TDOP

DOT-FR-742-4277

TRUCK DESIGN OPTIMIZATION PROJECT
PHASE II

FINAL PROJECT REVIEW

WYLE LABORATORIES

SCIENTIFIC SERVICES AND SYSTEMS GROUP
COLORADO OPERATIONS

APRIL 2, 1981
CHICAGO, ILLINOIS

AGENDA

INTRODUCTORY REMARKS (FRA)	P. OLEKSZYK
PROJECT OVERVIEW	G. BAKKEN
FIELD TESTING	G. BAKKEN
ENGINEERING ANALYSIS	P.V. RAMACHANDRAN
ECONOMIC ANALYSIS	R. GLASER
QUESTION AND ANSWER SESSION	

OVERVIEW

TRUCK DESIGN OPTIMIZATION PROJECT (TDOP)

OBJECTIVES

PERFORMANCE CHARACTERIZATION

PERFORMANCE SPECIFICATION

WEAR MEASUREMENT PROGRAM

BENEFIT/COST TRADE-OFF

TECHNICAL APPROACH

ENGINEERING ANALYSIS

FIELD TESTING

ECONOMICS

ENGINEERING ANALYSIS

PERFORMANCE CLASSIFICATION

TYPE II TRUCK SELECTION

PERFORMANCE CHARACTERIZATION

- TYPE I AND TYPE II TRUCKS

PERFORMANCE SPECIFICATION

- TYPE II TRUCKS

FIELD TESTING

TYPE I TRUCK TESTING

WEAR DATA COLLECTION

TYPE II TRUCK TESTING

ECONOMICS

ECONOMIC/ENGINEERING INTERFACE

ECONOMIC DATA COLLECTION

BENEFIT/COST TRADE-OFF

FIELD TESTING

WEAR DATA COLLECTION

DETERMINE WEAR DATA REQUIREMENTS

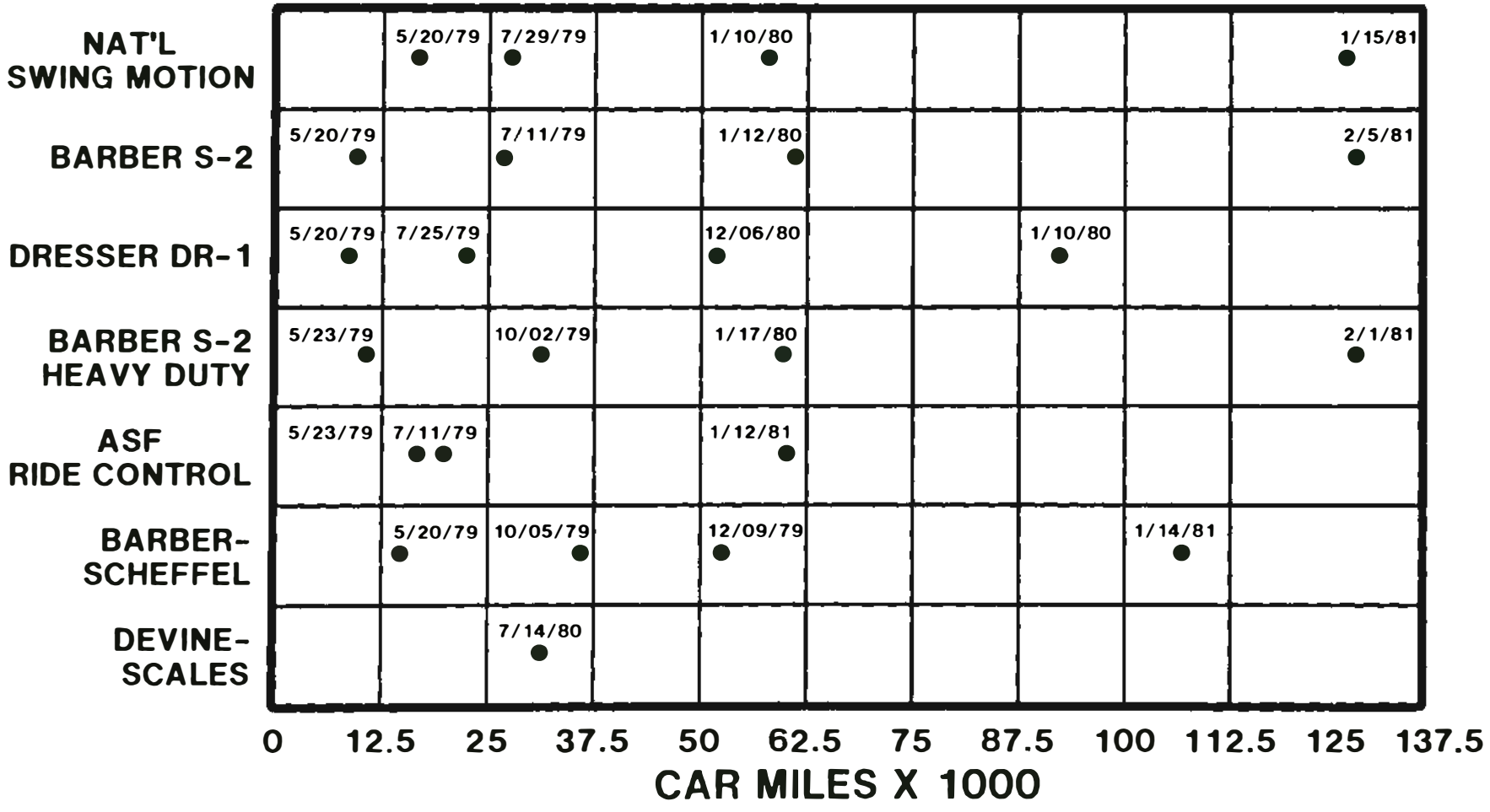
EVALUATE AND SELECT MEASUREMENT METHODS

DEVELOP WEAR DATA BASE

ESTABLISH WEAR TRENDS

PROVIDE DATA FOR ECONOMIC EVALUATION

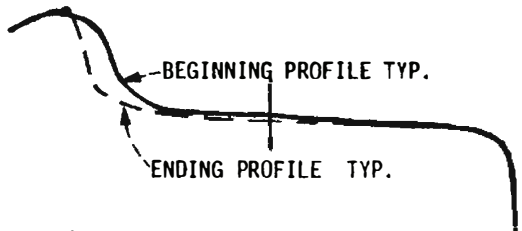
WEAR MEASUREMENT CYCLES



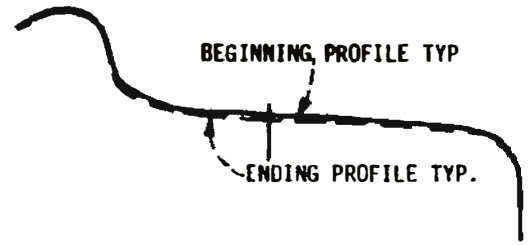
WYLE LABORATORIES

WEAR DATA MEASUREMENTS/TOOLS	
