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# THE NOISE AND TRACTION CHARACTERISTICS OF BIAS-PLY TRUCK TIRES

Volume 2 of 2

Wet Traction Findings

Project 361048

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October 1976

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16. Abstract

This project has established a data base of noise and traction characteristics for a sample of bias-ply heavy truck tires. The tire sample, representing both "rib" and "lug" type tread patterns, was tested according to the SAE J-57 tire noise procedure and in a variety of laboratory and over-the-road traction experiments. Dry-pavement traction results show that the noisier lug-type tires exhibit traction properties which are generally less desirable from the viewpoint of their influence on vehicle response to steering and braking. Wet traction results (in this volume) illustrate that the differences in braking traction between lug- and rib-type tires are even more discriminatory than on dry surfaces.

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# 1.0 INTRODUCTION

This document constitutes a companion volume to a report of the same title which was released in January 1976 under the subtitle "Noise and Dry Traction Findings." In total, the two-volume report serves to document a program of experimental measurements of noise and traction properties obtained on a selected sample of heavy truck tires. The study has been conducted by the Highway Safety Research Institute of The University of Michigan under support from the Motor Vehicle Manufacturers Association.

The reader is referred to Volume 1 for a comprehensive description of the tire sample, the test procedures and apparatuses employed, and, of course, to the complementing data sets characterizing the noise generation and dry traction properties of the common sample of tires.

## 2.0 DISCUSSION OF WET TRACTION RESULTS

In this section, measurements of longitudinal and lateral traction performance of the six-tire sample will be presented, as obtained on the wet concrete surface. These measurements involved use of one "fresh" specimen of each tire for each of the longitudinal and lateral test sequences. Insofar as the wet pavement condition principally influences force saturation phenomena rather than traction stiffnesses, the data will be discussed only in regard to observations of limit traction behavior.

### 2.1 Longitudinal Traction Results

Shown in Table 1 are the peak and slide values of normalized longitudinal force which were measured during the five repeat runs conducted on each tire.* The repeatability of both peak and slide values would appear to suggest that a relatively stable wet surface condition was being sustained throughout any given sequence of runs on one tire.

The sensitivity of peak and slide traction performance to varying values of load and velocity are summarized in Figures 1, 2, 3, and 4. Figures 1 and 2 illustrate the velocity sensitivity of peak and slide traction values, respectively. We see that over the 20- to 55-mph range of velocity, all tires exhibit the classic downward trend in shear force limits with velocity. While the band of locked-wheel force performance is narrower and somewhat less discriminating than that of the peak traction performance values, the three rib tires illustrate decidedly higher levels of both measures than the three lug-type specimens. Over the velocity range, the average rib tire exhibits a 23% advantage in peak traction and a 15% advantage in slide traction over the performance of the average lug tire. Clearly, the average lug

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*The reader is referred to the description of the standard sequence of test runs presented as page 12 of Volume 1.

Table 1. Peak and Slide Values of $F_X/F_Z$ as Obtained Over the Five Repeat Runs for Each of the Six Sample Tires on Wet Concrete.

Goodyear Super Hi Miler

| Run | $\mu_p$ | $\mu_s$ |
|---|---|---|
| 1 | .68 | .47 |
| 4 | .69 | .47 |
| 7 | .66 | .45 |
| 10 | .66 | .42 |
| 13 | .68 | .43 |
| Avg. | .674 | .448 |
| $\sigma$ | .012 | .0204 |

Firestone Transport 200

| Run | $\mu_p$ | $\mu_s$ |
|---|---|---|
| 1 | .67 | .49 |
| 4 | .64 | .49 |
| 7 | .65 | .50 |
| 10 | .63 | .48 |
| 13 | .64 | .48 |
| Avg. | .646 | .488 |
| $\sigma$ | .013 | .0075 |

Firestone Transport 1

| Run | $\mu_p$ | $\mu_s$ |
|---|---|---|
| 1 | .79 | .61 |
| 4 | .77 | .57 |
| 7 | .75 | .57 |
| 10 | .80 | .58 |
| 13 | .79 | .54 |
| Avg. | .780 | .574 |
| $\sigma$ | .0179 | .0195 |

Goodyear Custom Cross Rib

| Run | $\mu_p$ | $\mu_s$ |
|---|---|---|
| 1 | .58 | .46 |
| 4 | .62 | .47 |
| 7 | .61 | .47 |
| 10 | .62 | .47 |
| 13 | .61 | .44 |
| Avg. | .608 | .462 |
| $\sigma$ | .0147 | .0117 |

General GTX

| Run | $\mu_p$ | $\mu_s$ |
|---|---|---|
| 1 | .76 | .54 |
| 4 | .72 | .51 |
| 7 | .73 | .51 |
| 10 | .73 | .52 |
| 13 | .72 | .51 |
| Avg. | .732 | .518 |
| $\sigma$ | .0147 | .0156 |

Uniroyal Fleetmaster Super-Lug

| Run | $\mu_p$ | $\mu_s$ |
|---|---|---|
| 1 | .55 | .43 |
| 4 | .53 | .41 |
| 7 | .48 | .37 |
| 10 | .53 | .38 |
| 13 | .49 | .36 |
| Avg. | .516 | .390 |
| $\sigma$ | .0262 | .0261 |

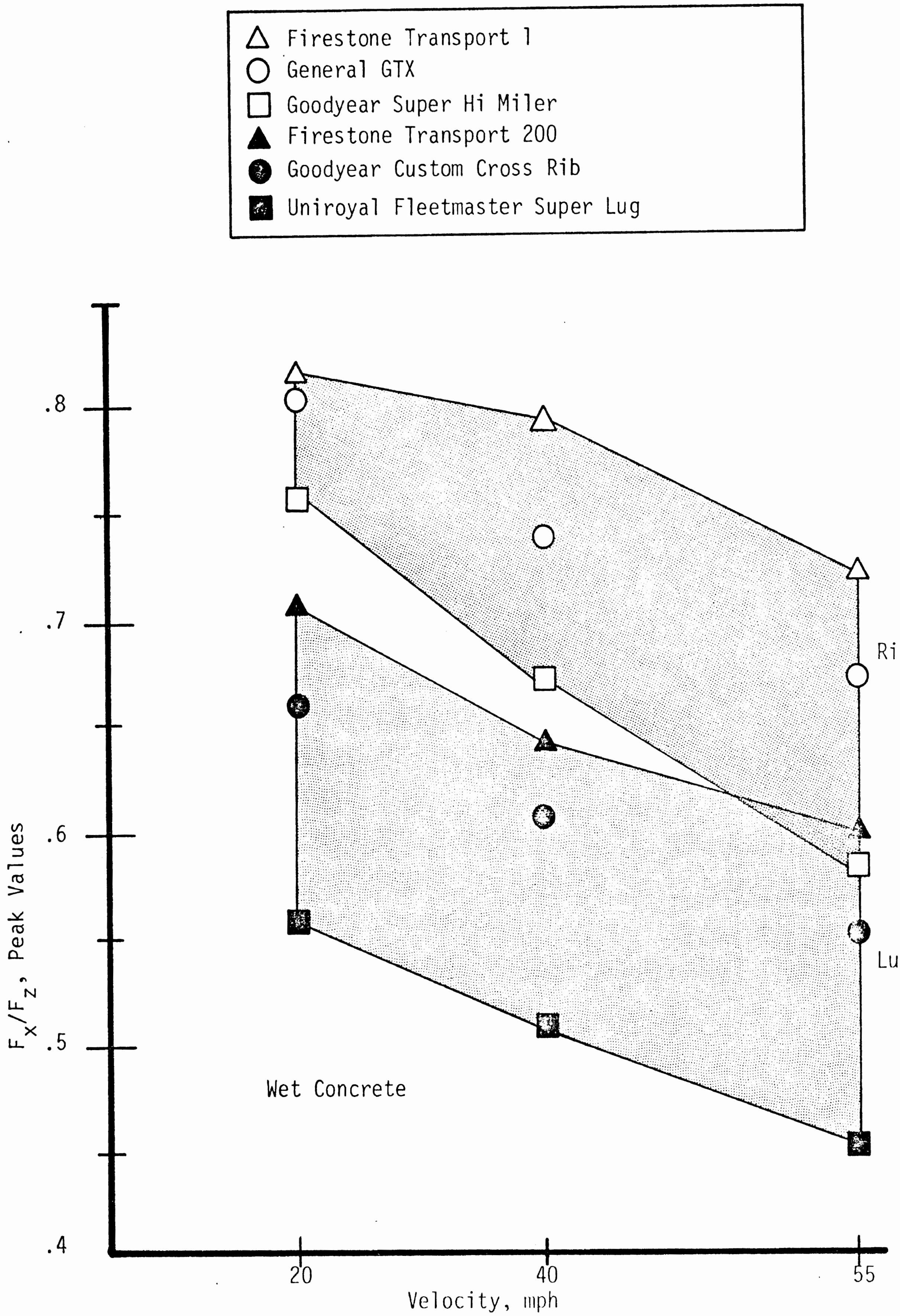



Figure 1. Velocity sensitivity of peak $F_x/F_z$ values at rated load.

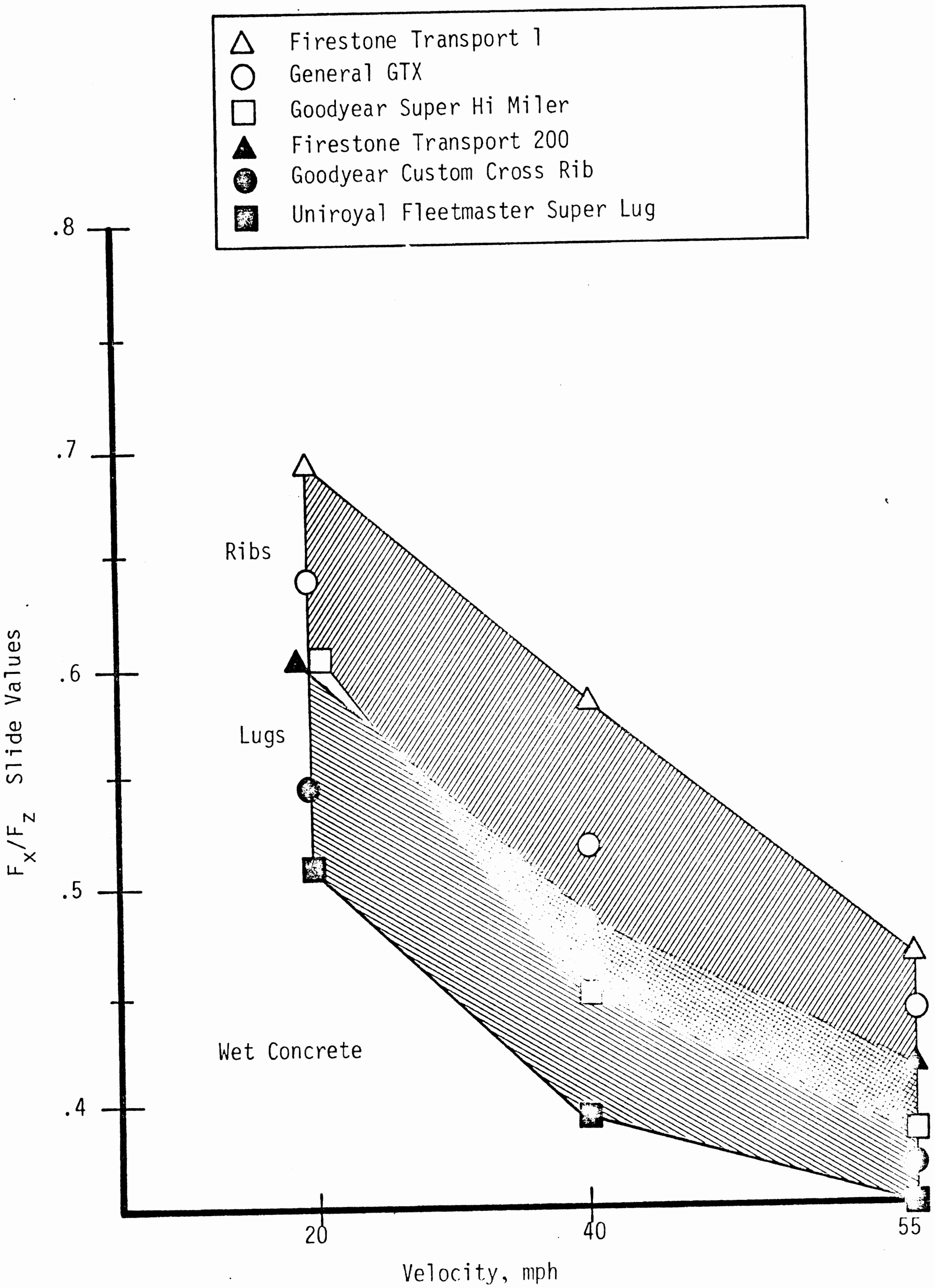



Figure 2. Velocity sensitivity of slide value of $F_x/F_z$ at rated load.

tire performance is "pulled down" considerably by the low traction capability of the Uniroyal Super Lug—a tire which did not rank so conspicuously low among the dry traction data given in Volume 1.

Figures 3 and 4 illustrate the load sensitivity of the six-tire sample on the wet concrete pavement. The load sensitivities are summarized here for the 55-mph condition on the conviction that hydrodynamic phenomena, if significant, will discriminate best among tire tread patterns at elevated speeds. While the average rib-type tire yields a peak traction performance over the load range which is 17% above that of the average lug tire, the contrast in slide traction is more mixed with rib tires providing an average traction value which is higher by 5%.

A general explanation of the superior wet traction performance of the bias-ply, rib-tread truck tire is not available. Further, it would appear that the additional water flow capacity afforded by the large volume of individual grooves within lug-type tread patterns exceeds that which is demanded for water drainage. Additionally, the drainage performance of heavy truck tires, in general, would seem to be inherently high as a consequence of (1) high contact pressures between tread and road, (2) low values of tire deflection (especially as effects lateral "closure" of grooves within the footprint), and (3) high groove volumes [1]. Thus we find in the foregoing data that while certain rib tires perform quite well on this wetted concrete surface (compared, say, to passenger car tire traction on such surfaces), the separation of rib- and lug-traction levels is, on the average, quite large with certain lug tires providing rather low traction levels.

Regarding the implications of these wet surface data to vehicle braking capabilities, the significance of a superior performance by rib tires is generally as discussed in Volume 1 for the case of braking on dry pavements. Significantly, however,

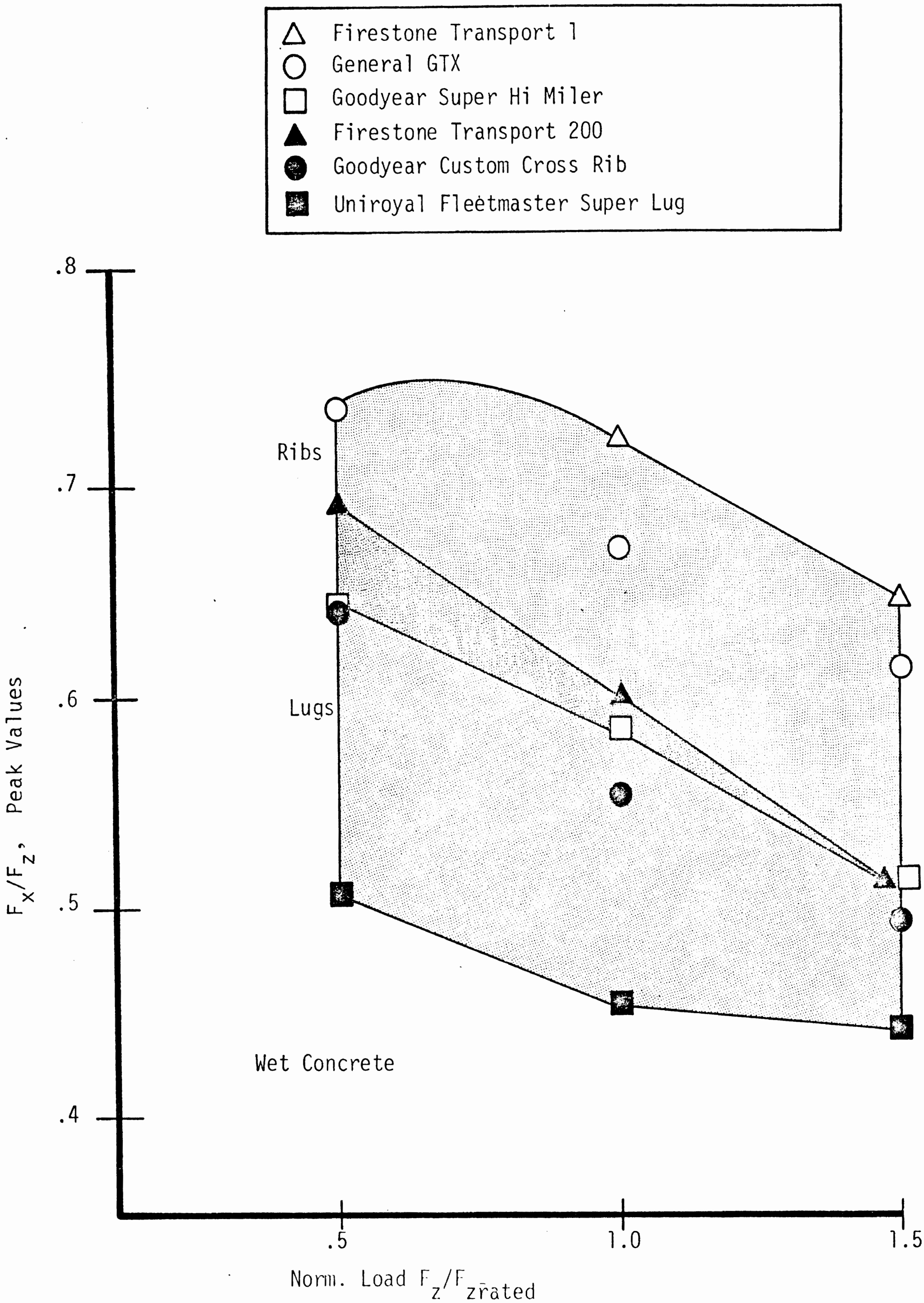



Figure 3. Load sensitivity of peak values of $F_x/F_z$ at 55 mph.

