HSRI-PF-75-1-1

2.

3. Recipient's Accession No.

4. Title and Subtitle
Vehicle-In-Use Limit Performance and Tire Factors
The Tire in Use

5. Report Date Jan. 31, 1975

6.

7. Author(s)
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8. Performing Organization Rept. No UM-HSRI-PF-75-1-1

9. Performing Organization Name and Address
Highway Safety Research Institute
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31971

10. Project/Task/Work Unit No.

11. Contract/Grant No. DOT-HS-031-3-693

12. Sponsoring Organization Name and Address
National Highway Traffic Safety Administration
U.S. Department of Transportation
Washington, D.C. 20590

cop 2

13. Type of Report & Period Covered
Summary Final Report
6/73 - 1/75

14.

15. Supplementary Notes

16. Abstracts
The influence of tire-in-use factors (inflation pressure, replacement mixes, and wear) on the steering and braking response of automobiles is examined through analysis, simulation, laboratory and over-the-road tire testing, and vehicle testing. Results for a 1971 Mustang and a 1973 Buick station wagon illustrate the influence of tire-in-use factors on (a) the open-loop braking and/or turning performance in drastic maneuvers on wet and dry surfaces, and (b) the understeer/oversteer factor for maneuvers involving lateral accelerations below 0.3 g.

This investigation shows that differences in tire mechanical properties between the front and rear wheels (as caused by tire-in-use factors) can cause significant and potentially dangerous changes in limit response and from the stability and control characteristics intended by the vehicle manufacturer. The report recommends that (1) inspection limits for inflation pressure be within ±1 psi of the manufacturer's recommended level, (2) minimum tread-groove depth exceed 2/32", and (3) further research be conducted to develop a cost-effective means for indicating the lateral force characteristics of a tire.

17. Key Words and Document Analysis. 17a. Descriptors

Key Words: Tire shear force, vehicle mechanics, tire wear, tire inflation pressure, replacement mixes, emergency maneuvers, linear analysis of directional response, vehicle simulation.

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 28
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (REV. 3-72) USCOMM-DC 14952-P72

DISCLAIMER

ACKNOWLEDGEMENTS

The Project Technical Manager for NHTSA was Lloyd Emery.

All vehicle testing was done at the Texas Transportation Institute (TTI) under the direction of Ronald Young and with the assistance of Monroe White. Dr. Young is the author of Appendix E of the Technical Report.

Significant contributions to this program were made by the following HSRI personnel: Rajiv Gupta, Robert Wild, Howard Moncarz, and Charles MacAdam. These individuals are all authors of appendices to the Technical Report. In addition, the flat-bed tire testing work was performed by Douglas Brown of HSRI.

PREFACE

The Final Report for this project is divided into two parts, a Summary Report and a Technical Report. This volume contains the Summary Report which is a condensation of the Technical Report. The conclusions and recommendations developed in the Technical Report are repeated herein.

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1.0 INTRODUCTION

This report presents, in summary, the findings, conclusions, and recommendations developed by The University of Michigan Highway Safety Research Institute (HSRI) for the National Highway Traffic Safety Administration (NHTSA) in a project entitled "Vehicle-In-Use: Limit Performance and Tire Factors." The goal of this research effort was to develop knowledge useful for refining and updating vehicle safety inspection criteria relating to tires. This project concentrated on studying the influence on vehicle performance of the following tire-in-use factors: (1) shoulder wear; (2) inflation pressure; (3) mixed tire construction, including snow tires; and (4) tread wear (tread depth). The effects of these tire-in-use factors were evaluated for tires of bias, belted-bias, and radial construction.

In studying vehicle performance, two questions were addressed: (1) How much do tire-in-use factors change the stability and control of the vehicle from that intended by the manufacturer? and (2) How much does the limit-maneuvering performance of a given vehicle change as a result of front-to-rear tire asymmetries deriving from tire-in-use factors? To answer the first question, vehicle stability and control were examined through the use of linear analysis and vehicle testing in the normal driving range. Limit-maneuver testing* and computer simulations were used to study accident-avoidance capabilities.

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*This report presents material which can be more fully understood if the reader is acquainted with the limit maneuver test methods put forth in an NHTSA-sponsored study entitled "Vehicle Handling Performance" [1]. (Numbers in square brackets indicate references.)

2.0 STRUCTURE OF THE RESEARCH APPROACH

A general overview of the project organization may be derived from the schematic diagram presented in Figure 1. The diagram indicates that three activities were planned to provide the results needed for meeting the objectives of this program and making the desired recommendations. Each of these activities was supported by an extensive tire testing program in which the HSRI flat-bed and mobile tire-testers [2] were used to obtain shear-force data for a comprehensive set of new and degraded tires.

A linear performance study was conducted to provide a rational foundation for discussing the influence of tire-in-use factors on vehicle stability, control, and response time in normal driving maneuvers. Vehicle understeer/oversteer factors* were determined by analysis and verified by test for various tire-in-use conditions.

A refined tire model was developed to aid in the study of limit-maneuver performance. This tire model provided a tool for accurately simulating tire shear-forces across the the entire range of conditions routinely encountered in limit maneuvers.

The limit-maneuver performance of a 1971 Mustang and a 1973 Buick were studied by means of simulation and full-scale testing. Simulation was used as an aid in structuring a cost-effective vehicle test program. The vehicle test results were then compared to the computed results to verify the validity of the calculations. Additional simulations were performed to augment and illuminate the results measured during the vehicle test program.

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*The understeer/oversteer factor is a measure of steady-state turning performance in the normal driving range. This quantity is defined and discussed thoroughly in the Technical Report.