BRAKE SHOES; SIDEFRAME COLUMN WIDTHS, GIBS & STOPS; PEDESTAL JAW WIDTHS & SPACINGS; BOLSTER GIBS, STOPS & SPACINGS; BOLSTER DIAMETERS & SIDEBEARINGS	MICROMETERS
BEARING ADAPTERS; FRICTION CASTINGS; PEDESTAL JAW ROOF AREAS	MICROMETERS WITH SPECIAL INDEX FIXTURES
HARDENED WEAR PLATES , CARBODY SIDEBEARING PLATES AND SIDEBEARING CAGE BASE	ULTRASONIC THICKNESS GAUGE
WHEELS	AAR FINGER GAUGE, WHEEL TAPE AND PROFILOMETER

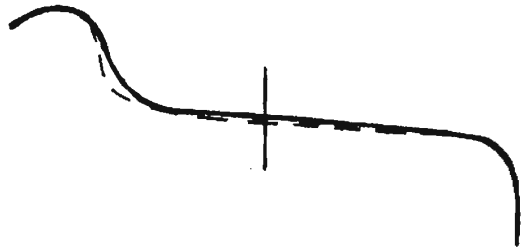
REPRESENTATIVE WHEEL PROFILE HISTORIES



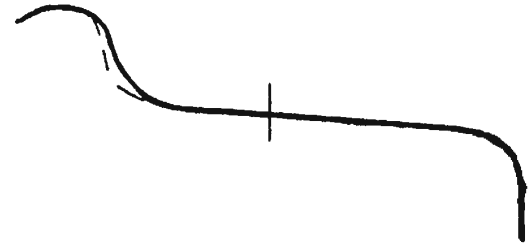
NAT'L SWING MOTION - 125,700 MILES



DRESSER DR-1 - 90,116 MILES

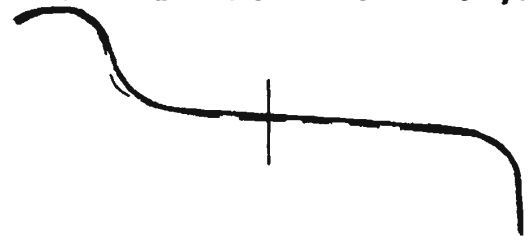


BARBER S-2-C - 100,094 MILES



ASF RIDE CONTROL - 59,813 MILES

BARBER S-2-HD - 131,493 MILES



BARBER-SCHEFFEL - 92,709 MILES

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PHASE II TRUCK TESTING

OBJECTIVES

ACQUIRE PERFORMANCE DATA FOR TYPE I & II TRUCKS IN PERFORMANCE REGIMES OF:

- LATERAL STABILITY
- TRACKABILITY
- CURVE NEGOTIATION
- RIDE QUALITY

ACQUIRE ROLLING RESISTANCE DATA FOR FUEL CONSUMPTION STUDY

FIELD TEST PLANNING & IMPLEMENTATION

DEFINE DATA REQUIREMENTS FOR

- Performance Characterization
- Fuel Consumption Studies

DEVELOP TEST PLANS & PROCEDURES

DEVELOP & DEPLOY INSTRUMENTATION AND DATA ACQUISITION SYSTEMS

- Design, Develop, Implement,& Calibrate Instrumentation Packages
- Deploy Data Acquisition Systems