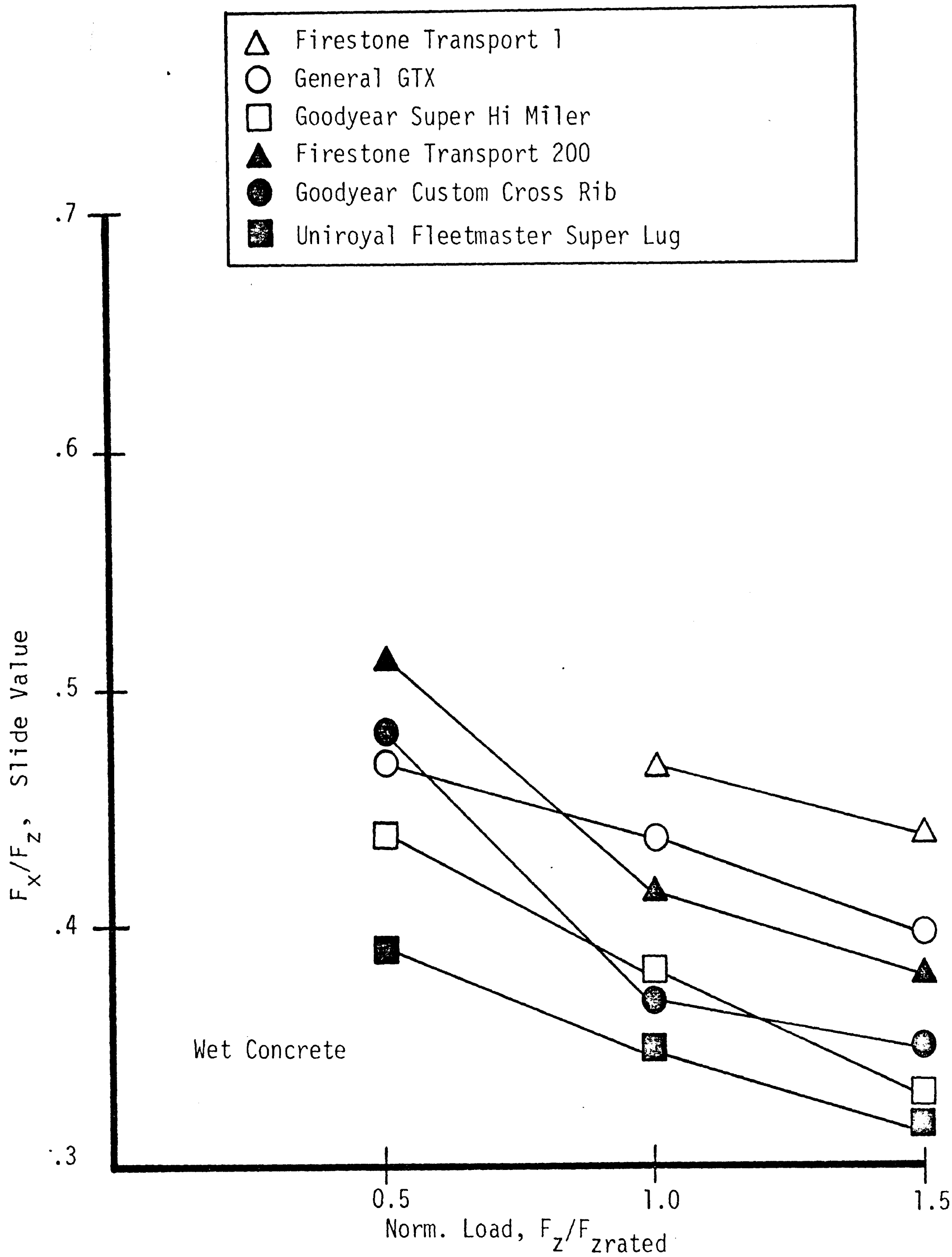



Figure 4. Load sensitivity of slide values of $F_x/F_z$ at 55 mph.

the wider range of peak traction capabilities measured on the wet surface might indicate a greater possibility of unfavorable wheel lockup occurrence under the wet condition. Such an "unfavorable" arrangement, for example, might result in jackknife of a non-antilock-protected tractor-semitrailer which mounts a traction-poor lug tire on its rear driving axles, together with a traction-capable rib selection at its other axle positions. By contrast, for example, the lowest and highest traction levels measured for the six-tire sample on dry concrete involved a lug tire which provided 80% of the traction capability of the highest-performing rib tire. On the wet surface, however, the "poorest" lug yielded only 66% of the performance attained by the highest-performing rib tire. Since, again, the lug-type tire will be typically mounted on the driving axle of the tractor, the depressed traction performance at that wheel position during wet-weather braking tends to aggravate the jackknife possibility.

## 2.2 Lateral Traction Results

The side force ($F_y$) response of the six-tire sample to varying slip angle ($\alpha$) was measured over a matrix of load and velocity conditions on the wet concrete surface. These results are summarized in Figures 5 and 6, in the form of $F_y$ versus $\alpha$ plots at selected load and velocity conditions. In general, these data concur with the nondiscriminatory character of the side force measurements obtained for the rib and lug selections on a dry concrete pavement. Thus no generalized distinction exists between the side force limits afforded by rib- and lug-type tires on the wetted concrete surface in question.

Notably, the Firestone Transport 1 tire was seen to register substantially higher shear force levels than any of the other tire selections. Although this same tire model was seen to yield the highest dry side force levels as well as the highest wet

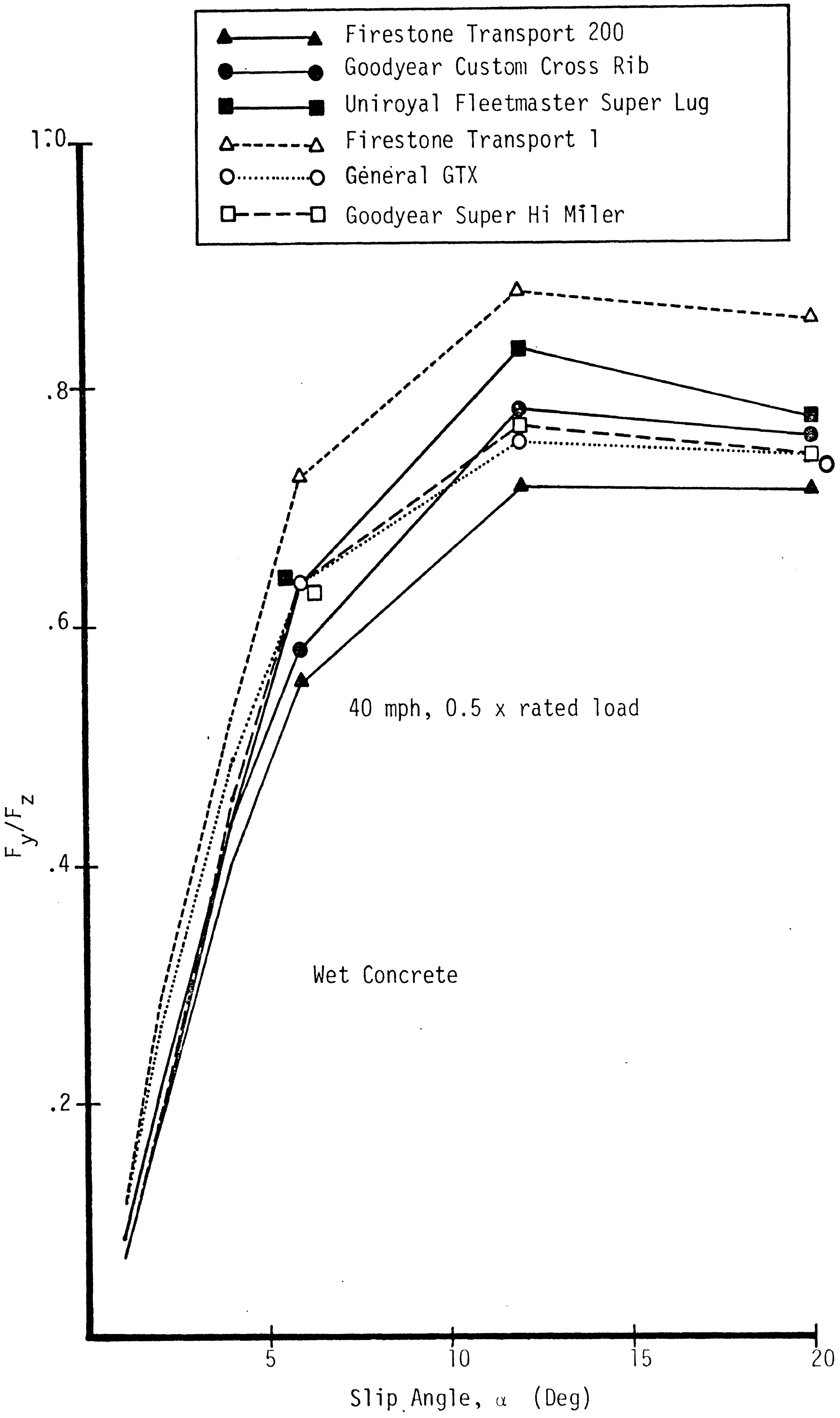



Figure 5. Lateral traction results, 40 mph, 0.5 x rated load.

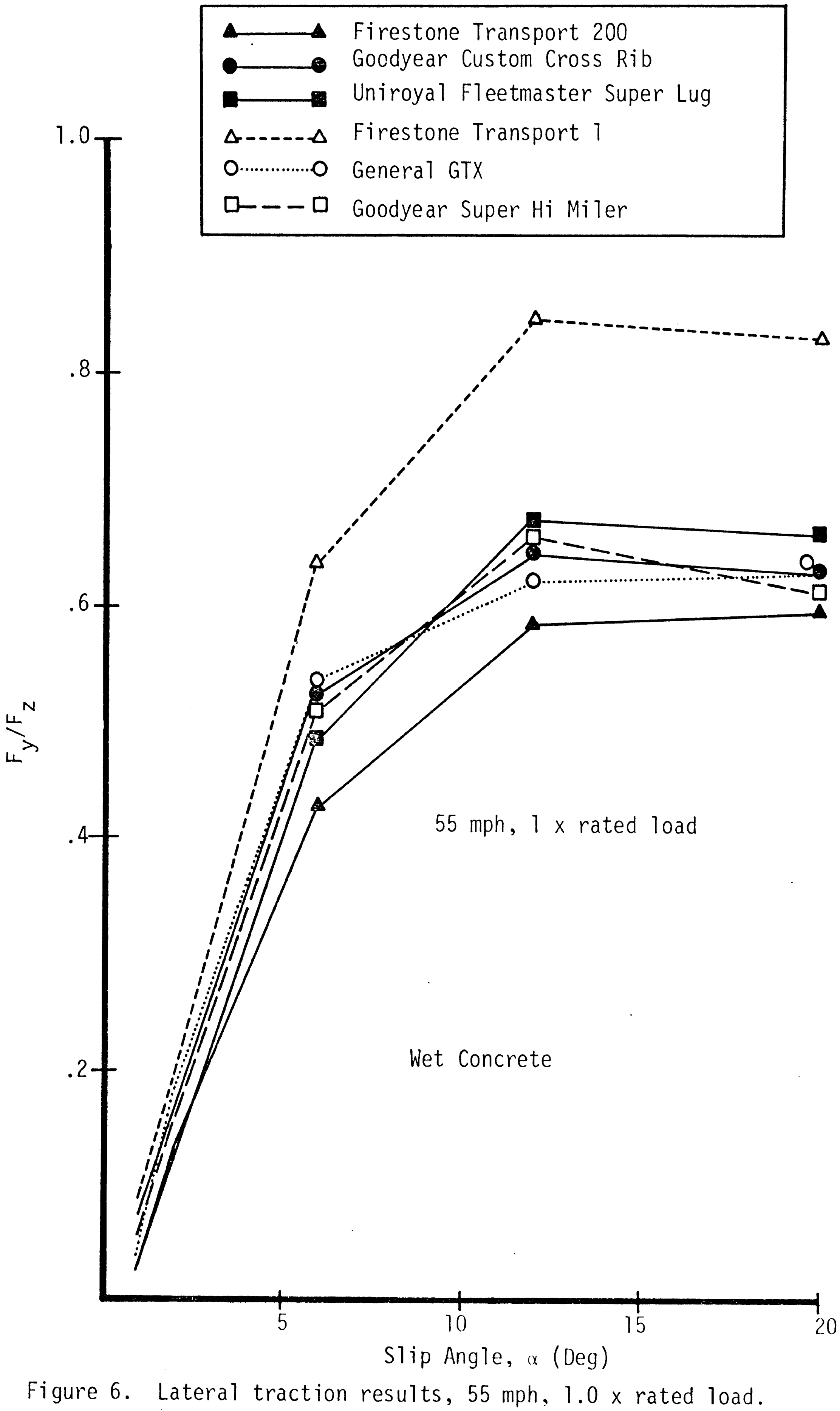
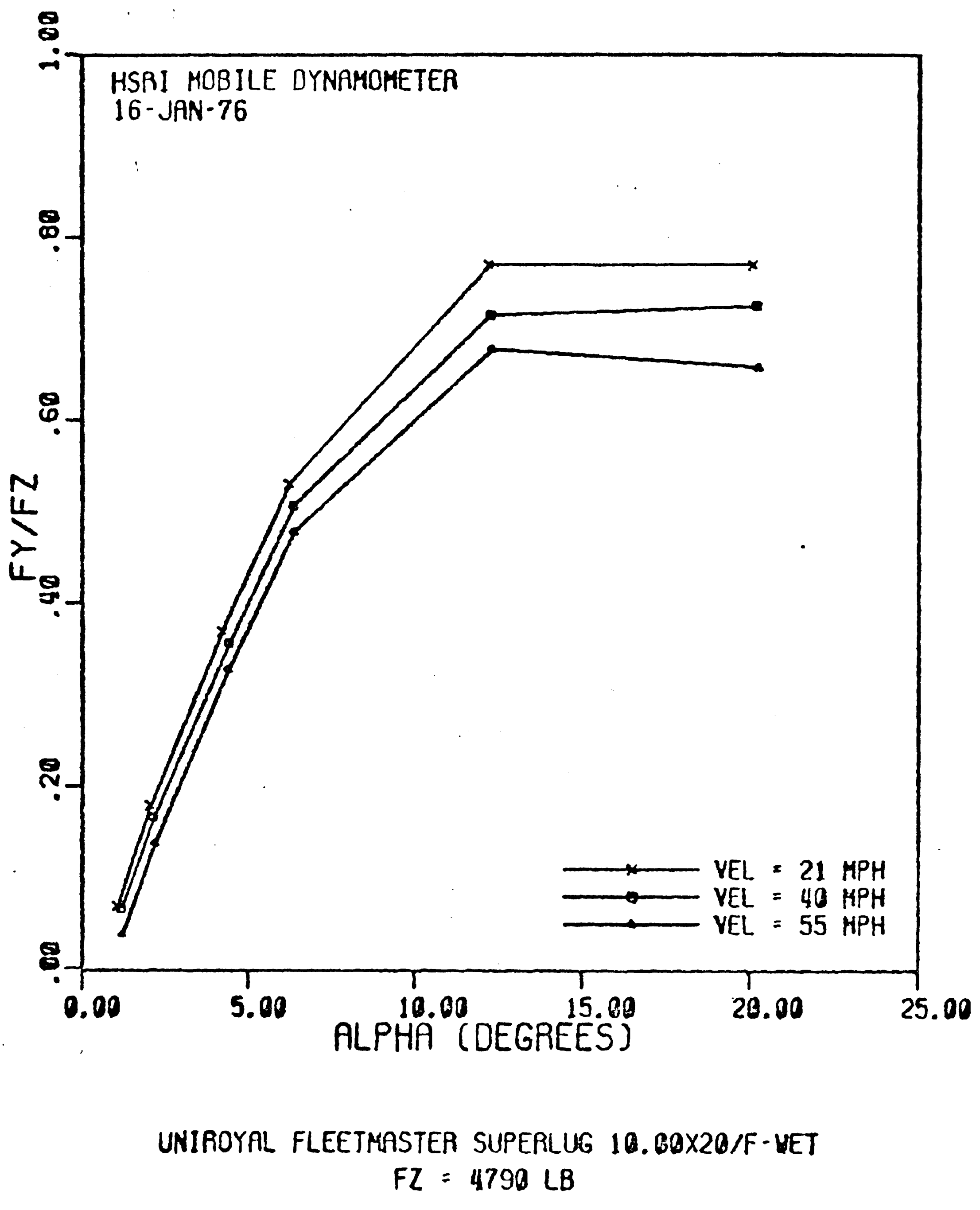



Figure 6. Lateral traction results, 55 mph, 1.0 x rated load.

longitudinal force levels, the 30% traction superiority illustrated in Figure 6 would seem to call for some confirming follow-up.