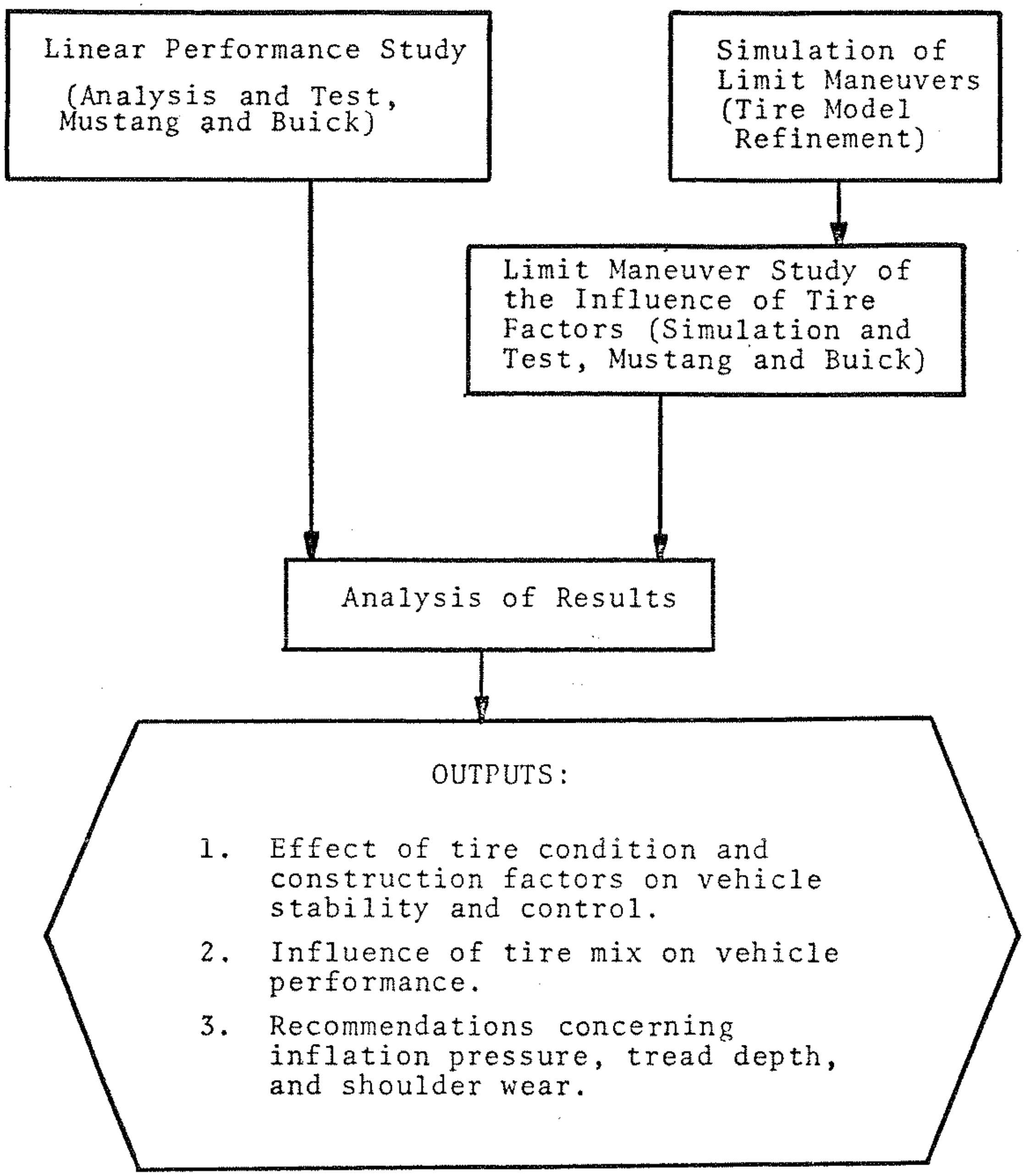

Figure 1. Overview of the project organization.

3.0 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This section contains:

(1) a list of specific findings extracted from the results of this investigation,

(2) general conclusions drawn from these findings,

(3) a discussion of the implications of the conclusions, and

(4) recommendations based on all of the above.

3.1 SUMMARY OF RESULTS AND FINDINGS

In the course of conducting this study of the influence of tire-in-use factors on limit and normal maneuvering performance, findings were developed in six areas, viz.:

- Test-Induced Tire Wear
- Inflation Pressure
- Replacement Tire Mixes
- Tread Wear
- Mathematical Modeling of Tires
- Vehicle-Testing Procedures

Each area is discussed separately below.

3.1.1 TEST-INDUCED TIRE WEAR. (When tires are operated at the high lateral force conditions commonly occurring in limit steering maneuvers, they tend to wear at the tread shoulder. Such wear does not occur with normal use, consequently, it is herein referred to as "test-induced wear.")

Findings:

(1) Mobile tire tests of certain bias-belted tires show that a barely discernible amount of test-induced tire wear causes a significant increase in the lateral forces generated at high slip angles. Similar tests of radial tires yielded only small changes in lateral forces with test-induced wear.

(2) Flat-bed tire tester results show that test-induced wear can cause significant alterations in tire shear force characteristics across the entire range of slip angles tested (1° to 18°).

(3) Test results for a 1973 Buick station wagon and a 1971 Mustang indicate that test-induced tire wear markedly increases the maximum lateral acceleration attained in trapezoidal steer maneuvers. The sinusoidal steer results for these vehicles show much less sensitivity to test-induced wear.

(4) The influence of test-induced wear can be controlled to an acceptable level by frequently changing tires during high-speed tire and vehicle testing on a dry surface.

(5) No significant changes from OE performance were obtained in tests performed on a wet surface using shoulder-worn tires.

3.1.2 INFLATION PRESSURE.

Findings:

(1) Flat-bed tire tester results <u>verify</u> that for all the tires tested in this investigation a <u>reduction</u> in inflation pressure causes:

(a) a decrease in cornering stiffness,

(b) a decrease in camber stiffness, and

(c) an increase in aligning torque stiffness.

(2) Mobile-tire-tester results show that maximum longitudinal tire-force levels drop slightly with decreasing inflation pressure. However, straight-line braking and braking-in-a-turn test results indicate that the magnitude of this change in tire force characteristics is not large enough to cause detectable changes in vehicle braking performance. This finding is verified by analytical calculations.

(3) Mobile-tire-tester results verify that lateral tire force capability at high slip angles (8 to 16 degrees) and high vertical loads (such as occur on the outside tires in a severe turn) decreases significantly with reductions in inflation pressure. An example of these results is given in Figure 2.

(4) Limit-maneuver test results for the Buick station wagon show that a reduction in inflation pressure from the manufacturer's specified levels of 24 psi front and 28 psi rear to 20 psi for all four tires does not cause significant changes in limit performance for the normally loaded vehicle.