TEST CONDUCT

- Coordination of Test Operations on Revenue Service Track

DATA ACQUISITION & QUALITY CONTROL

TDOP PHASE II TEST MATRIX

Truck	Carbody	Wheel Profile	Lading	Lateral Stability & Ride Quality		Trackability		Curve Negotiation
				Class 4 BJR	Class 5 CWR	Harmonic Roll Class 2 BJR	Track Twist Yard BJR	Class 4 BJR
Dresser DR-1	100-Ton Open Hopper Car	CN	Empty	●	●	●	●	●
			Loaded	●		●	●	●
Barber-Scheffel	100-Ton Open Hopper Car	CN	Empty & Loaded	●		●	●	●
Devine-Scales	100-Ton Open Hopper Car	CN	Empty & Loaded	●		●	●	●
National Swing Motion	100-Ton Open Hopper Car	CN	Empty & Loaded	●		●	●	●
Maxiride 100	100-Ton Open Hopper Car	CN	Empty &	●	●	●	●	●
			Loaded	●		●	●	●
ACF Fabricated	100-Ton Open Hopper Car	CN	Empty & Loaded	●		●		*
Alusuisse	70-Ton Open Hopper Car	AAR 1:20 Taper	Loaded	●		●		

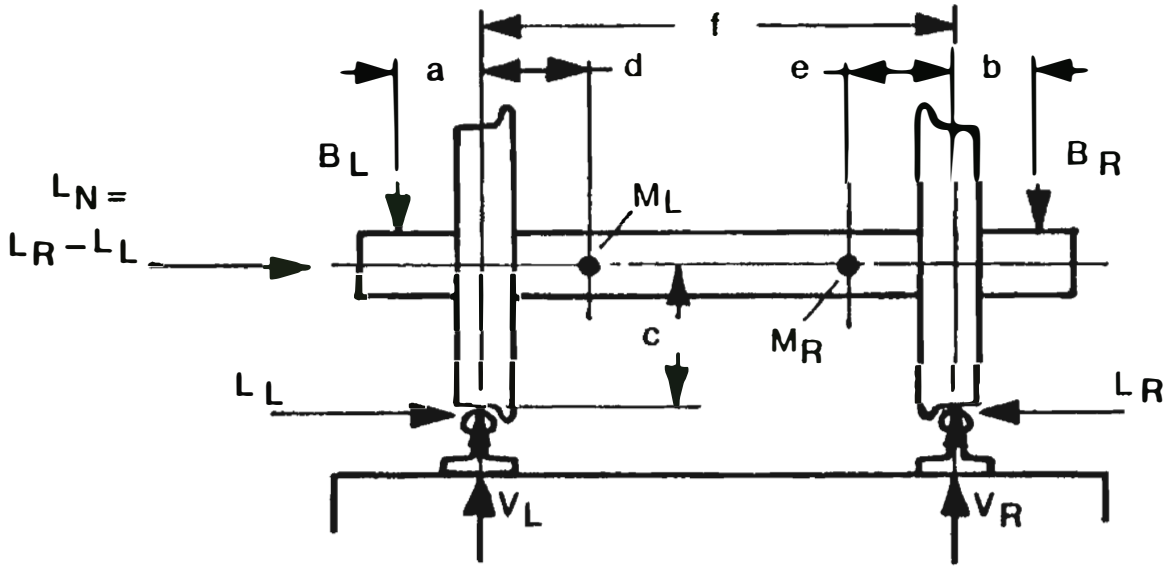
Legend

● Test Data Available

▥ No Test Data Available

* Curving Data Consisting of Angle of Attack; No L/V Forces

TDOP/Phase II Instrumentation for Measuring Wheel/Rail Forces



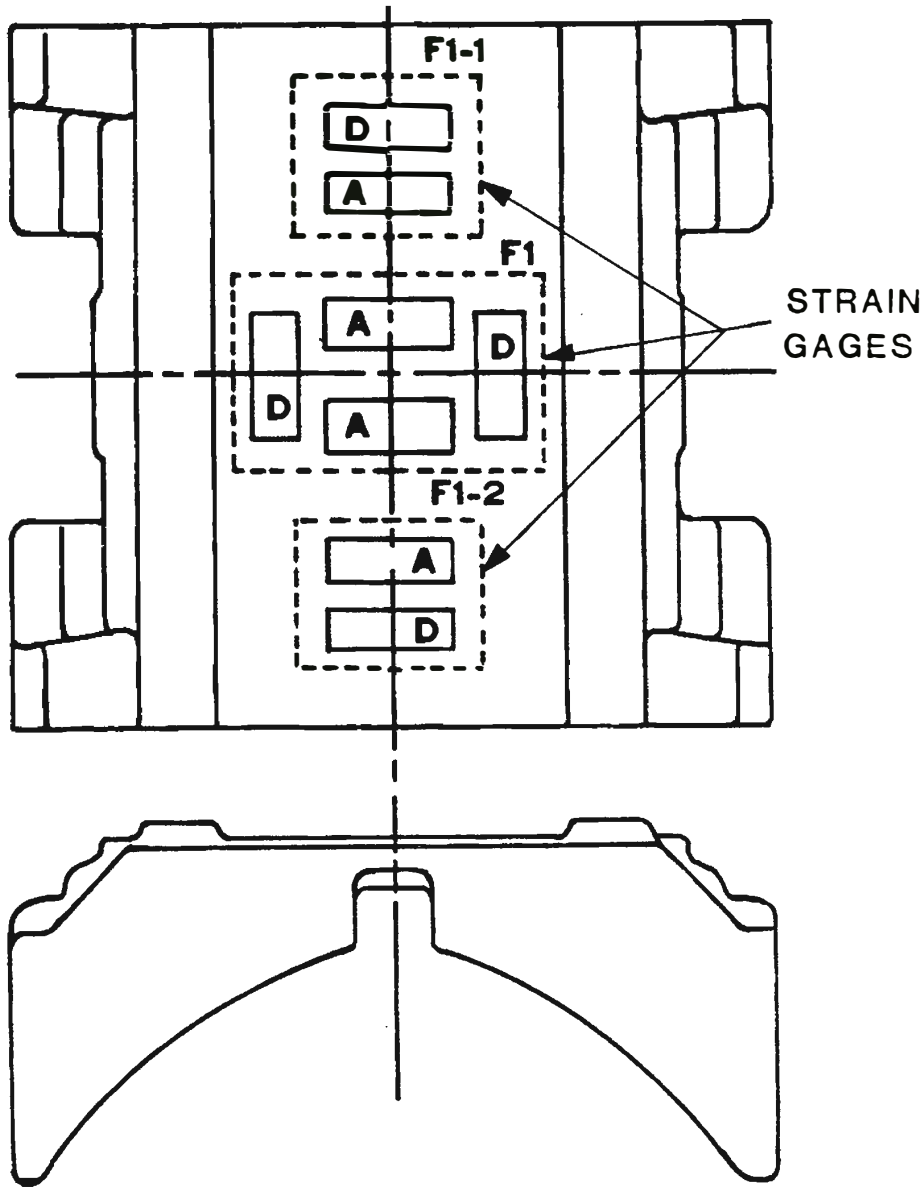
M_L, M_R : Strain gage locations for measuring axle bending

B_L, B_R : Vertical loads measured through strain gaged bearing adapters

V_L, V_R : Vertical forces at wheel/rail interface

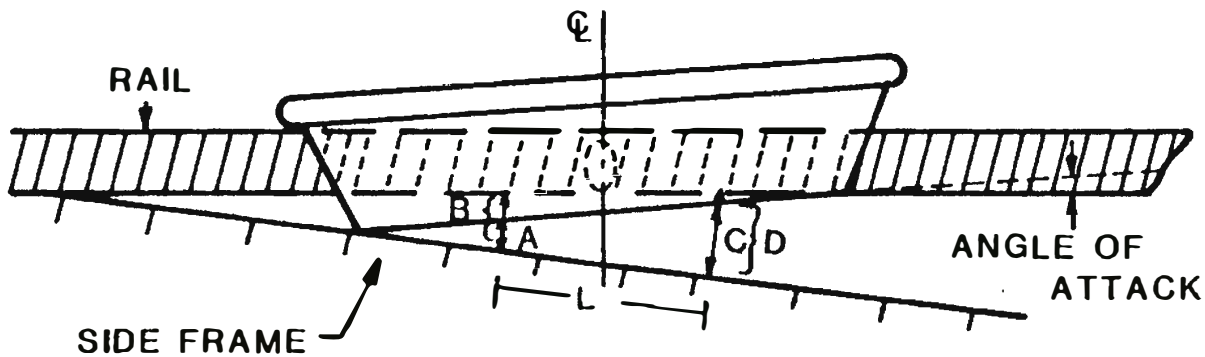
L_L, L_R : Lateral forces at wheel/rail interface