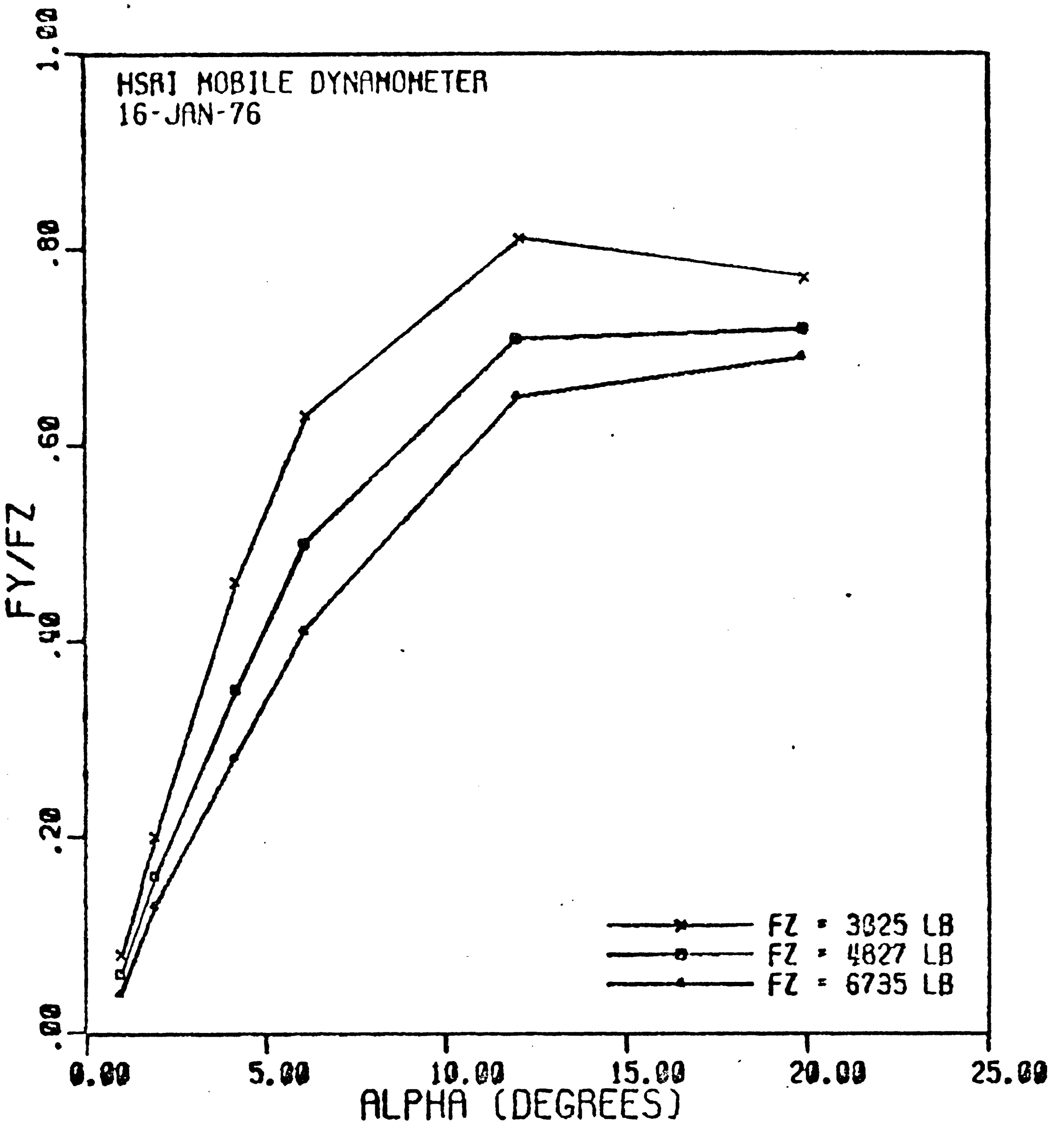
A plot of the typical $F_y$ versus $\alpha$ sensitivity to velocity is shown in Figure 7. The extent to which shear force output at large slip angles falls off with velocity is about the same here as was observed in the velocity sensitivity of peak values of longitudinal force shown previously in Figure 1. It would seem reasonable to speculate that the velocity sensitivity in Figure 7 derives principally from a hydrodynamics mechanism since the lateral traction measurements shown in Volume 1 for dry concrete exhibited virtually zero sensitivity to velocity.

Shown in Figure 8 is a typical example of the load sensitivity of the $F_y/\alpha$ behavior measured on wet concrete. An interesting feature of these data is that traction levels on the wet surface have been most reduced below the corresponding values obtained on the dry pavement for the conditions of light load. When the tire is operated above its rated load we observe that very little reduction in the shear force coupling afforded by this concrete surface has resulted from the 0.020-inch water covering. Presumably, the contact pressure of bias-ply heavy truck tires does increase substantially with load such that water drainage beneath the more heavily-loaded tire is enhanced.



HSRI MOBILE DYNAMOMETER
16-JAN-76
1.00
.80
.60
.40
.20
.00
FY/FZ
0.00
5.00
10.00
15.00
20.00
25.00
ALPHA (DEGREES)
VEL = 21 MPH
VEL = 40 MPH
VEL = 55 MPH
UNIROYAL FLEETMASTER SUPERLUG 10.00X20/F-WET
FZ = 4790 LB


Figure 7.




UNIROYAL FLEETMASTER SUPERLUG 10.00X20/F-WET
VEL = 40 MPH

Figure 8

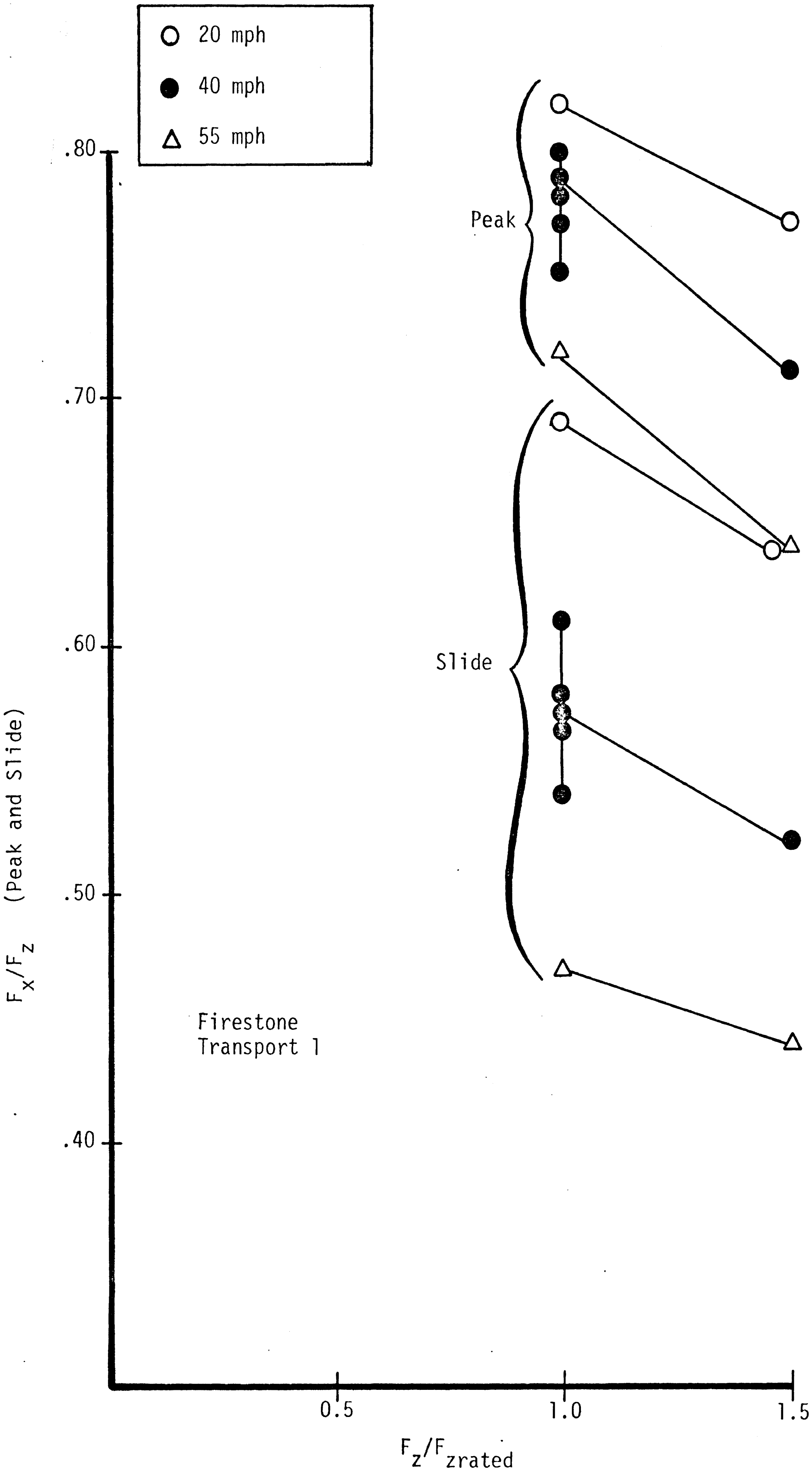
## 3.0 REFERENCE

1. Yeager, R.W., "Tire Hydroplaning: Testing Analysis and Design," The Physics of Tire Traction, a symposium held at the General Motors Research Laboratories, October, 1973.

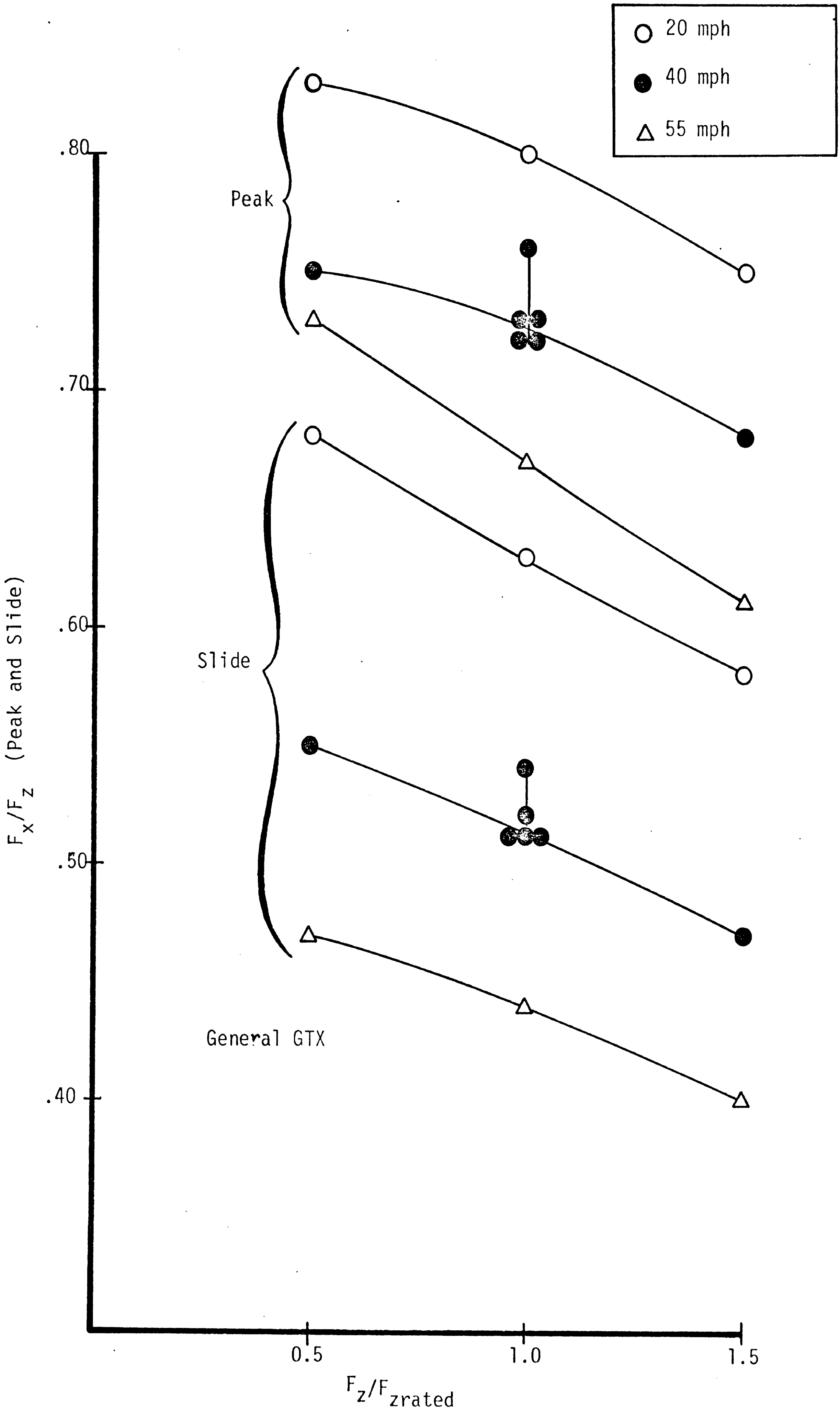
# APPENDIX D-I

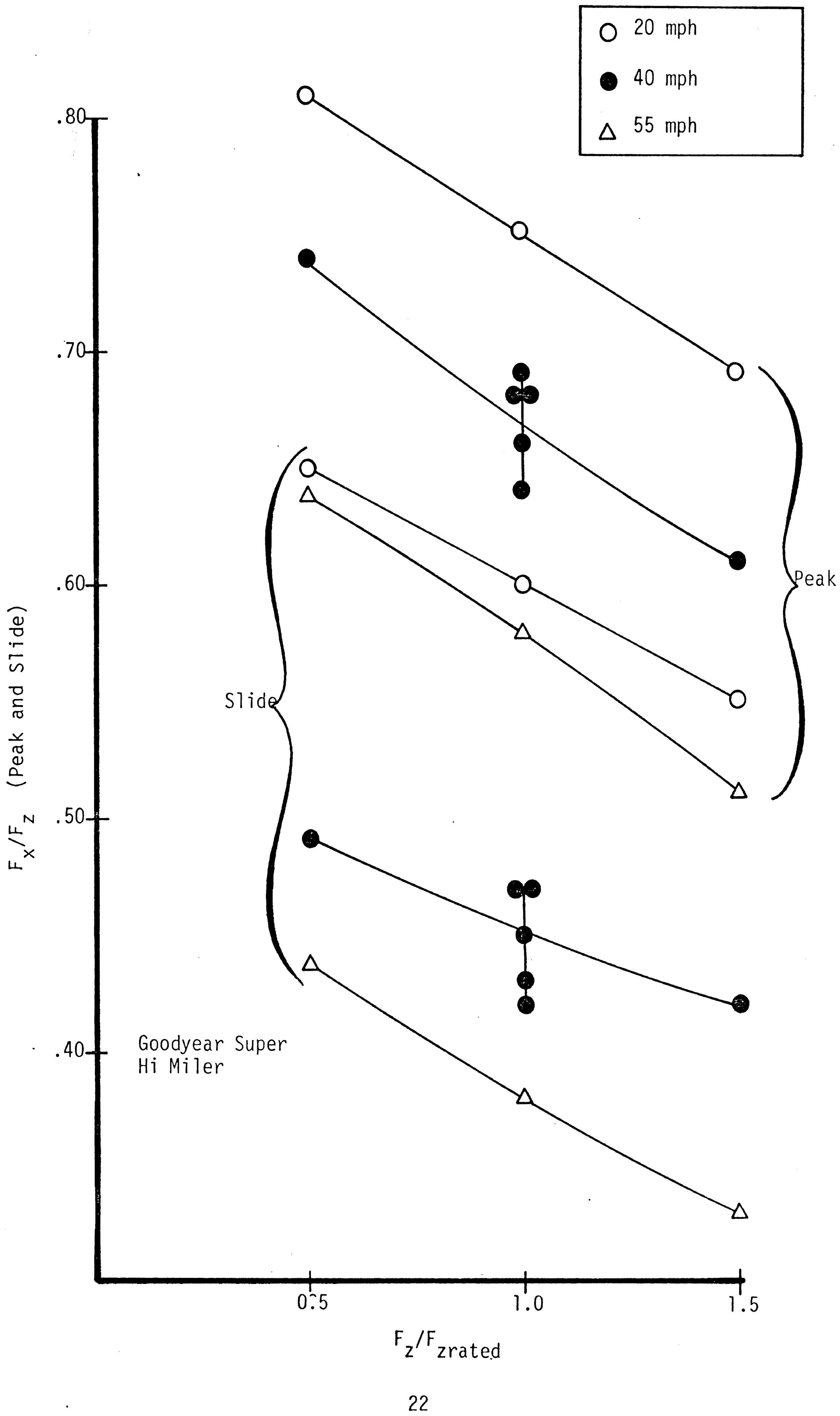
## INDIVIDUAL LONGITUDINAL FORCE PLOTS FROM WET TRACTION TESTS

The following plots represent the "peak" and "slide" values of normalized longitudinal force obtained during the braking traction testing of the six-tire sample on a wet Portland cement concrete pavement. Each plot illustrates the influence of both load and velocity on the values of $F_x/F_z$ obtained at the peak of the "$\mu$-slip" curve and at the 100% slip condition. Additionally, data from the five repeats of the reference condition run, at $F_z = 1.0 \times$ rated load and V = 40 mph, are plotted as an indicator of the basic repeatability of the experiments.