(5) Significant and potentially dangerous deviations from the OE limit performances of the Buick and the Mustang were caused by lowering the inflation pressure in the rear tires significantly below the level recommended by the manufacturer, while leaving the front tires inflated to the

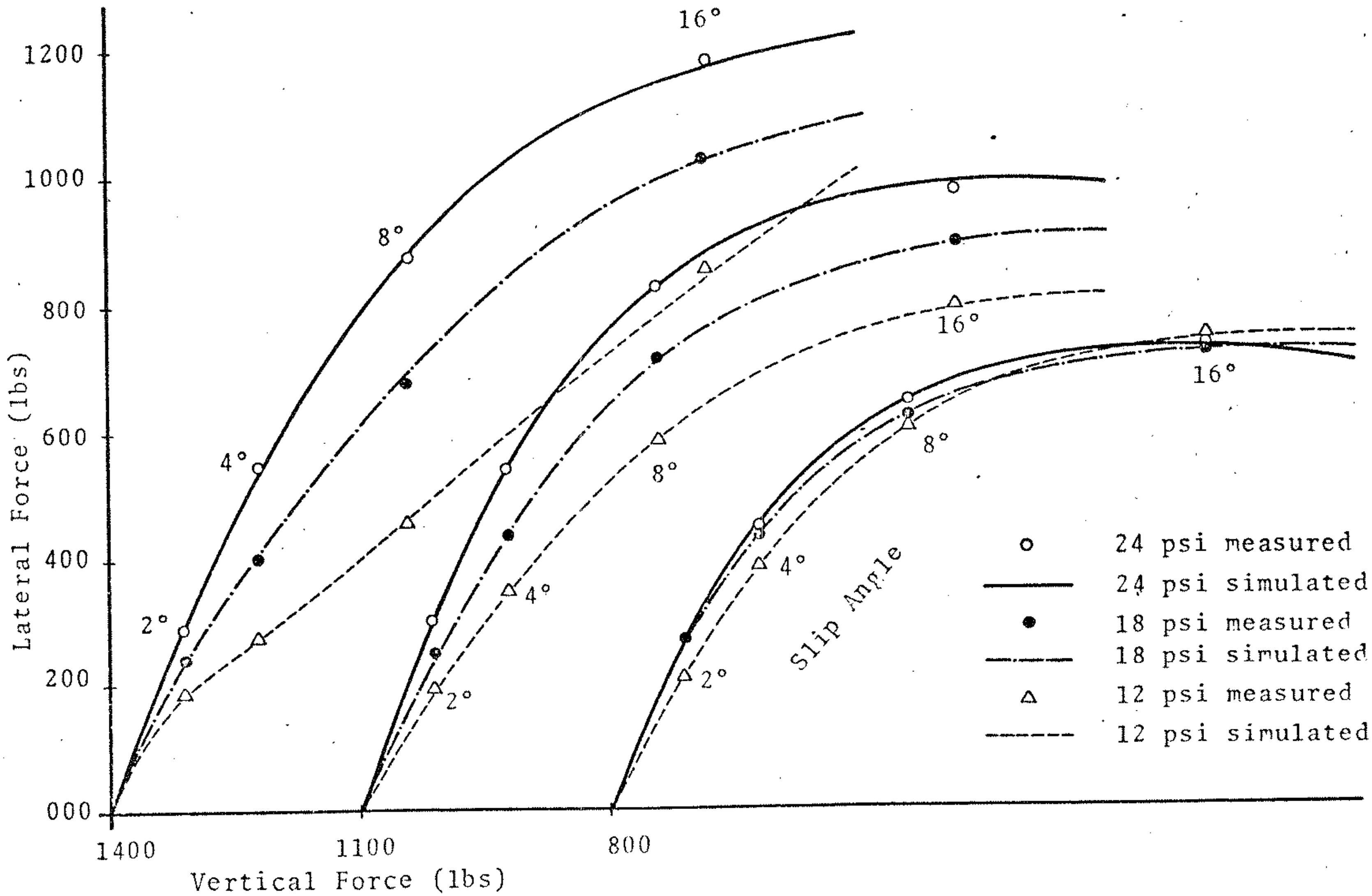

Figure 2. Lateral force vs. slip angle at various inflation pressures
B.F. Goodrich Silvertown Belted E78-14.

manufacturer's recommended pressure. Some test results supporting this finding are presented in Figure 3, in which peak lateral sideslip angles of the Buick in trapezoidal steer maneuvers are compared to corresponding data measured with reduced rear inflation pressure.

(6) No degradations from OE performance were obtained in vehicle tests using under-inflated tires on a wet surface.

(7) Test results and calculations pertaining to the normal driving range performance of the Buick and Mustang (i.e., for lateral accelerations less than about 0.3 g on a dry surface) indicate that in the neighborhood of the OE inflation pressure conditions, front-to-rear differences in inflation pressure are more significant than simultaneous equal reductions (or increases) in both front and rear inflation pressures. Some calculated results showing the influences of front and rear inflation pressures on understeer/oversteer factor, K (degrees/G), are presented in Figure 4.

3.1.3 REPLACEMENT TIRE MIXES. Due to the wide variety of replacement tire choices available (including different construction types and snow tires), an immense number of replacement tire mixes is possible. Several important mixes of replacement tires were investigated in this study.

Findings:

(1) Based on flat-bed tire-test results, "stiff" radial tires were chosen to replace the OE bias-belted tires used on the Buick and the Mustang. These tires had