Instrumented Bearing Adapter For Vertical Load Measurement



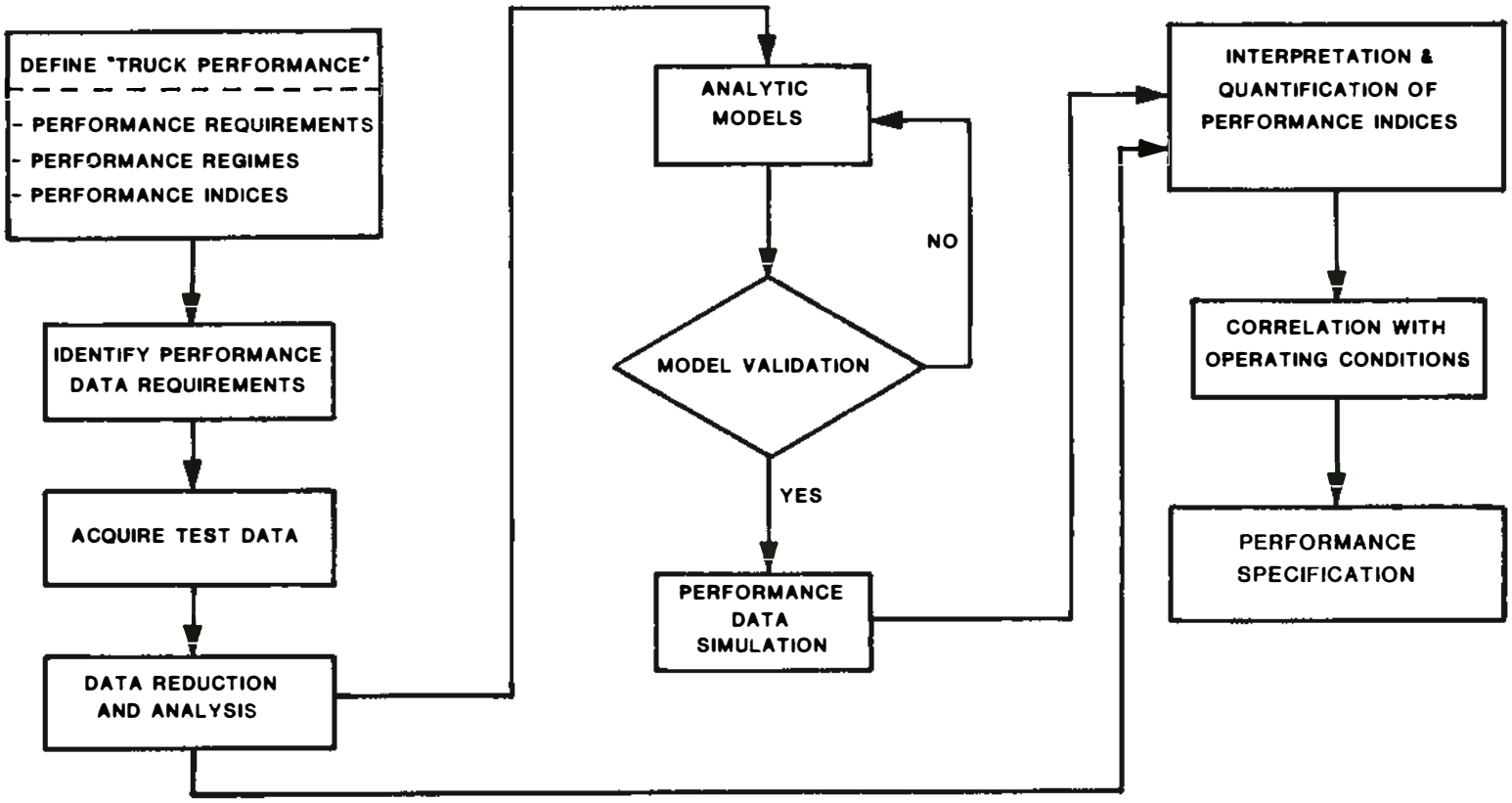
WYLE LABORATORIES

Wheel/Rail Position Measurement for Angle of Attack



ENGINEERING EVALUATION
AND
CHARACTERIZATION
OF TYPE II TRUCK PERFORMANCE

Methodology



TDOP PHASE II TEST MATRIX

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				Class 4 BJR	Class 5 CWR	Harmonic Roll Class 2 BJR	Track Twist Yard BJR	Class 4 BJR
Dresser DR-1	100-Ton Open Hopper Car	CN	Empty	●	●	●	●	●
			Loaded	●		●	●	●
Barber-Scheffel	100-Ton Open Hopper Car	CN	Empty & Loaded	●		●	●	●
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National Swing Motion	100-Ton Open Hopper Car	CN	Empty & Loaded	●		●	●	●
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				●		●	●	●
ACF Fabricated	100-Ton Open Hopper Car	CN	Empty & Loaded	●		●		*
Alusuisse	70-Ton Open Hopper Car	AAR 1:20 Taper	Loaded	●		●		