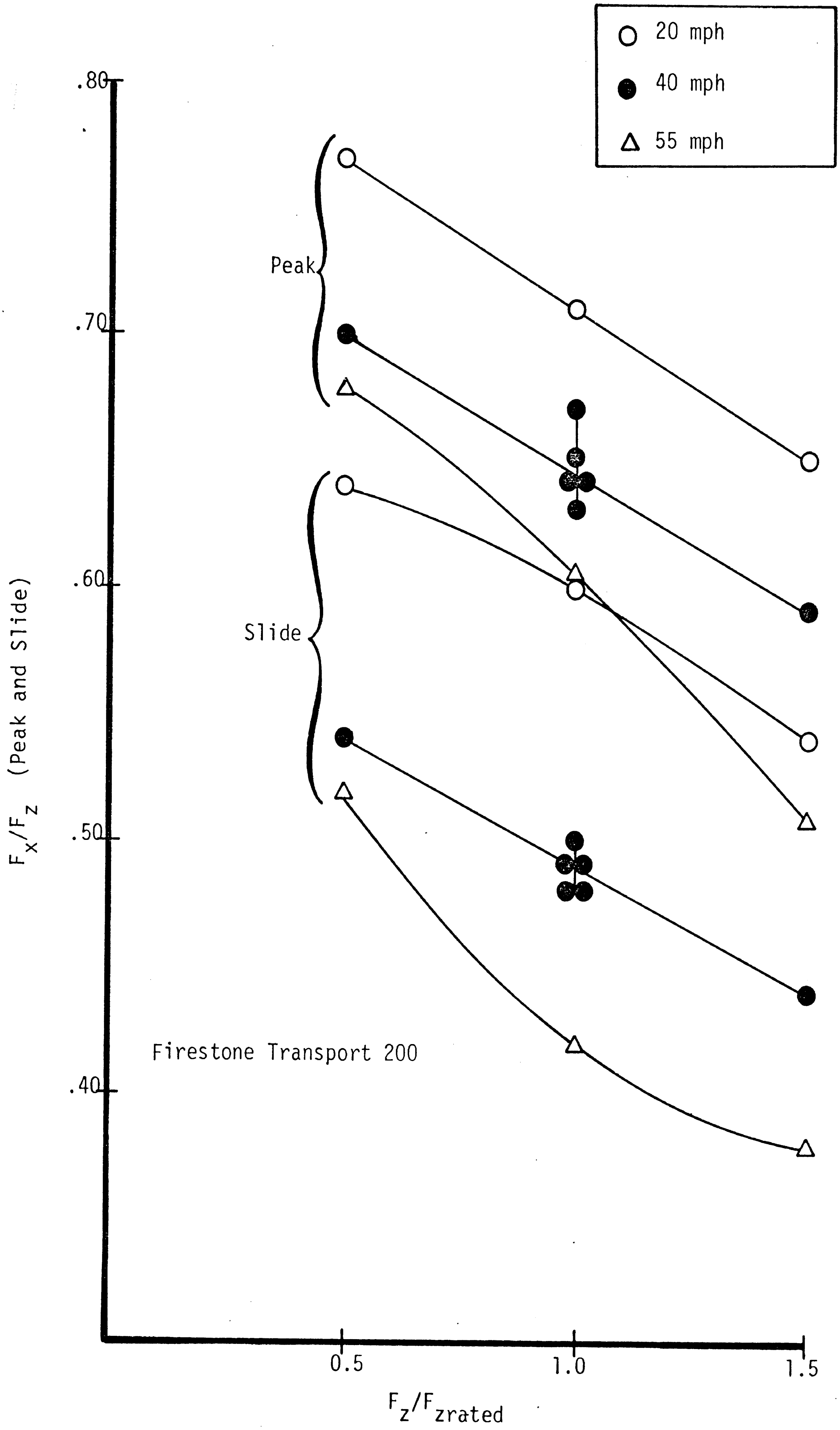


20 mph
40 mph
55 mph
Peak
Slide
Firestone Transport 1
.80
.70
.60
.50
.40
$F_x/F_z$ (Peak and Slide)
0.5
1.0
1.5
$F_z/F_{zrated}$

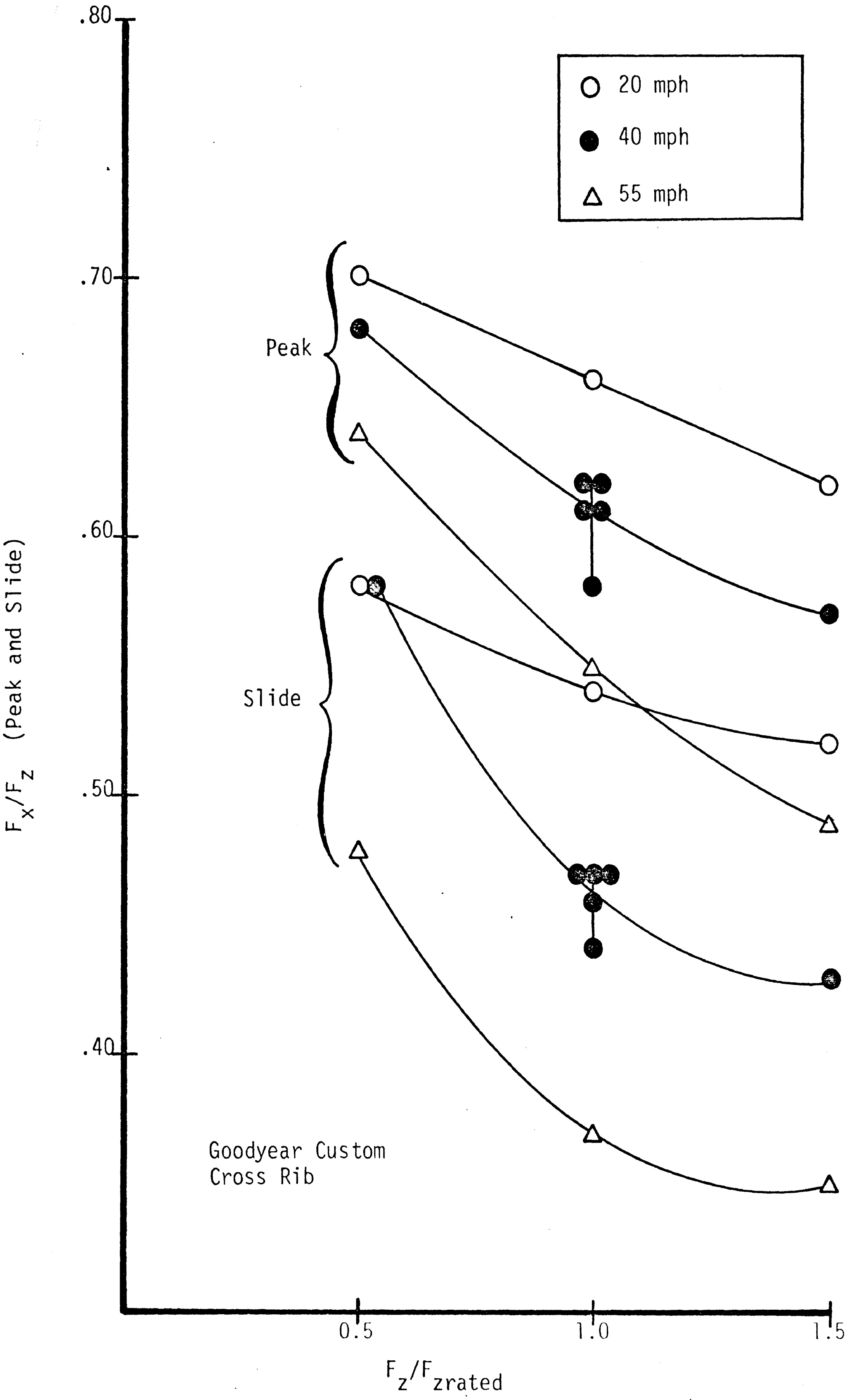

20 mph
40 mph
55 mph
.80
.70
.60
.50
.40
Peak
Slide
General GTX
$F_x/F_z$ (Peak and Slide)
0.5
1.0
1.5
$F_z/F_{z\,rated}$

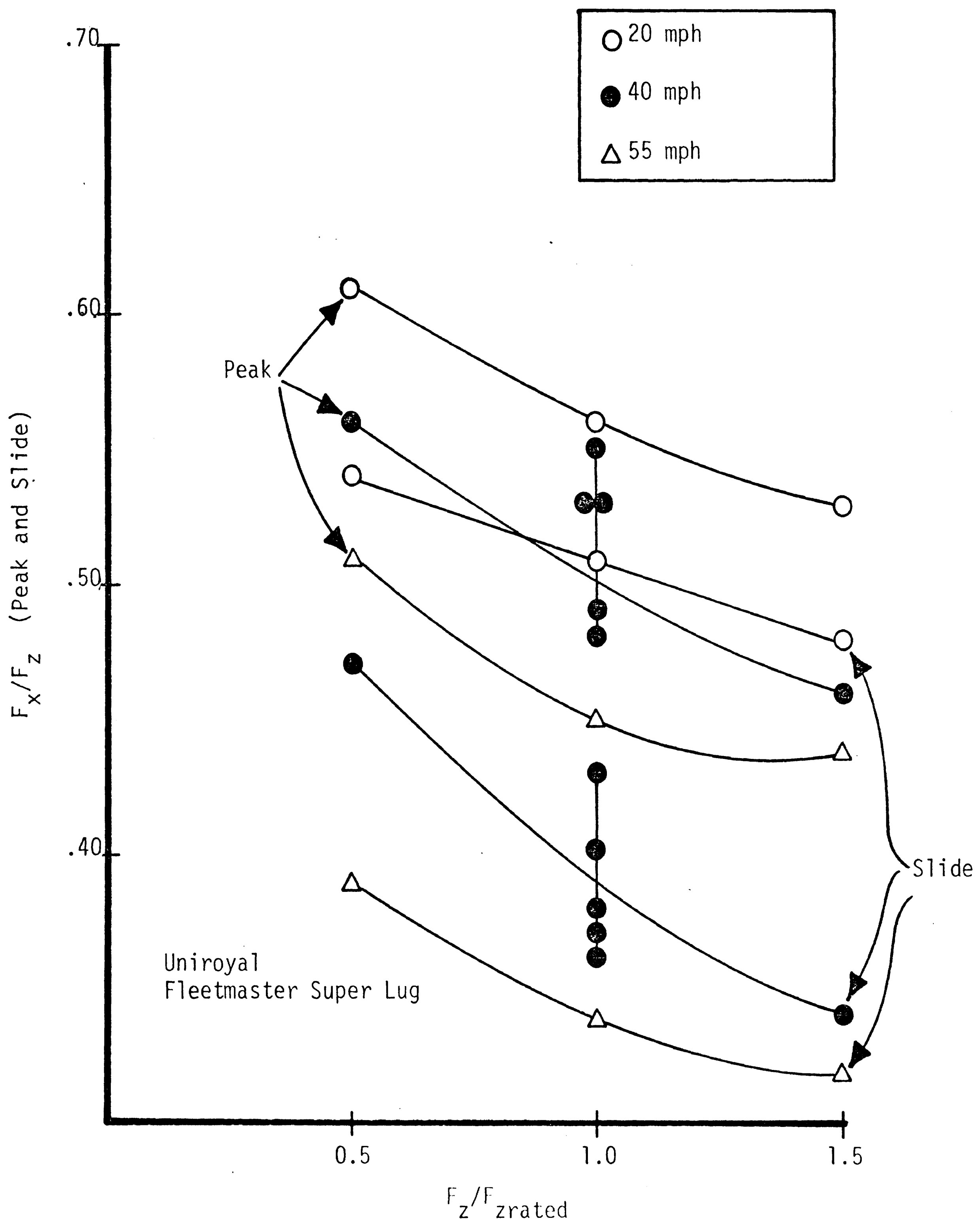


20 mph
40 mph
55 mph
.80
.70
.60
.50
.40
$F_x/F_z$ (Peak and Slide)
Peak
Slide
Goodyear Super Hi Miler
0.5
1.0
1.5
$F_z/F_{zrated}$



20 mph
40 mph
55 mph
.80
.70
.60
.50
.40
Peak
Slide
$F_x/F_z$ (Peak and Slide)
Firestone Transport 200
0.5
1.0
1.5
$F_z/F_{zrated}$


.80
.70
.60
.50
.40
20 mph
40 mph
55 mph
Peak
Slide
$F_x/F_z$ (Peak and Slide)
Goodyear Custom
Cross Rib
0.5
1.0
1.5
$F_z/F_{zrated}$


20 mph
40 mph
55 mph
.70
.60
.50
.40
Peak
Slide
$F_x/F_z$ (Peak and Slide)
Uniroyal
Fleetmaster Super Lug
0.5
1.0
1.5
$F_z/F_{zrated}$

## APPENDIX D-II

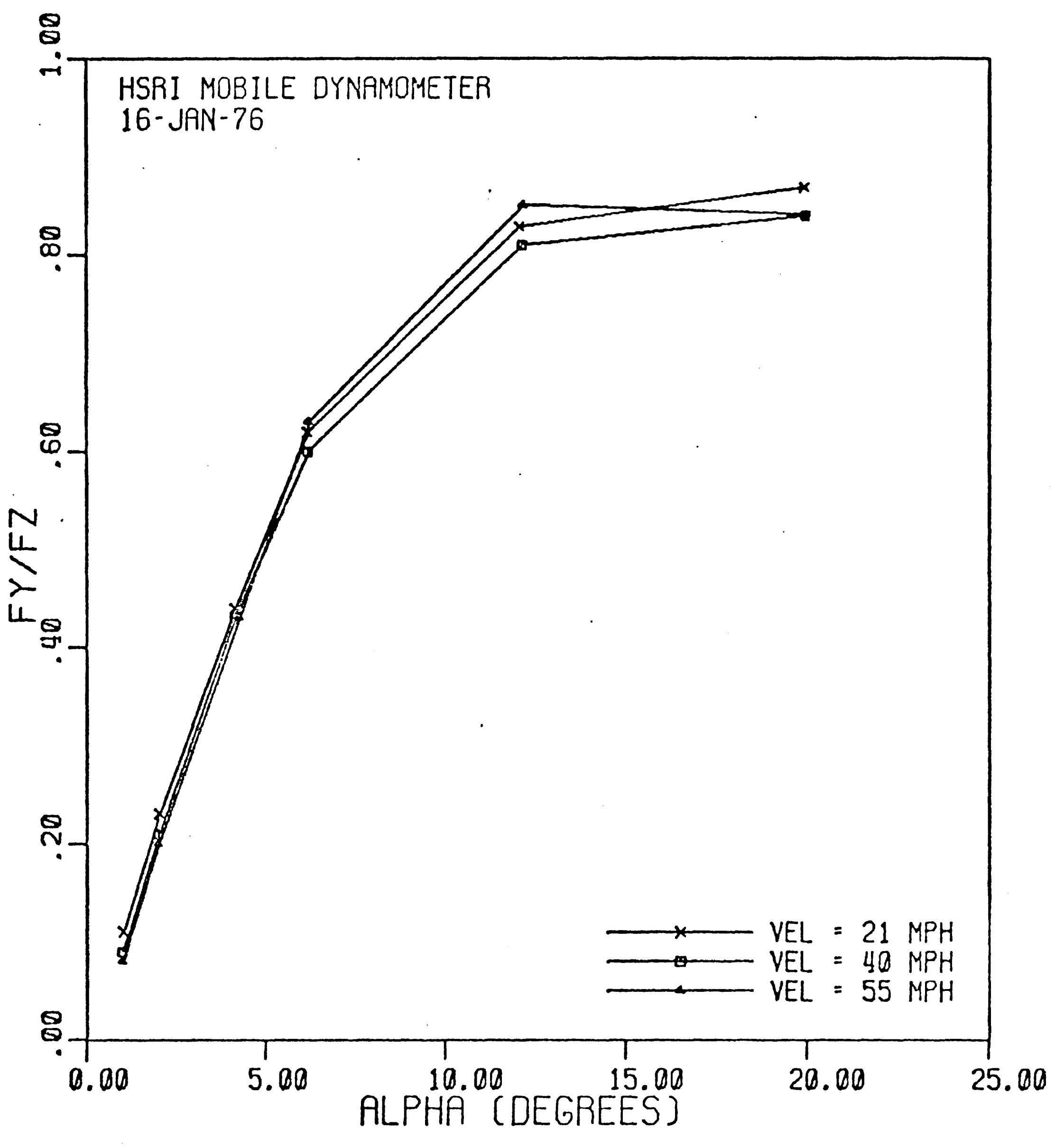
## INDIVIDUAL LATERAL FORCE PLOTS FROM WET TRACTION TESTS

The following plots represent the lateral force, $F_y$, or the normalized lateral force, $F_y/F_z$, versus slip angle, $\alpha$, behavior of each tire in the test sample. These data were obtained using the HSRI mobile dynamometer on a wet Portland cement concrete pavement. Each tire is represented by three plots indicating the influence on lateral traction of