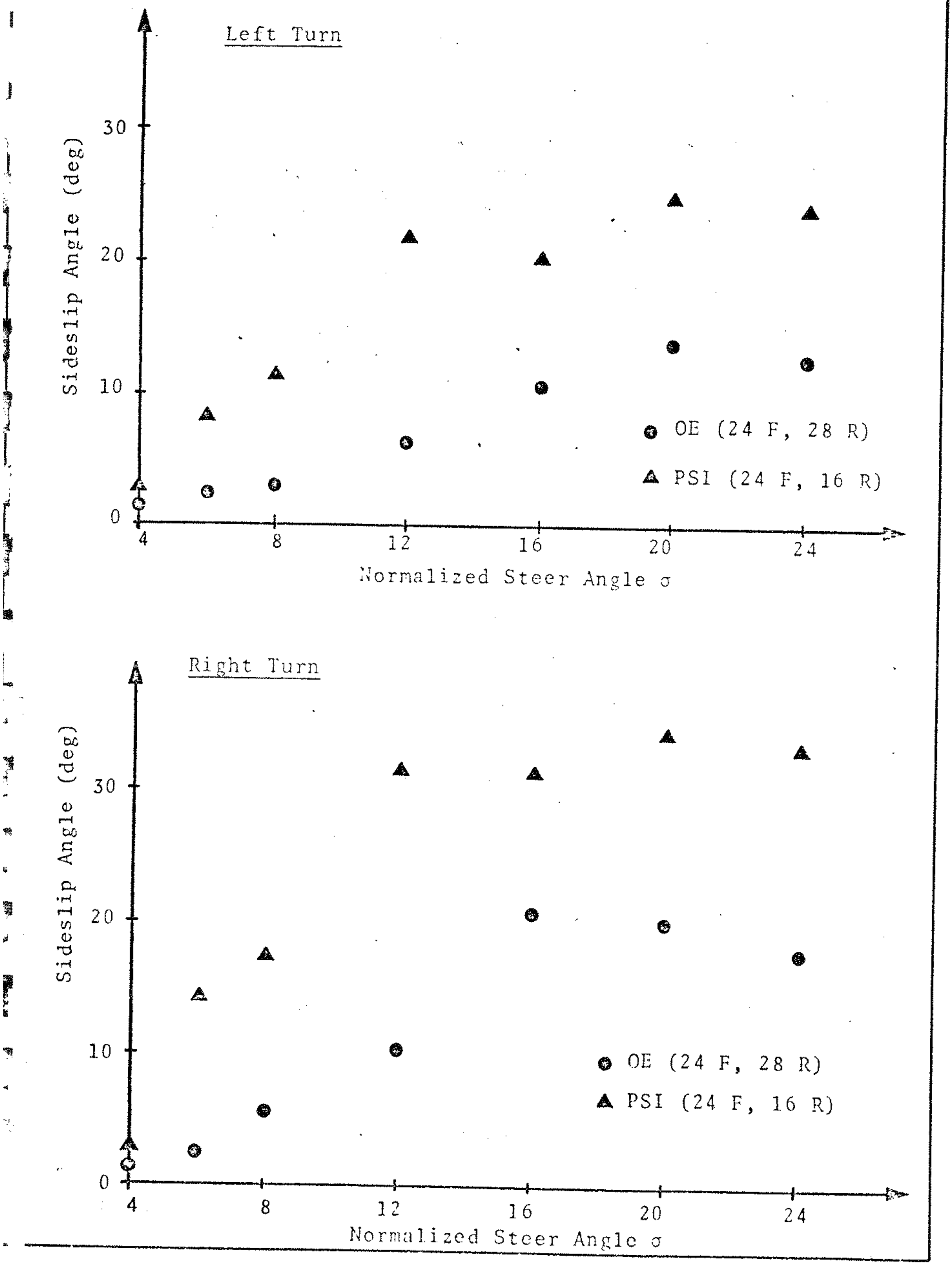

Figure 3. Buick trapezoidal steer results.

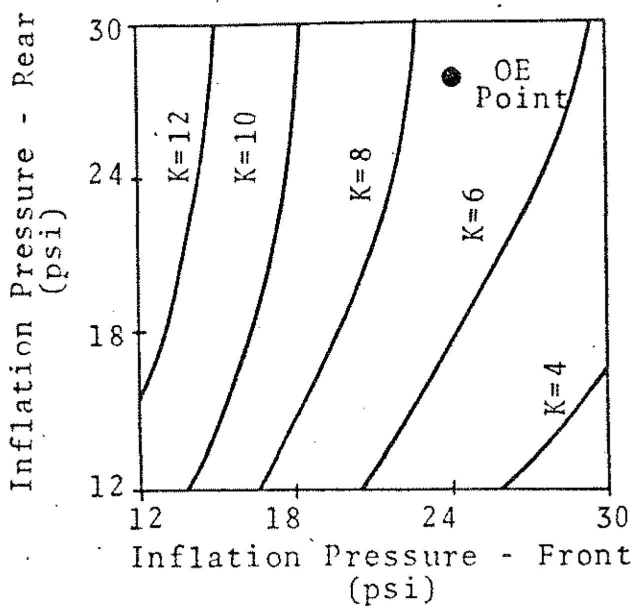

Figure 4a. The influence of inflation pressure on the understeer/oversteer factor, K, for the Buick.

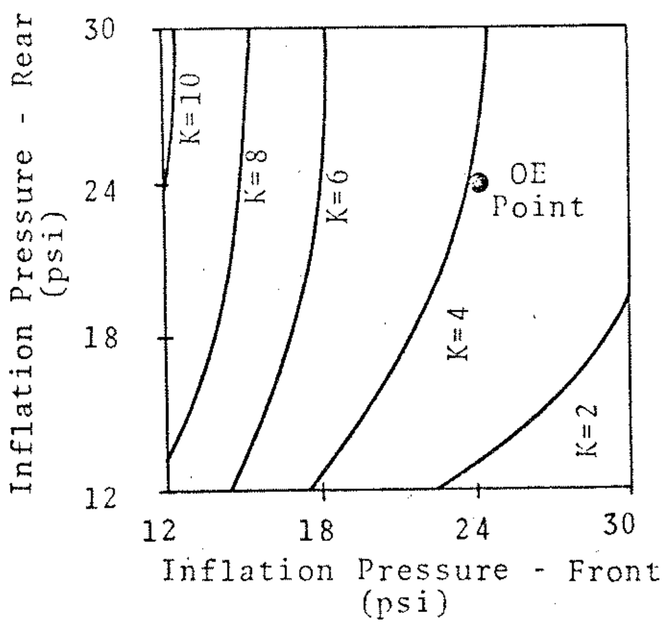

Figure 4b. The influence of inflation pressure on the understeer/oversteer factor, K, for the Mustang.

(a) a higher cornering stiffness,

(b) a higher aligning torque stiffness, and

(c) a much lower camber stiffness than the OE tires.

(2) Mobile-tire-tester results show that the maximum-braking-force capabilities of the radial tires used in this investigation are nearly equal to the maximum-braking-force capabilities of the equivalent-size OE bias-belted tires. On the other hand, these radial tires produce much higher lateral forces than the OE bias-belted tires in the 2° to 6° slip angle range.

(3) Simulation and test results indicate that the replacement of one or more front tires by any tires (whether radial, bias-belted, or bias ply) which generate higher lateral forces than the OE tires in the low to mid slip angle range (up to 10°), while leaving the OE tires on the rear, leads to significant deviations from the OE response in sinusoidal and trapezoidal steer maneuvers. This is demonstrated in Figure 5 in which computed results are presented for the Buick in a high-level sinusoidal steer maneuver with

(a) OE tires,

(b) a stiff radial replacing the OE left front tire,

(c) a stiff radial tire replacing the OE right front tire, and

(d) stiff radials replacing both OE front tires.