Legend

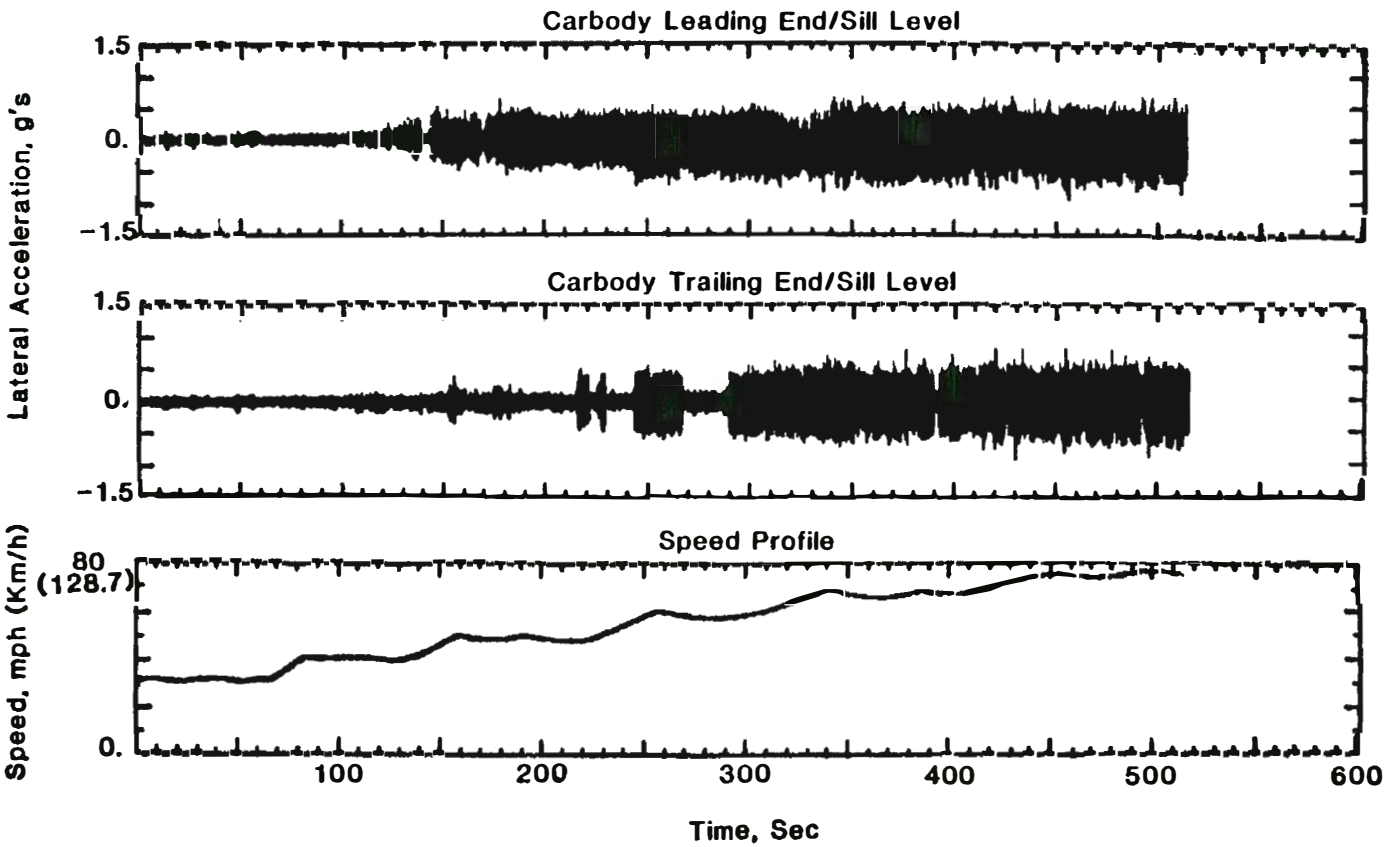
● Test Data Available

▨ No Test Data Available

* Curving Data Consisting of Angle of Attack; No L/V Forces

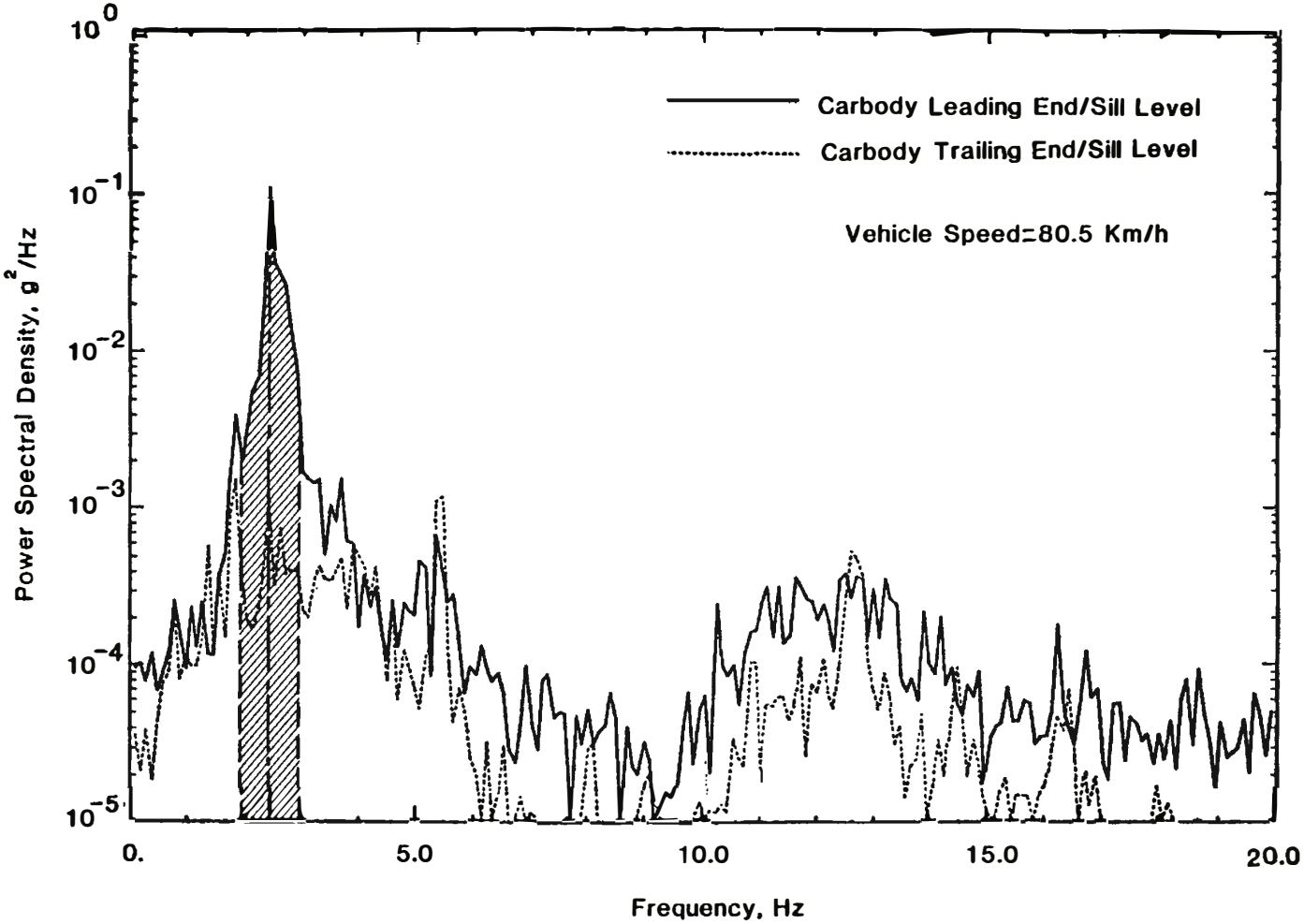
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Lateral Stability



PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

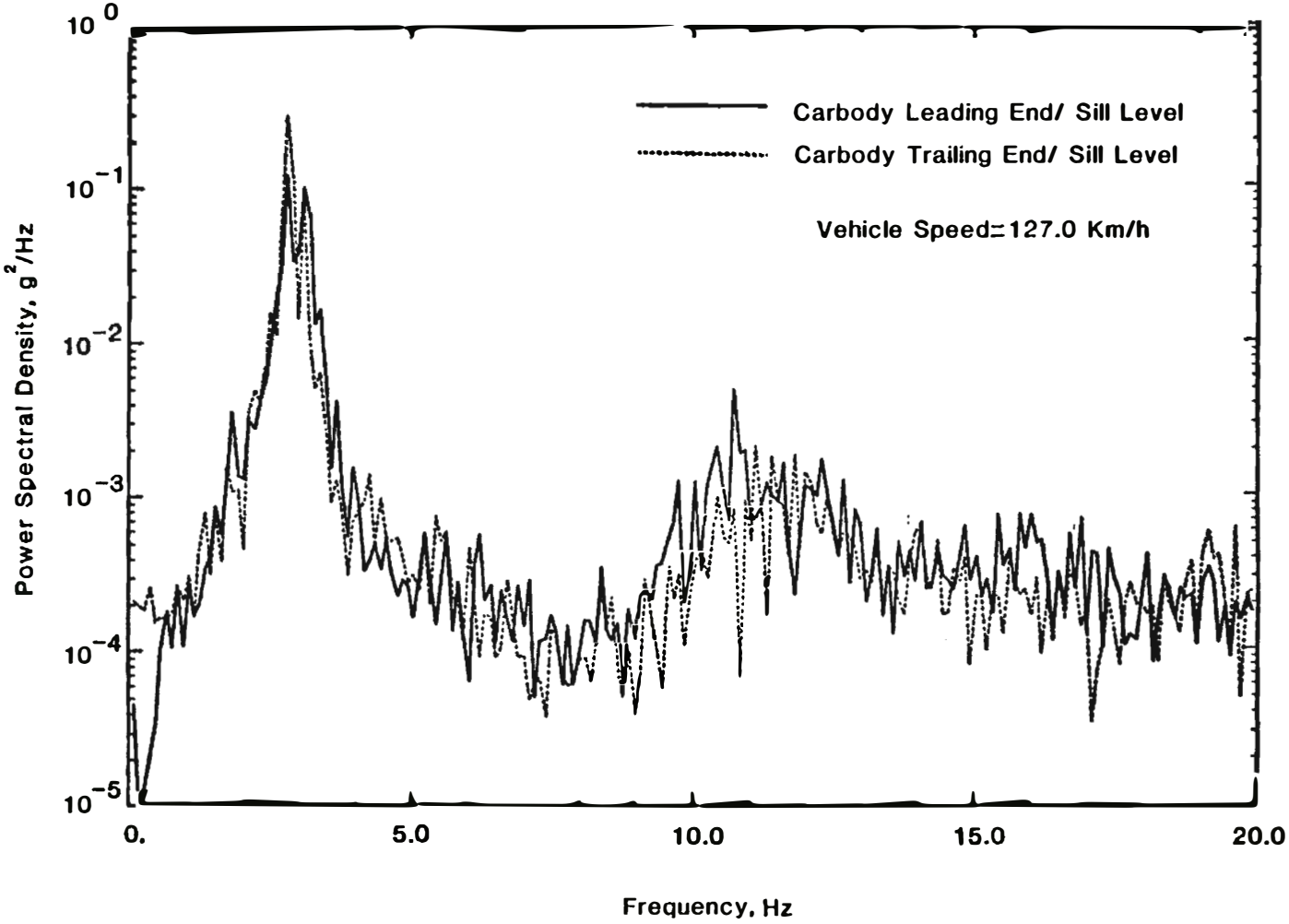
Lateral Stability



WYLE LABORATORIES