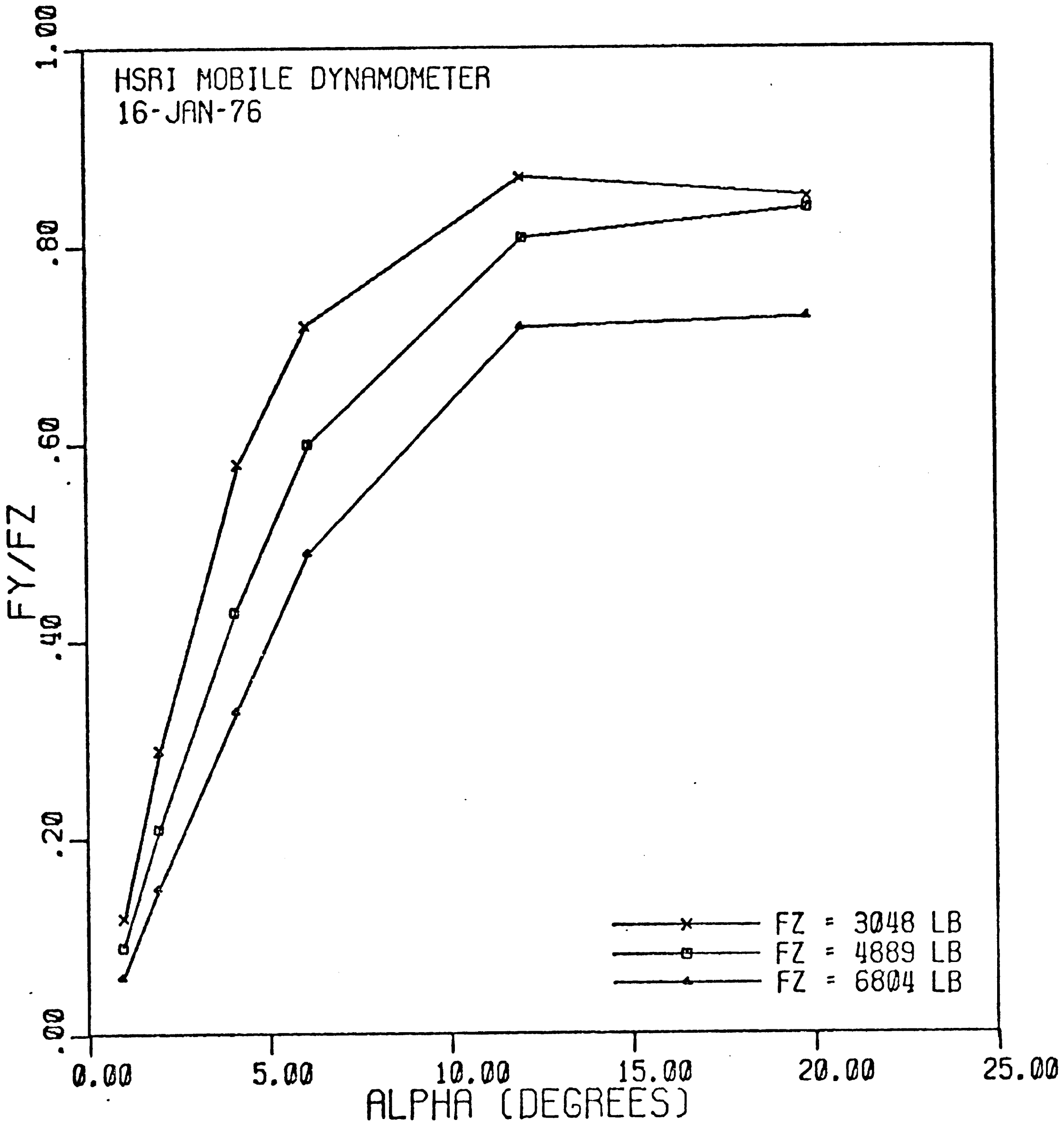
1) velocity
2) load
3) repeated test runs.

Accordingly, the first plot for each tire represents tests conducted all at rated load, but at velocities of nominally 20, 40, and 55 mph.

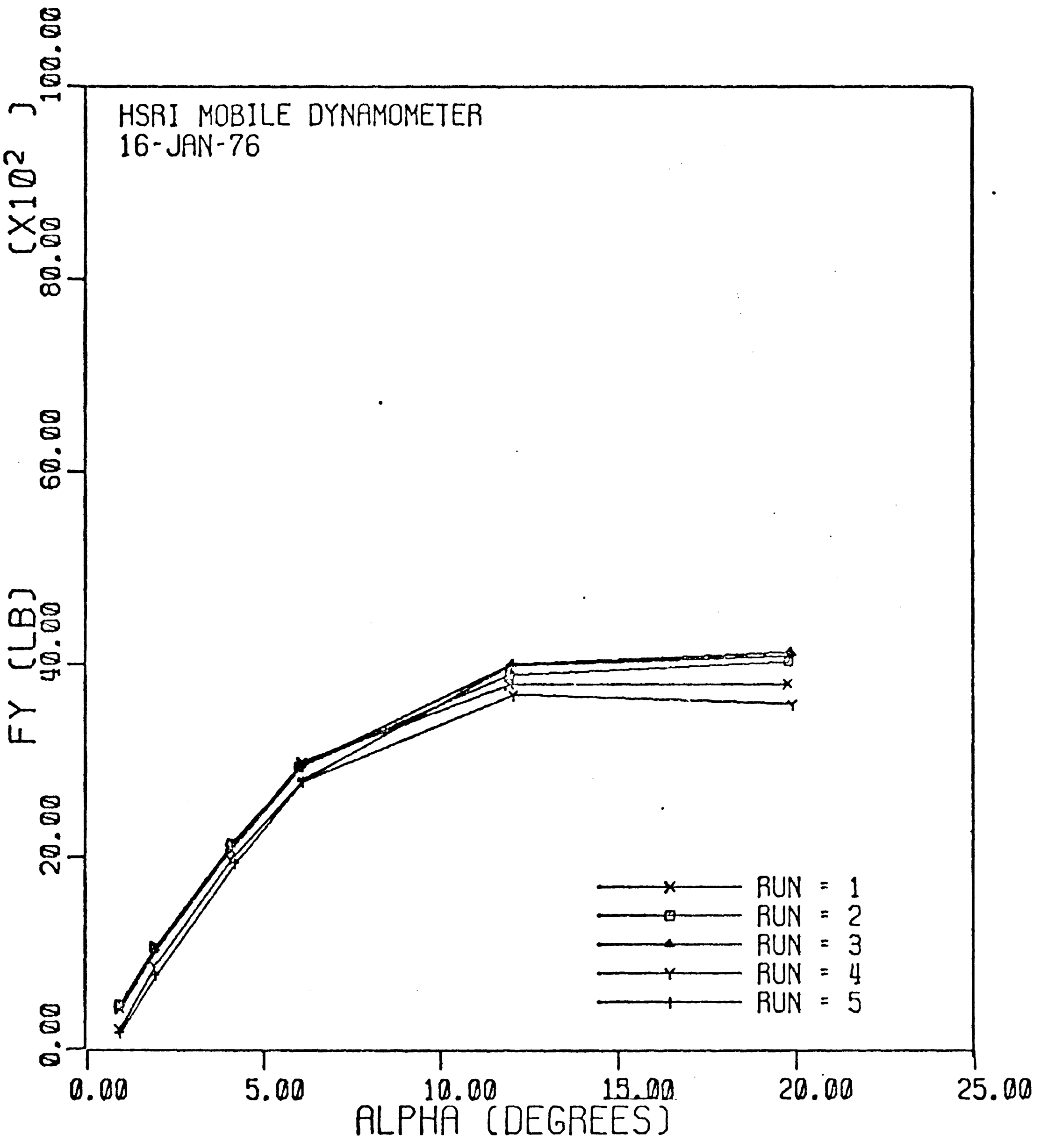
Similarly, the second plot for each tire represents tests conducted at 40 mph and at vertical loads of $F_z$ = 0.5, 1.0, and 1.5 times the T&RA rated load. The final plot serves to document the stability of the tire specimen as a force-producing mechanism over the sequence of test runs. These data indicate the tire's $F_y/\alpha$ behavior as measured during each of five "spot checks" at conditions of $F_z$ = rated load and V = 40 mph.