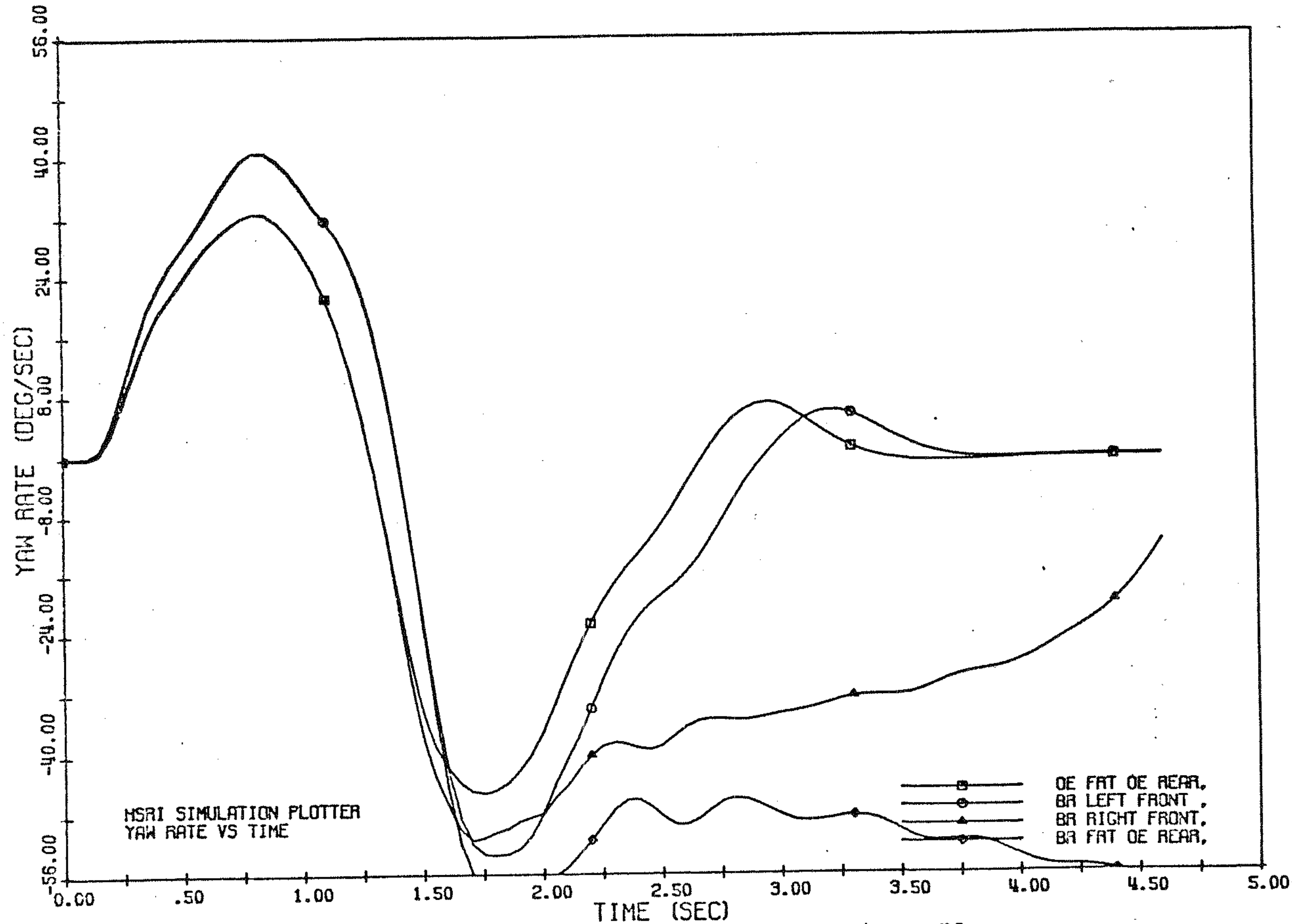

Figure 5a. Buick Wagon: 340 deg sine. asymmetry runs.

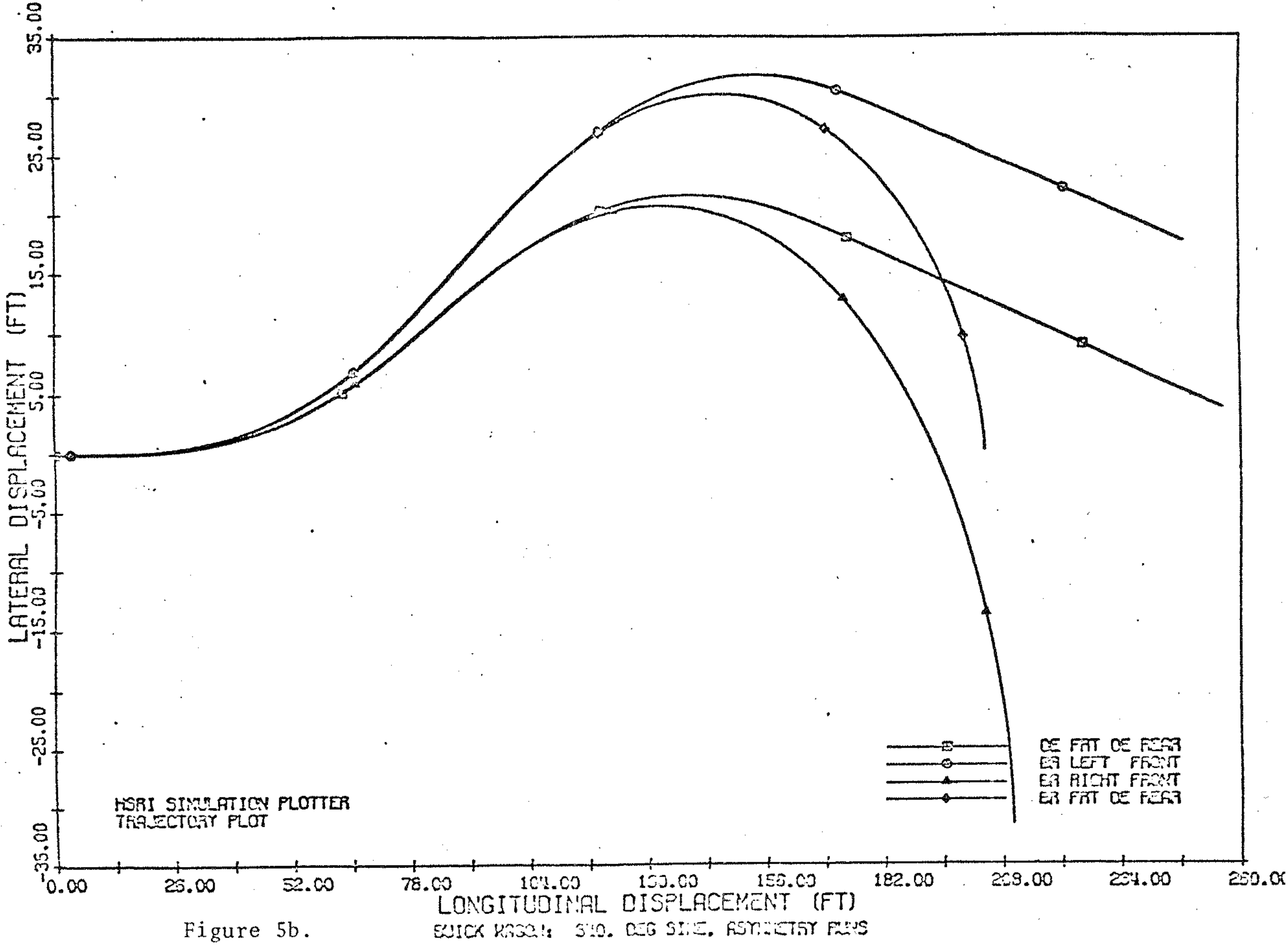
LATERAL DISPLACEMENT (FT)
LONGITUDINAL DISPLACEMENT (FT)
HSRI SIMULATION PLOTTER
TRAJECTORY PLOT
35.00
25.00
15.00
5.00
-5.00
-15.00
-25.00
-35.00
0.00
26.00
52.00
78.00
130.00
156.00
182.00

Figure 5b.

(4) Limit-maneuver test results show that insignificant deviations from OE limit performance were obtained for the Buick when operated with the bias-belted OE tires on the front wheels and bias-ply snow tires on the rear wheels. (This result is not surprising since the tire test results show that this particular snow tire has shear force properties very similar to the properties of the OE tires.)

(5) No significant changes from OE performance were obtained in tests performed on a wet surface using radial or snow tires to replace the bias-belted OE tires.

(6) Test results and analytical calculations show that

(a) the use of stiff radial tires on the front wheels of the Mustang or Buick will cause significant reductions in the understeer/oversteer factors for these vehicles,

(b) replacing only the rear OE tires with stiff radial tires does not produce a significant increase in the understeer of the Buick or Mustang (in fact, an increase from the OE value in rear tire cornering stiffness—as might occur due to tire replacement, wear, or inflation pressure—has little influence on the understeer/oversteer factor for either the Mustang or the Buick).

3.1.4 TREAD WEAR. The results summarized here pertain to uniform wear across and around the tread of the tire. Tires with tread groove depths of 6/32, 4/32, and 2/32 of an inch were used in this investigation to study the influence of varying levels of tread wear.

(1) Mobile-tire-tester results show that the maximum longitudinal force capabilities of the tires tested on a dry surface increase slightly with increased tread wear (reduced-tread groove depth). However, the magnitude of this change in tire performance does not cause significant changes in vehicle braking performance.

(2) Mobile-tire-tester results show that in the low to mid slip angle range (i.e., from approximately 2° to 10°) the lateral force levels for tread-worn Mustang and Buick OE tires are significantly higher than the lateral force levels for the OE tires tested on a dry surface. However, the maximum lateral force capabilities of the OE and tread-worn tires are nearly equal.

(3) Marked differences from OE performance were obtained in sinusoidal- and trapezoidal-steer tests for both the Buick and the Mustang operated on a dry surface with front tires having 2/32" tread groove depths and rear tires having OE (new tire) groove depths. These differences in vehicle performance were largest at an intermediate normalized steer angle of about 8°.

(4) Vehicle tests and calculations show that the influence of tread wear on normal driving performance (as quantified using an understeer/oversteer factor in degrees/G) is insignificant for the Buick and the Mustang. The reasons for this insensitivity to tread wear are (1) when worn tires are used on the front wheels, the increase in cornering stiffness is offset by the increase in aligning torque stiffness accompanying tread wear; and (2) increasing the cornering stiffness of the rear tires has very little influence on the understeer/oversteer factor of these vehicles.

(5) Straight-line braking, braking-in-a-turn, and sinusoidal steer maneuvers were performed on a wet jennite surface. The measured braking performance with four tires worn to 2/32" groove depth was significantly degraded from the OE performance. Sinusoidal steer maneuvers performed on wet surfaces yielded startling and repeatable disparities between results obtained with worn and non-worn tire configurations. Both the Mustang and the Buick exhibited a violent "spin-out" behavior in a mid-range sinusoidal steer maneuver at 40 mph when the vehicles were equipped with OE front tires and rear tires which were worn to 2/32" tread groove depth. (This response was not obtained with 4/32" groove depth tires on the rear wheels at 40 mph, but a violent spin was obtained at 45 mph with 4/32", 6/32", and OE groove depth tires.) Measured results showing the suddenness of the transition from an acceptable response to a drastic spin-out is given in Figure 6.

3.1.5 MATHEMATICAL MODELING OF TIRES. In this study, a previously-developed semi-empirical tire model [3] was refined and augmented to provide a more accurate mathematical representation of measured tire data. (Typical results from calculations using this model are indicated in Figure 2.)

Findings:

(1) To obtain computed results within 5% of measured lateral shear force data across the entire range of slip angles and loads routinely encountered in limit maneuvers requires