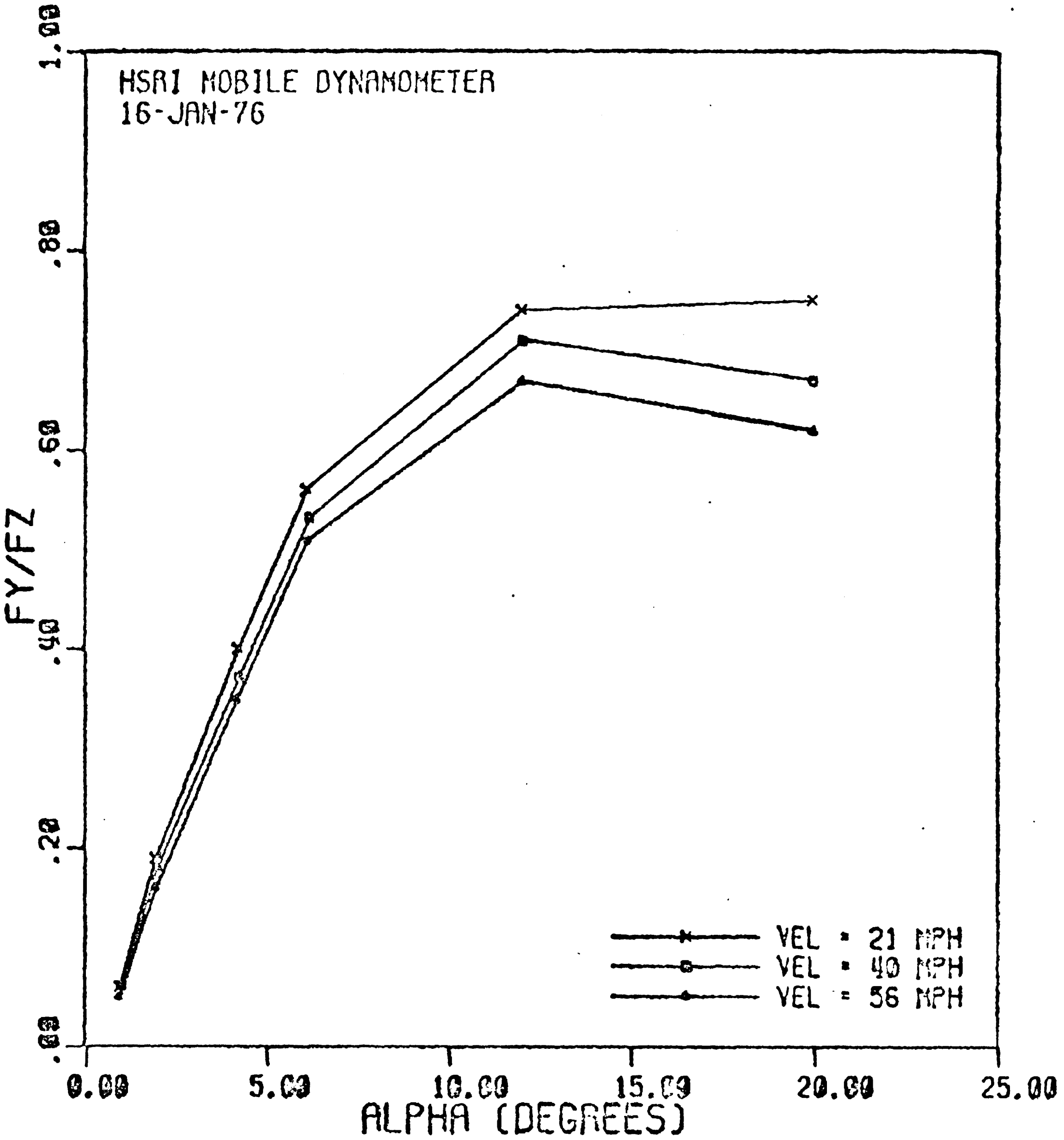

FIRESTONE TRANSPORT I 10.00X20/F-WET
FZ = 4867 LB



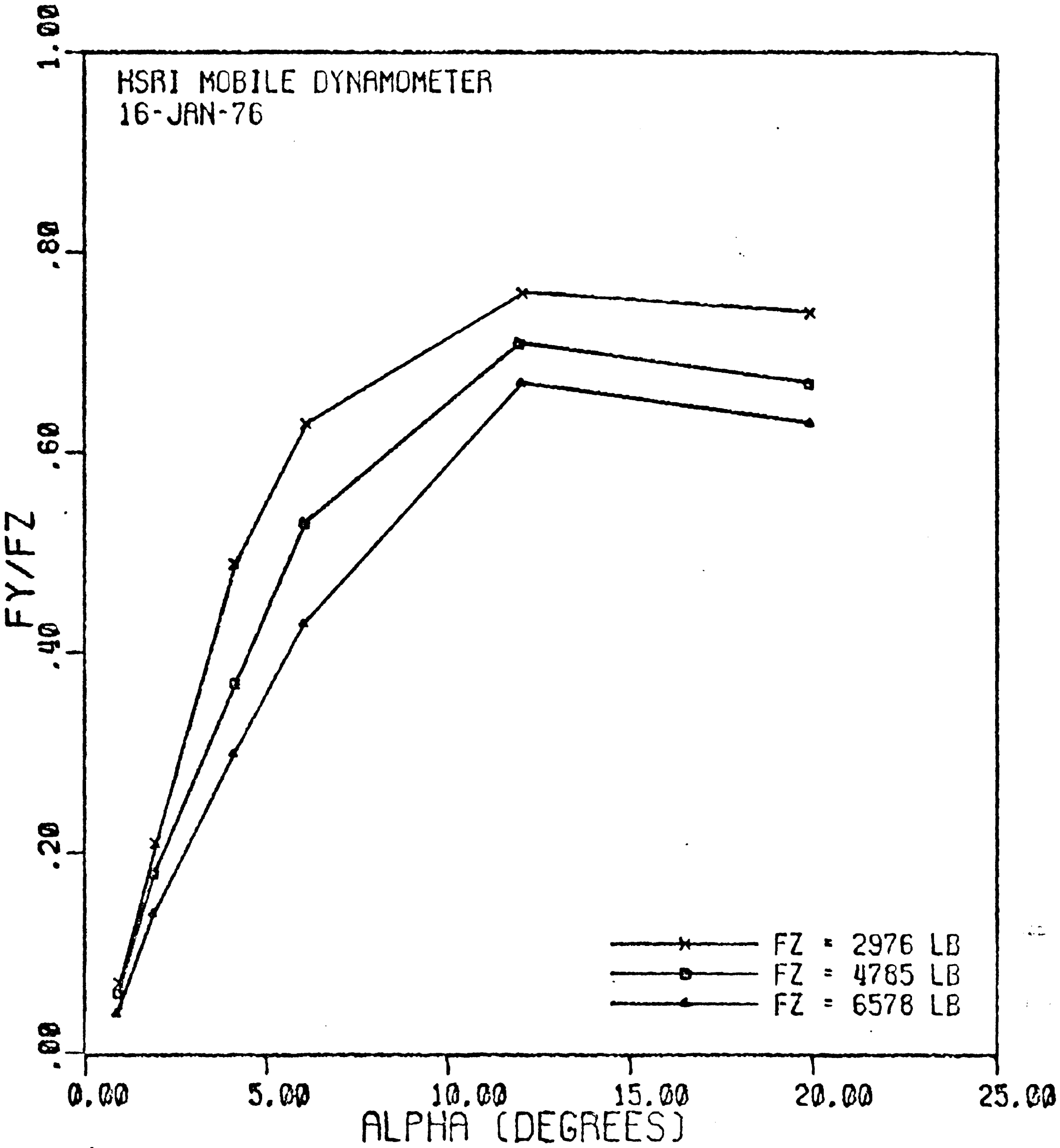

FIRESTONE TRANSPORT I 10.00X20/F-WET
VEL = 39 MPH



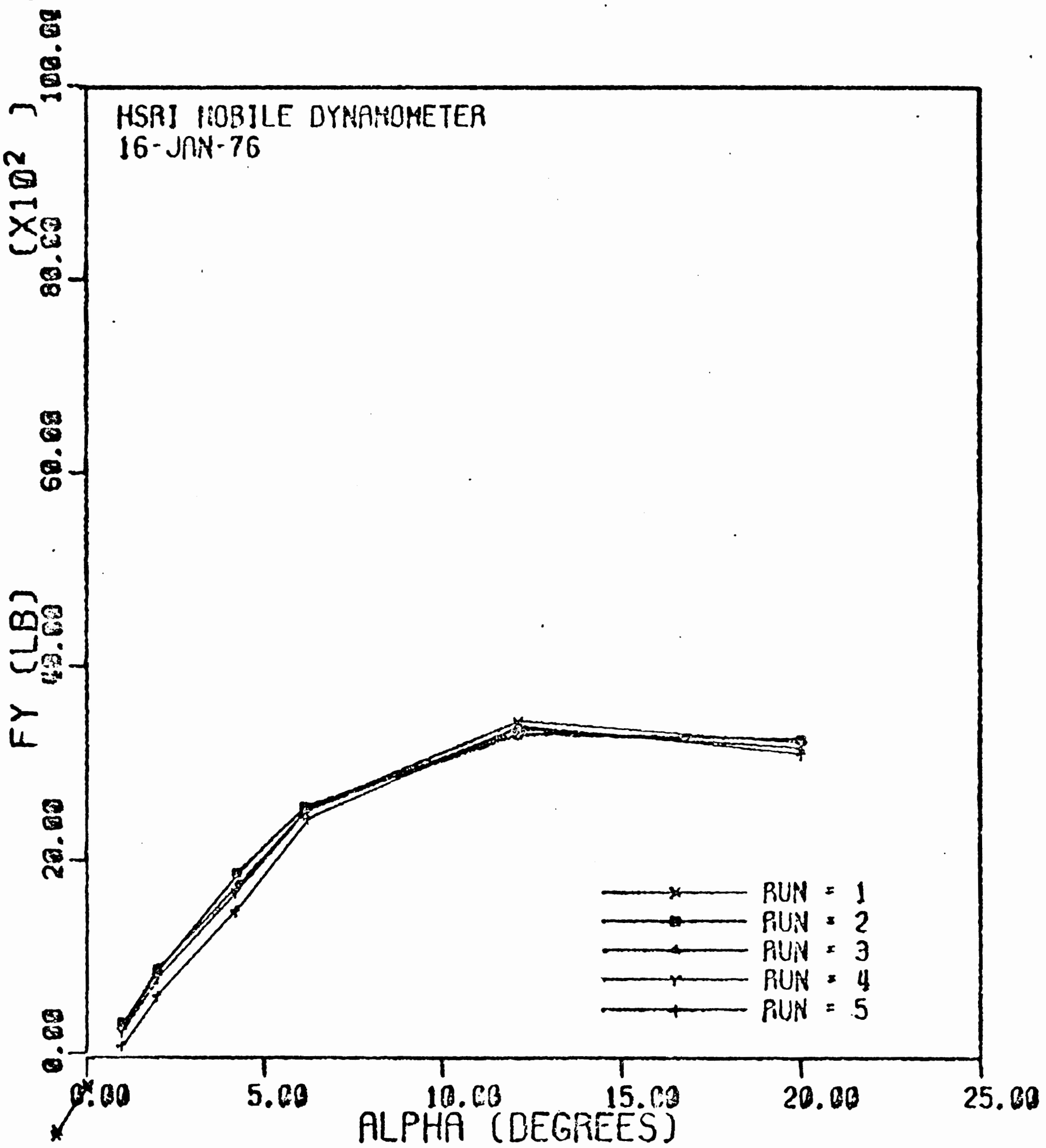

FIRESTONE TRANSPORT I 10.00X20/F-WET
FZ = 4858 LB VEL = 40 MPH




GOODYEAR SUPER HI-MILER 10.00X20/F-WET
FZ = 4761 LB




GOODYEAR SUPER HI-MILER 10.00X20/F-WET
VEL = 40 MPH

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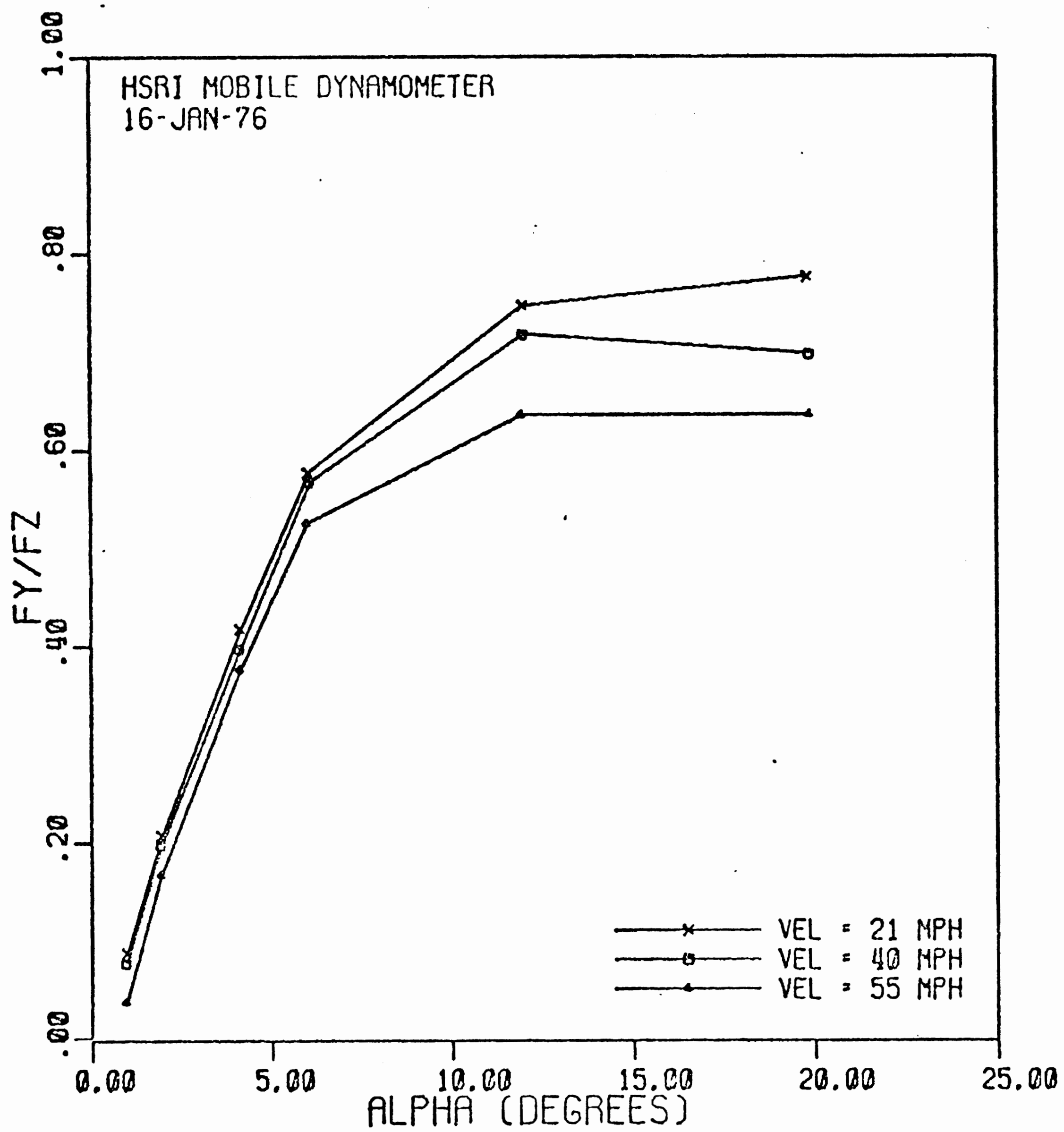
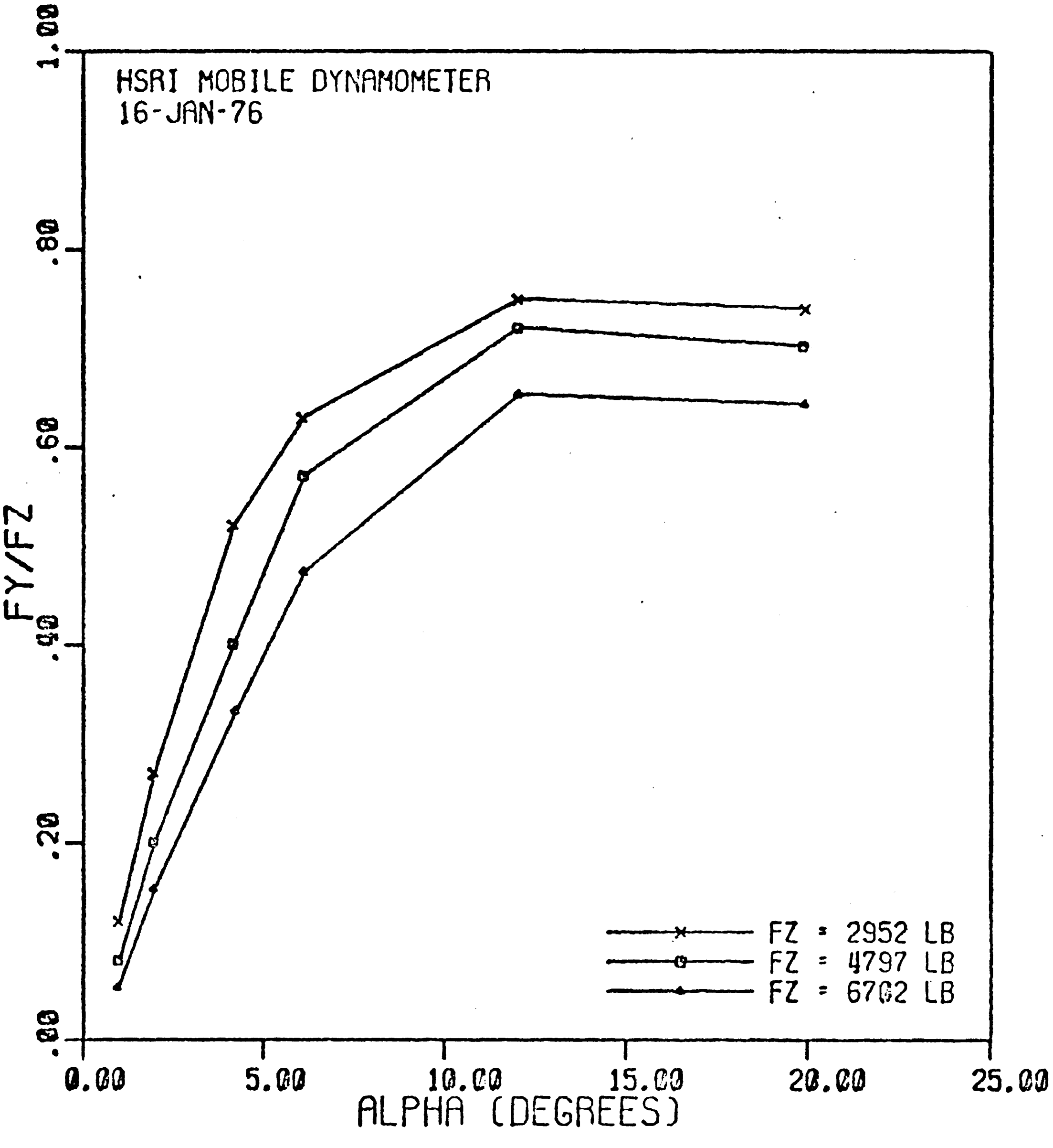
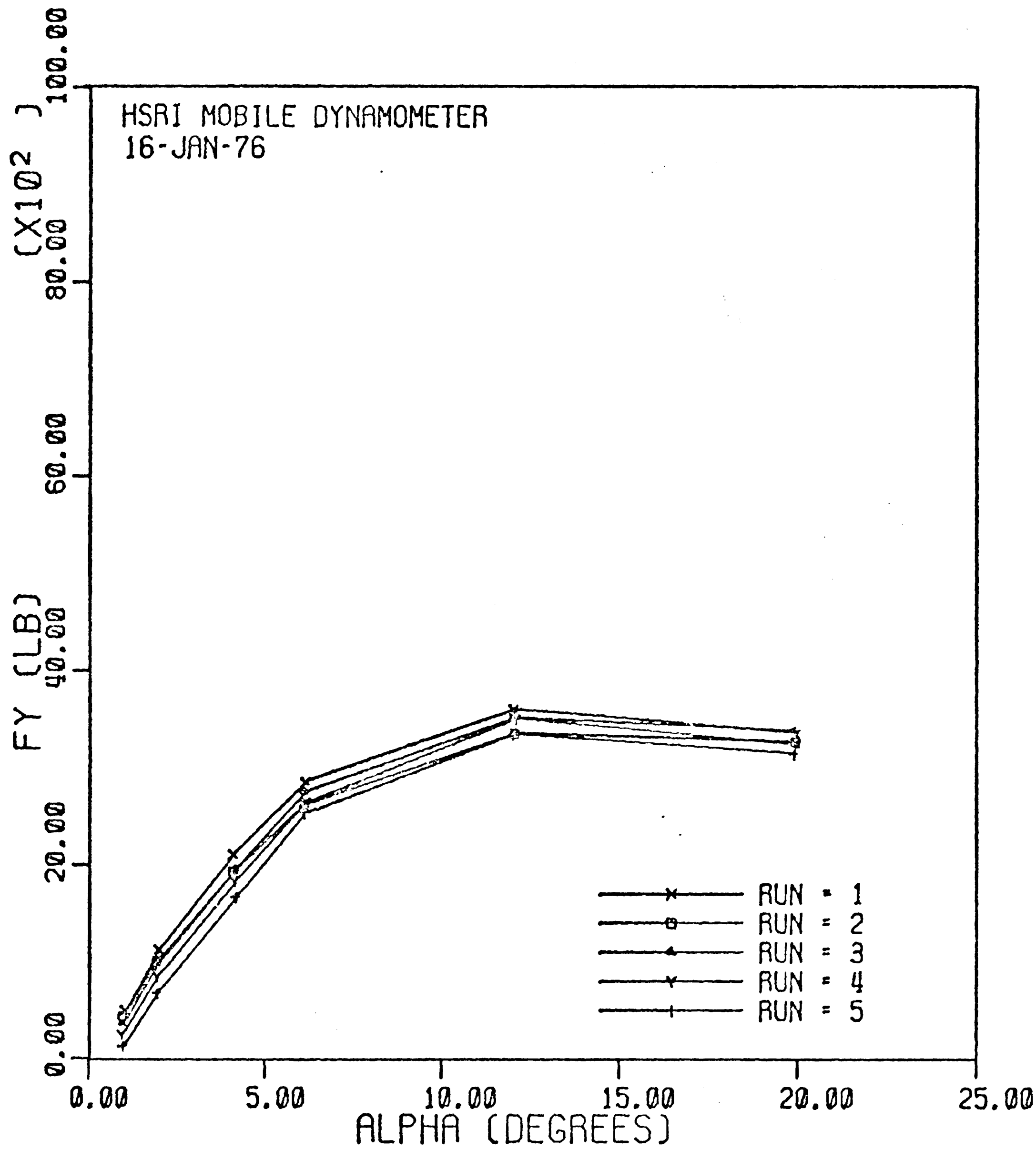
FZ = 4685 LB VEL = 39 MPH