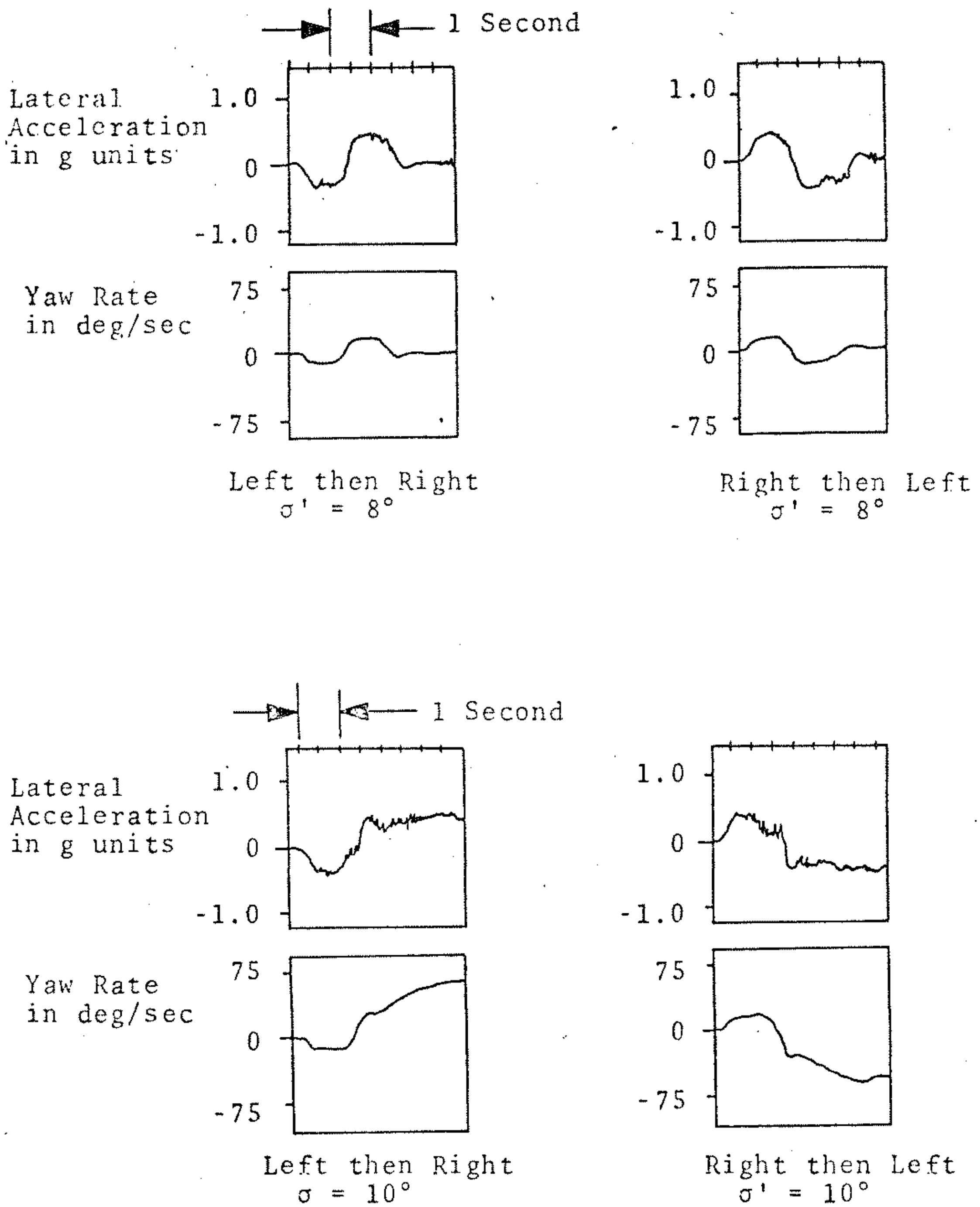

Figure 6. Mustang lane changes with rear tires worn to 2/32" groove depth.

(a) the use of nonlinear functions to describe rates of change of heretofore assumed constant tire parameters such as lateral spring rate,

(b) recognition of the differing pressure distributions at the tire-road interface for radial and non-radial tires, and

(c) the use of load-sensitive stiffness and peak-friction descriptors.

(2) The new tire model was found useful both for extrapolating tire data measured in the present investigation to more extreme values, and for simulating limit maneuvers, particularly trapezoidal and sinusoidal steer.

3.1.6 VEHICLE TESTING PROCEDURES. This section presents observations made concerning the process of collecting, examining, analyzing, and interpreting data from normal-driving-range and limit-maneuver testing activities. The findings bear on the results of this program and on future research activities.

Findings:

(1) For the constant steering-wheel angle method used to assess normal driving performance, it was found that

(a) the results are highly susceptible to measurement errors at low lateral accelerations (i.e., below 0.15 g), and

(b) very accurate measurements of vehicle-response variables, particularly yaw rate, are needed to accurately determine the understeer/oversteer factor.

(2) The limit-maneuver tests performed on a wet surface indicate that

(a) variations in water depth estimated to range from 0 to 0.25 inches made it very difficult to interpret many of the test results, and

(b) the sinusoidal-steer tests on the wet surface are useful for illustrating gross changes in directional stability (such as violent spin-outs) but they are not useful for quantifying the subtleties of directional response (see Figure 6).

(3) The dry-surface limit maneuvers that proved to be the most useful in the present investigation of tire-in-use factors were straight-line braking, trapezoidal steer, and sinusoidal steer.

3.2 GENERAL CONCLUSIONS

The following general conclusions were drawn from the evidence gathered in this research investigation.

Inflation Pressure

• Vehicles in use on the highway often exhibit significant inflation-pressure deviations below the manufacturer's recommendations. Such deviations can severely degrade the directional response of the vehicle in emergency maneuvers, particularly when the rear inflation pressure is lower than the manufacturer's recommendation and the front inflation pressure is properly maintained.

• In the normal driving range, improper maintenance of inflation pressure leading to under-inflated front or rear tires can cause significant deviations from the vehicle stability and control properties intended by the manufacturer.

• Tire test results verified that cornering stiffness drops rapidly with decreasing inflation pressure, and this effect is more pronounced at high vertical loads. Also, aligning torque stiffness increases and camber stiffness decreases slightly with decreasing inflation pressure.

Tire Replacement Mix

• The mixing of tires that are not of the same generic type, brand, aspect ratio, and size can (1) degrade the directional response of passenger cars in limit-turning maneuvers, and (2) alter significantly the stability and control properties intended by the manufacturer. This degradation and/or change is likely to be serious if very stiff tires are mounted in front, with relatively less stiff tires in the rear.

$$\frac{W_F}{C_F} - \frac{W_R}{C_R} = U_{\text{WE BIAS}}$$

Uniform Tread Wear

$\approx$ BEST WHEN $\frac{W_F}{C_F} \geq \frac{W_R}{C_R}$

• On a dry surface, tire wear is likely to degrade the directional-response characteristics of passenger cars only if the wear is asymmetric, with severely worn tires in front and non-worn tires in the rear. This degradation is more likely to be evident in limit maneuvers than in the normal driving range.

• On a wet surface, severe tread wear will lead to much lower peak shear forces than those obtained from corresponding non-worn tires. Thus, braking performance may be significantly degraded due to tread wear of any tire. Furthermore, if the rear tires are severely worn while the front tires are not, potentially disastrous yaw instability may result.

Test-Induced Wear (Including Shoulder Wear)

• Tire testing and vehicle testing at high speeds and high slip angles may rapidly change the measured lateral shear force characteristics of some, but not all, passenger car tires. The lateral force capabilities of radial tires (with rounded shoulders) do not appear to be sensitive to this phenomenon.

• Vehicles equipped with tires with test-induced wear will not necessarily have the same directional-response characteristics as the same vehicles equipped with new tires or tires worn in routine service.

• In the present investigation, tire-test- and vehicle-test-induced wear were limited to tolerable levels by frequently changing tires.

Vehicle Testing

• Testing in the normal driving range can provide much needed insight into passenger vehicle performance. However, such testing requires much-higher-quality instrumentation than limit-maneuver testing and a great deal of care by testing personnel.

• The most useful limit maneuvers for the purposes of the present investigation were straight-line braking, trapezoidal steer, and sinusoidal steer.

• An appropriate methodology for detecting the subtleties of vehicle directional response on a wet surface is not currently available. However, in the present program the wet-surface test results provide graphic insight into the instability that may result from using new front tires with severely worn rear tires.

Mathematical Modeling of Tires

• The semi-empirical tire model developed in this investigation to compute the shear forces at the tire-road interface is capable of (a) reasonable estimations of the tire-traction field, based on very few input tire-surface descriptors; or (b) extremely accurate matching of measured data based on more detailed user input.

3.3 IMPLICATIONS OF THE FINDINGS AND CONCLUSIONS

The stability, control, and accident-avoidance capability of passenger cars are significantly influenced by tire-in-use factors. In particular, differences in front-to-rear tire shear force characteristics due to improper inflation pressure, poor choices for replacement tires, or front-to-rear mixing of new tires with worn tires can cause potentially dangerous directional performance characteristics which do not exist in properly maintained original equipment vehicles.