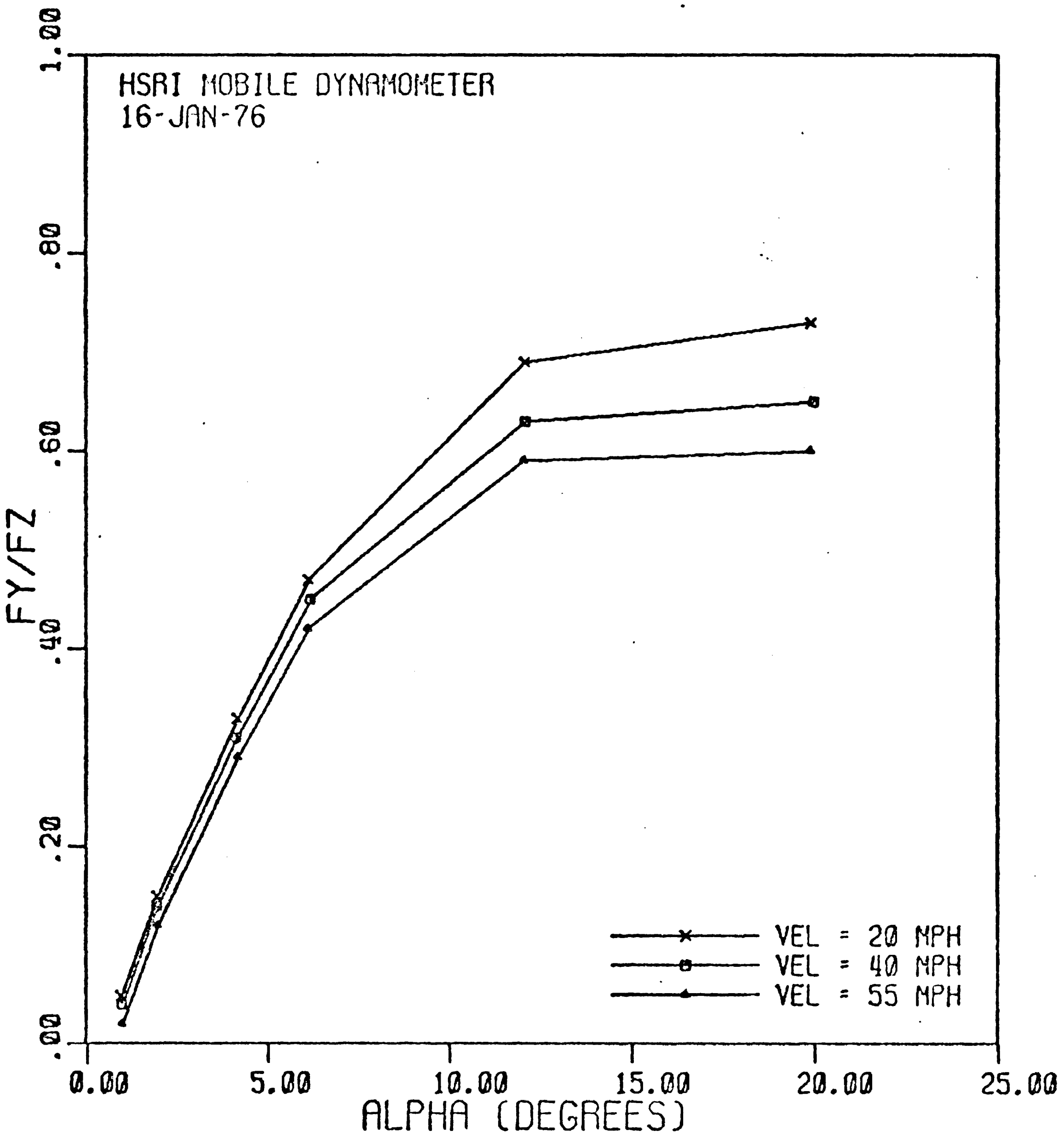

GENERAL GTX 10.00X20/F-WET
FZ = 4776 LB



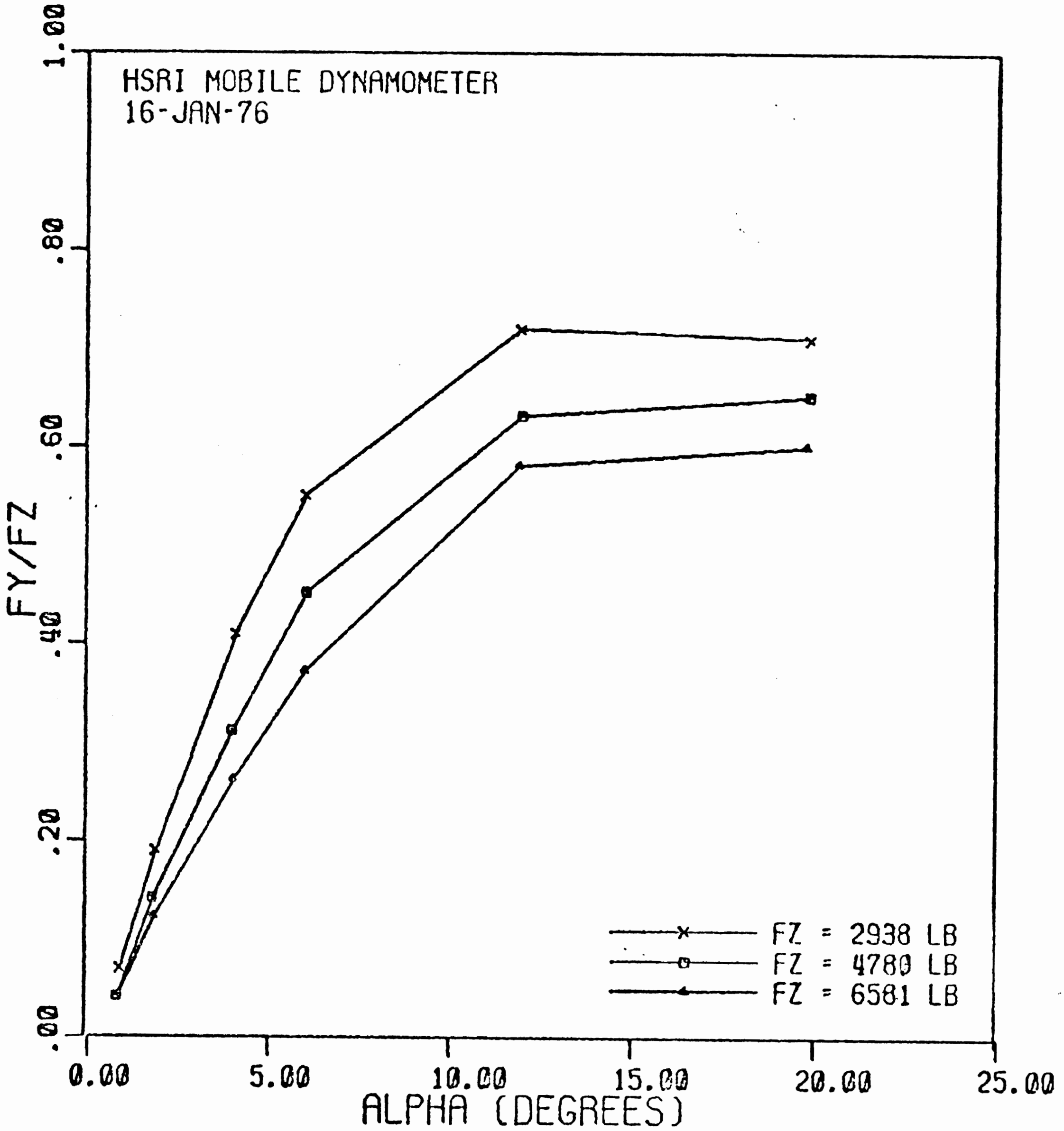

GENERAL GTX 10.00X20/F-WET
VEL = 41 MPH



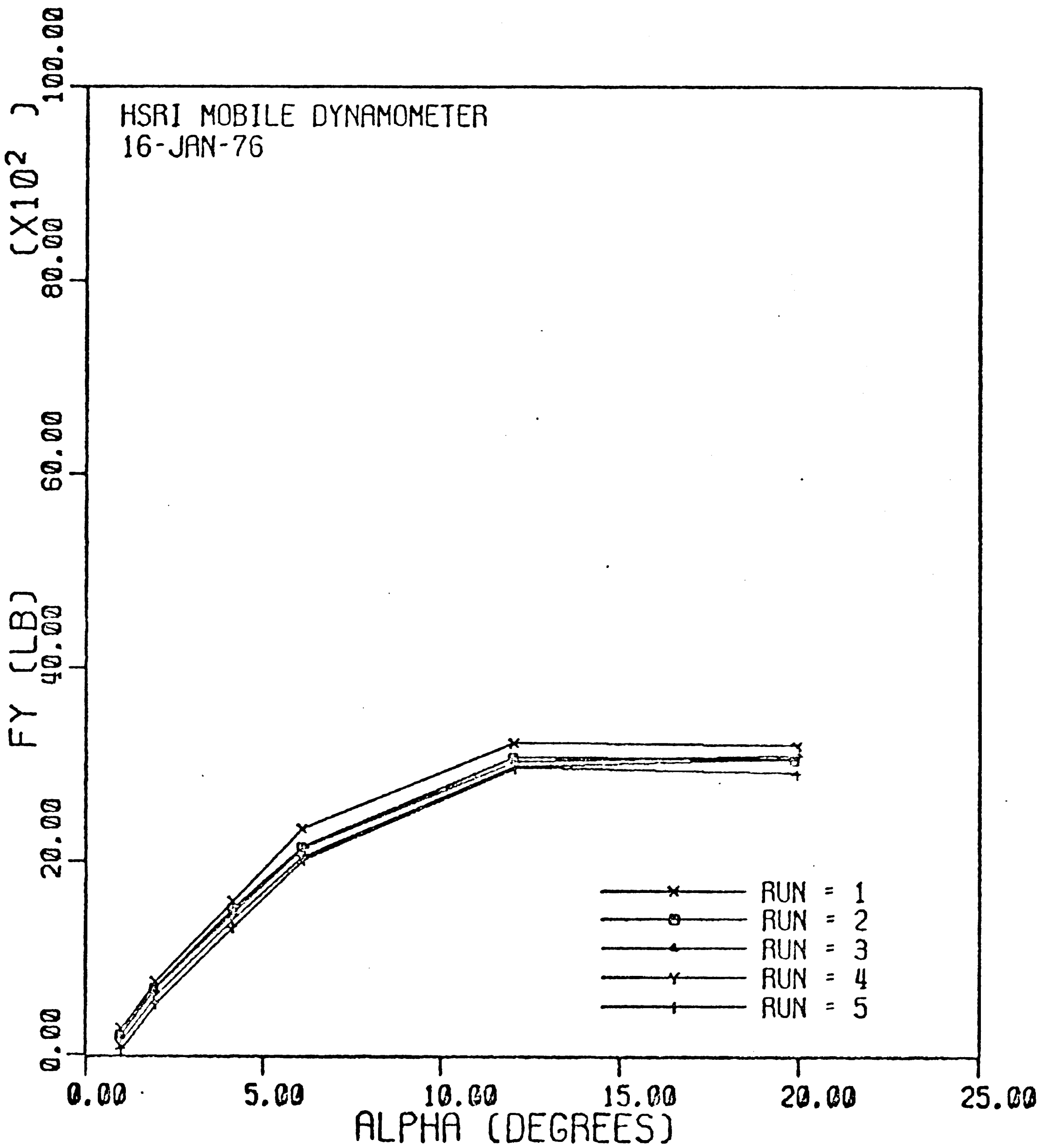

GENERAL GTX 10.00X20/F-WET
FZ = 4780 LB VEL = 40 MPH




FIRESTONE TRANSPORT 200 10.00X20/F-WET
FZ = 4743 LB




FIRESTONE TRANSPORT 200 10.00X20/F-WET
VEL = 40 MPH

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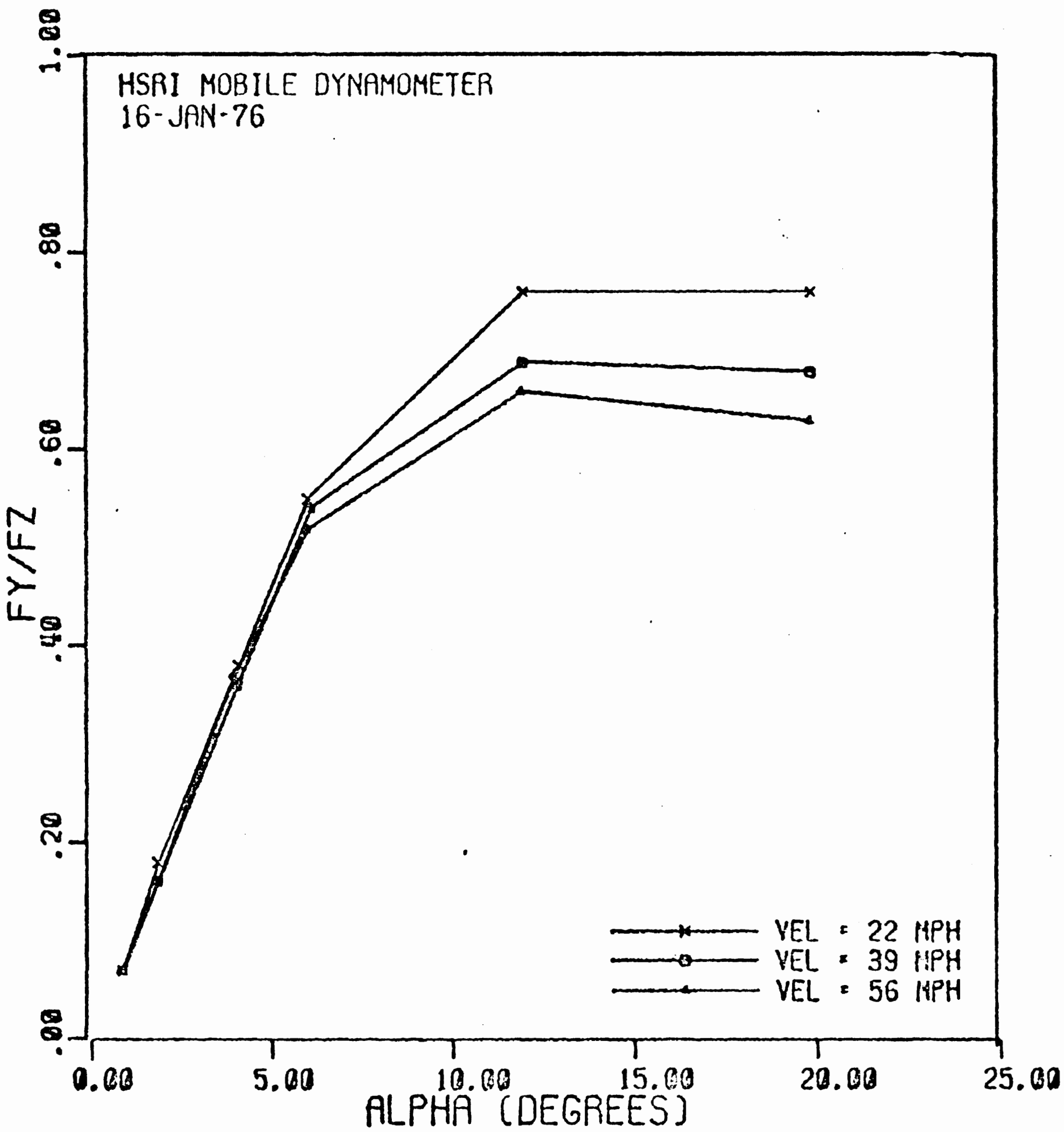
FZ = 4740 LB VEL = 40 MPH

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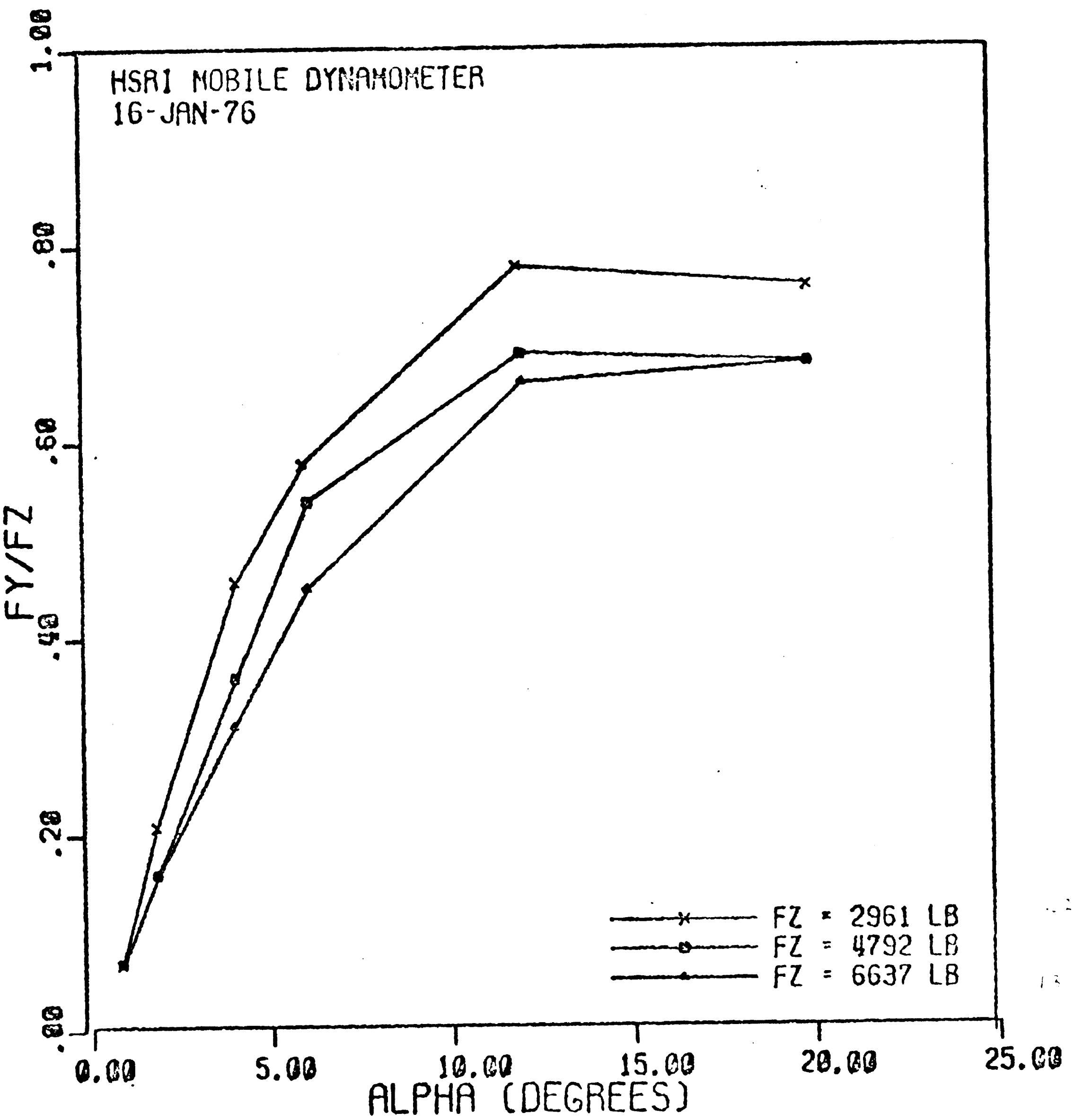
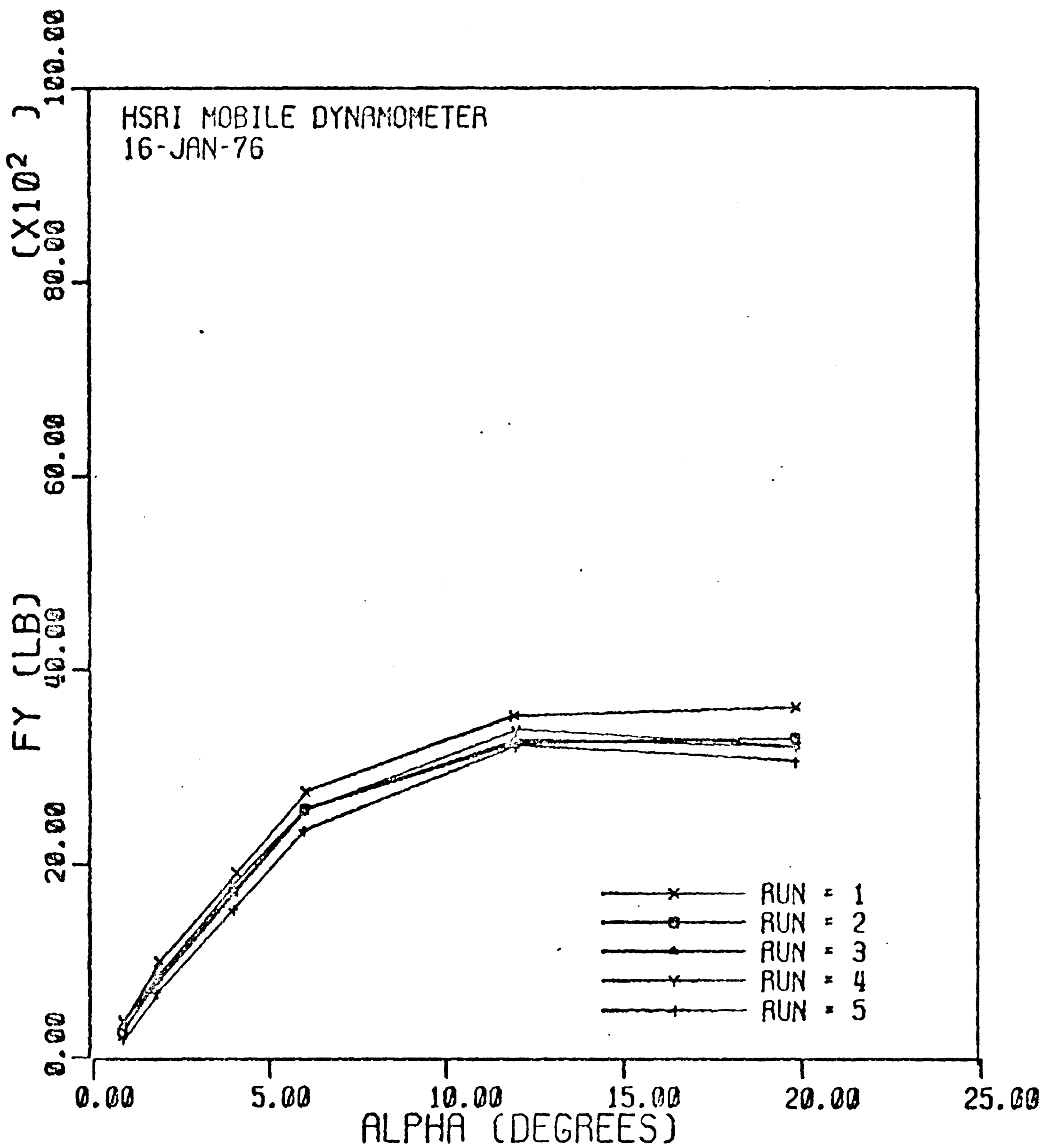
FZ = 4738 LB

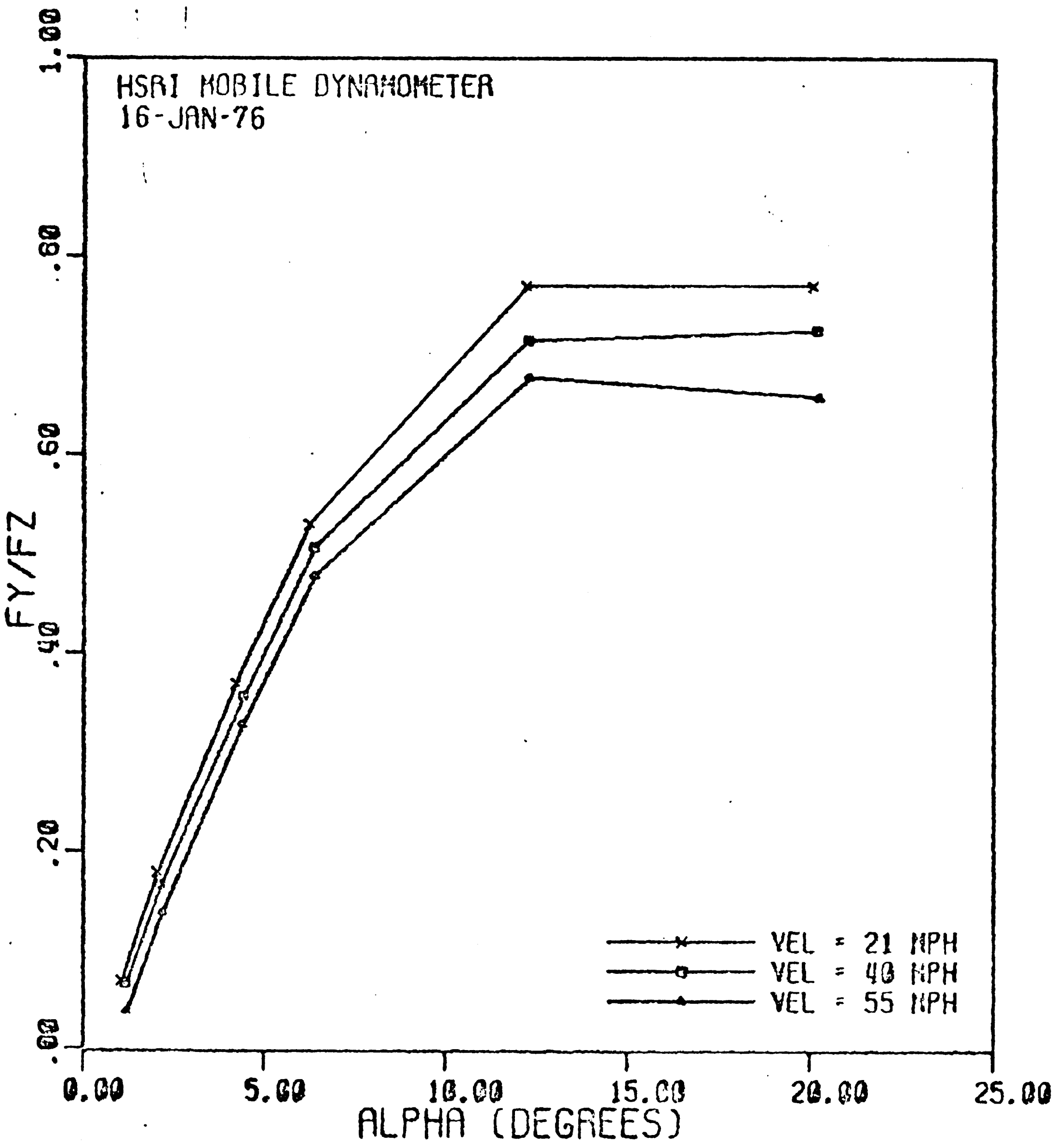



GOODYEAR CUSTOM CROSS RIB 10.00X20/F-WET
VEL = 39 MPH

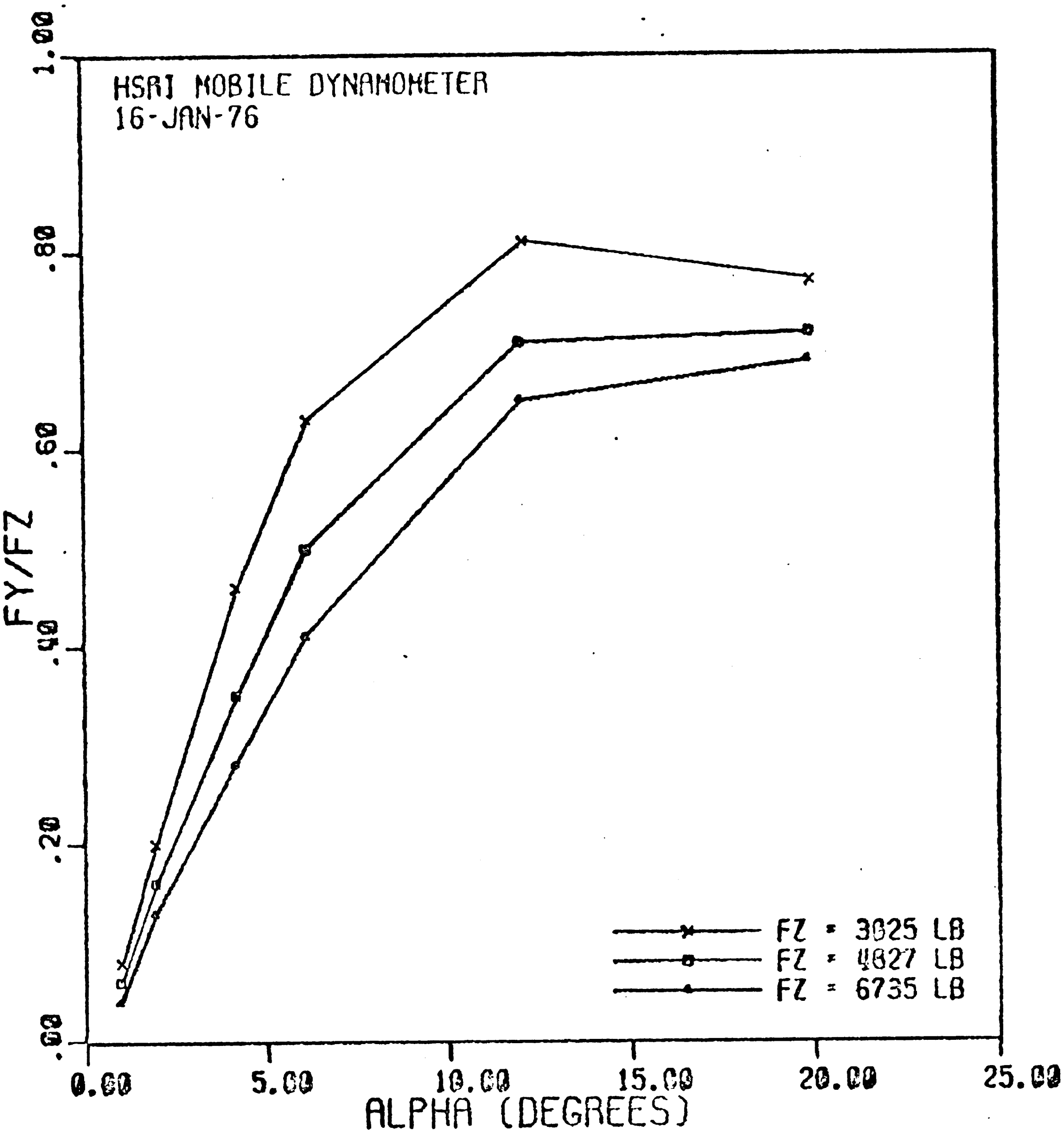



GOODYEAR CUSTOM CROSS RIB 10.00X20/F-WET

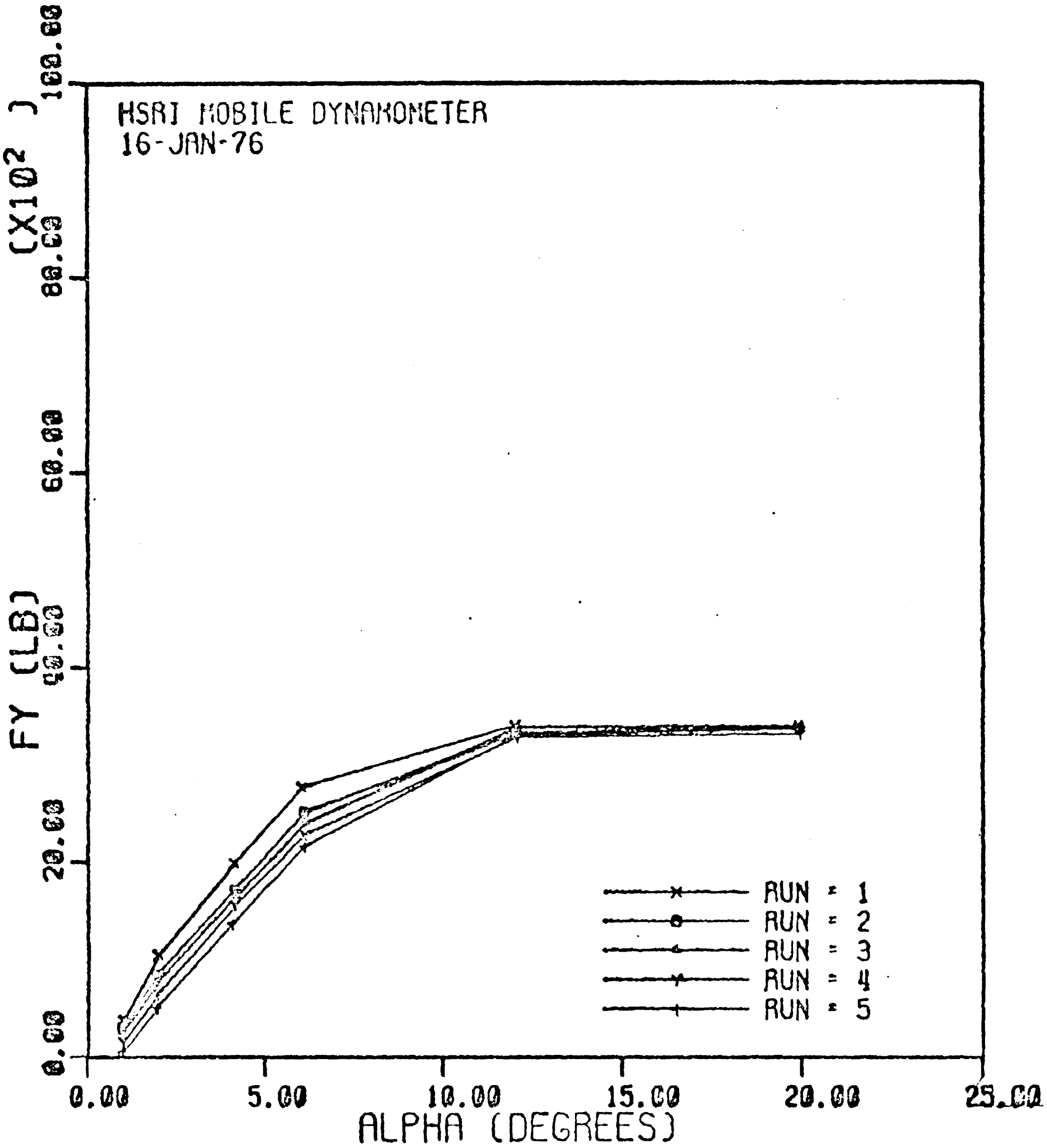
FZ = 4751 LB VEL = 39 MPH




UNIROYAL FLEETMASTER SUPERLUG 10.00X20/F-WET
FZ = 4790 LB




UNIROYAL FLEETMASTER SUPERLUG 10.00X20/F-WET
VEL = 40 MPH




UNIROYAL FLEETMASTER SUPERLUG 10.00X20/F-WET
FZ = 4795 LB VEL = 40 MPH