Furthermore, surveys of (a) the condition of tires in use on the highway [4] and (b) tire replacement practices [5] indicate that many vehicles-in-use are operated with undesirable tire configurations. Clearly, proper tire maintenance and replacement practices could eliminate a number of potentially hazardous vehicle conditions from highway driving.

The research objectives of this study were addressed and fulfilled, but not without some difficulty. Further investigations are needed to reduce these difficulties. Specifically, further research is needed to

(1) Evaluate the influence of the steady-state and transient response characteristics of passenger cars on the performance of the driver-vehicle system in normal driving.

(2) Develop a test methodology suitable for studying vehicle directional response and control on wet surfaces.

(3) Improve the utility of the sinusoidal-steer maneuver by (a) identifying the causes for asymmetric response, and (b) developing simpler measures for interpreting the results.

(4) Improve the utility of the trapezoidal-steer maneuver by (a) developing a better understanding of the meaning of the absolute level of the side-slip angle response, and (b) improving the accuracy of sideslip angle measurements.

(5) Extend the state of knowledge concerning the type of wear induced by high-speed tire testing or drastic turning maneuvers to include a deeper understanding of (a) the physical mechanisms involved in lateral-force generation, and (b) the relevance of this type of wear to vehicle-in-use safety.

3.4 RECOMMENDATIONS

The results of this study indicate that departures from inflation pressures recommended by the manufacturer introduce significant vehicle-response problems. Low inflation pressure in the rear tires with proper inflation pressure in the front tires is particularly hazardous. For example, the limit-maneuvering performance of the Mustang was degraded by reducing the inflation pressure in the rear tires from the recommended 24 psi to 18 psi, and the Buick limit performance was seriously degraded by reducing the rear inflation pressure from the recommended 28 psi to 16 psi.

Since inflation pressure is easily adjusted, quite often low in vehicles in use, and extremely important in vehicle maneuvering, it is recommended that inflation pressures be set as closely as possible to the manufacturer's recommended levels (corrected for tire temperature). They should be set within ±1 psi and inspection stations should be equipped with air pressure gages which are accurate to ±1 psi. Results from studies of service-station air towers show that a simple periodic calibration is sufficient to maintain this accuracy [4].

Maintaining inflation pressure to close tolerance is fairly difficult because inflation pressure changes as the tire absorbs heat during usage (or even due to changes in ambient temperature). Traditionally, cold inflation pressures have been specified, and currently the recommended cold inflation pressures are labeled on new vehicles. However, a tire can go from cold to hot very quickly in use. Furthermore, twenty minutes may be needed for a tire to cool to ambient conditions [4]. Consequently, inflation pressure inspection criteria need to take tire temperature into account.

Since inflation pressure is not difficult or costly to set, vehicles passing through inspection facilities should exit with the manufacturer's recommended inflation pressures.

There may be some question as to the proper inflation pressure if the vehicle owner has replaced his original equipment tires with another type of tire. Inspection station personnel should note any change from OE tires and indicate to the vehicle owner that the recommended inflation pressures labeled on the vehicle do not necessarily apply to the currently installed tires.

The results of this study indicate that tire tread depth has little influence on directional response in normal driving. But asymmetric wear (front-to-rear) can degrade braking and/or directional performance in limit maneuvers. In particular, severely worn front tires with OE rear tires can lead to directional control problems in severe turning maneuvers on a dry surface, and worn rear tires can lead to directional response problems on a wet surface. In addition, severe tread wear of any or all four tires will significantly degrade braking performance on a wet surface.

Setting an optimum level of tread groove depth is a trade-off between the costs inherent in observing a high minimum groove depth and the resulting benefits in improved braking and directional performance. Our recommendation, based on the results of this investigation and tempered by our perception of the economics involved, is that tires should be replaced when they reach a groove depth of 2/32 of an inch.

Data collected on the flat-bed tire tester show that a major change in lateral force characteristics takes place between OE and 6/32" (approximately half-worn) tread groove depths, and a significantly smaller change in lateral force characteristics takes place between 6/32" and 2/32" of tread groove depth. In addition, on a heavily wetted surface, a 5-mph increase in speed from 40 to 45 mph was found to be sufficient to cause poor vehicle directional response in lane-change maneuvers with 2/32", 4/32", 6/32", and OE tread groove depths on the rear tires. These results indicate that the gains obtained by requiring groove depths higher than 2/32" may not be very large (only the 2/32" condition caused poor directional response at 40 mph).

Tread groove depth is not the only tire factor determining the ability of a tire to operate satisfactorily on a wet road. Recent research investigations [6] and [7] have used measures of flow rate or pressure rise to quantify the capacity of tread grooves for handling water. Tread pattern geometry, contact patch width (or area), and groove width are all tire factors which can influence the shear force capability of a tire on a wet road.

Due to the relatively large number of wet-weather accidents, research into inspection methods for assessing the capacity of a vehicle's tires to provide a path for expelling water is recommended. Possibly a simple device can be invented which would apply water to a vehicle's tires and measure groove flow-capacity directly (or indirectly using pressure measurements). The devices described in [6] or [7] provide a foundation for this work.

In some cases, test-induced wear causes significant deviations from the lateral force characteristics of normally broken-in, original equipment tires. For tire test programs whose purpose is to determine the lateral force capabilities of a tire in the first (and possibly only) emergency turning maneuver to which that tire is subjected, it is recommended that no more than one high-force-level, high-speed test be made on a single tire sample.

Replacement tire mixes which result in very stiff tires mounted on the front wheels and relatively less stiff tires on the rear wheels are likely to cause significant and potentially dangerous changes from the directional response characteristics of the vehicle with original equipment tires. Since replacing tires two at a time is often done for economic reasons, many replacement tire mixes exist on the road.

However, there does not appear to be any worthwhile alternative to having tire lateral force data to decide if a given tire mix is likely to cause a significant change in vehicle behavior. For example, radial tires are on the average stiffer than belted-bias tires, but many radial tires are less stiff than some belted-bias tires. Unless the lateral force characteristics of the tires are known, the buyer or the inspector cannot identify unfavorable construction mixes.

An obvious course of action would be to require the tire manufacturer to supply the needed data. Whether this is a reasonable course of action cannot be determined from the results of this study. Furthermore, the longitudinal traction numerics used in the uniform tire quality grading system are not sufficient for evaluating lateral shear-force characteristics. Consequently, further research is recommended for determining a cost-effective methodology for specifying the range of lateral traction performance provided by replacement tires.

4.0 REFERENCES

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