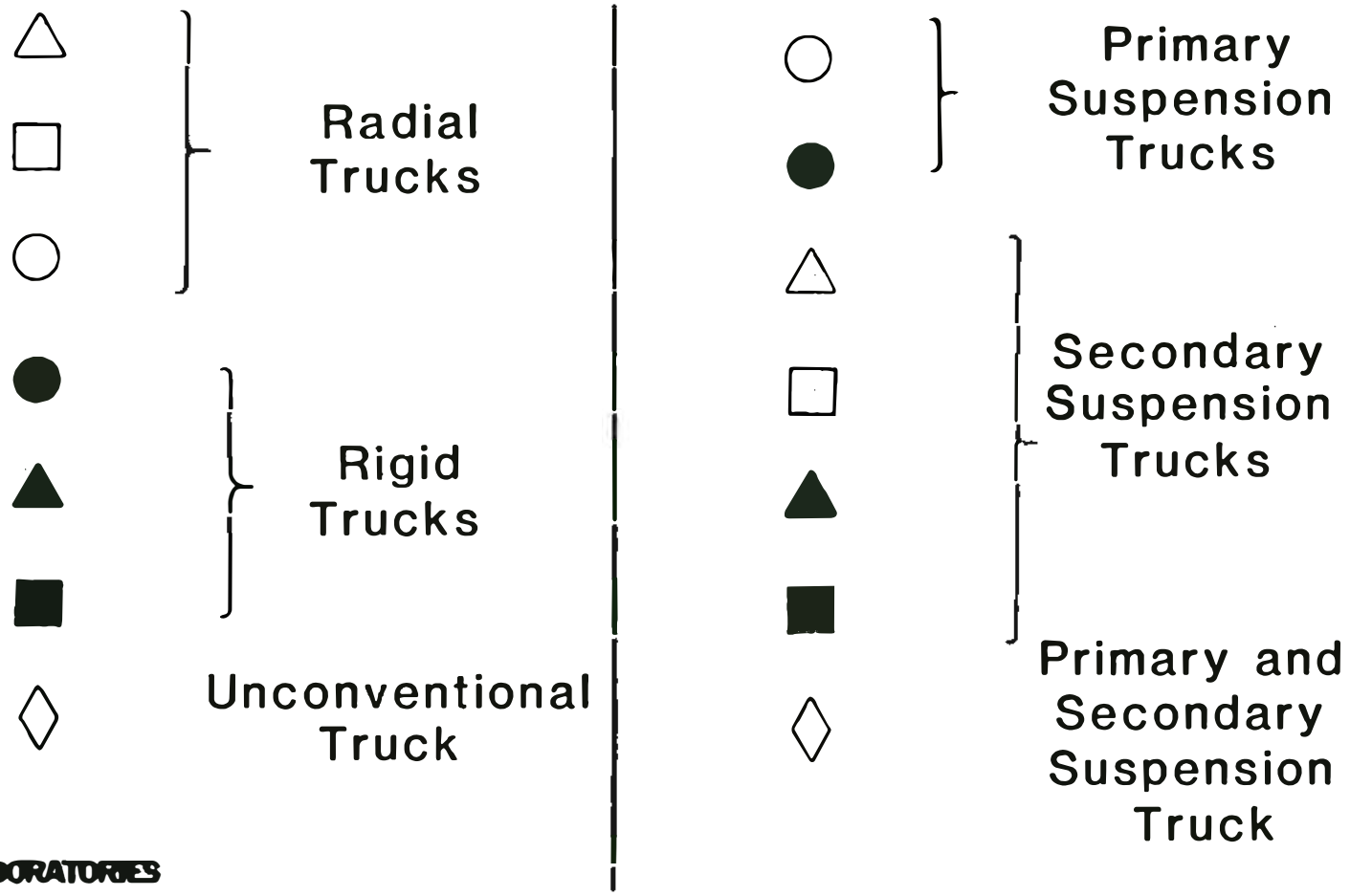
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Lateral Stability



WYLE LABORATORIES

LEGEND

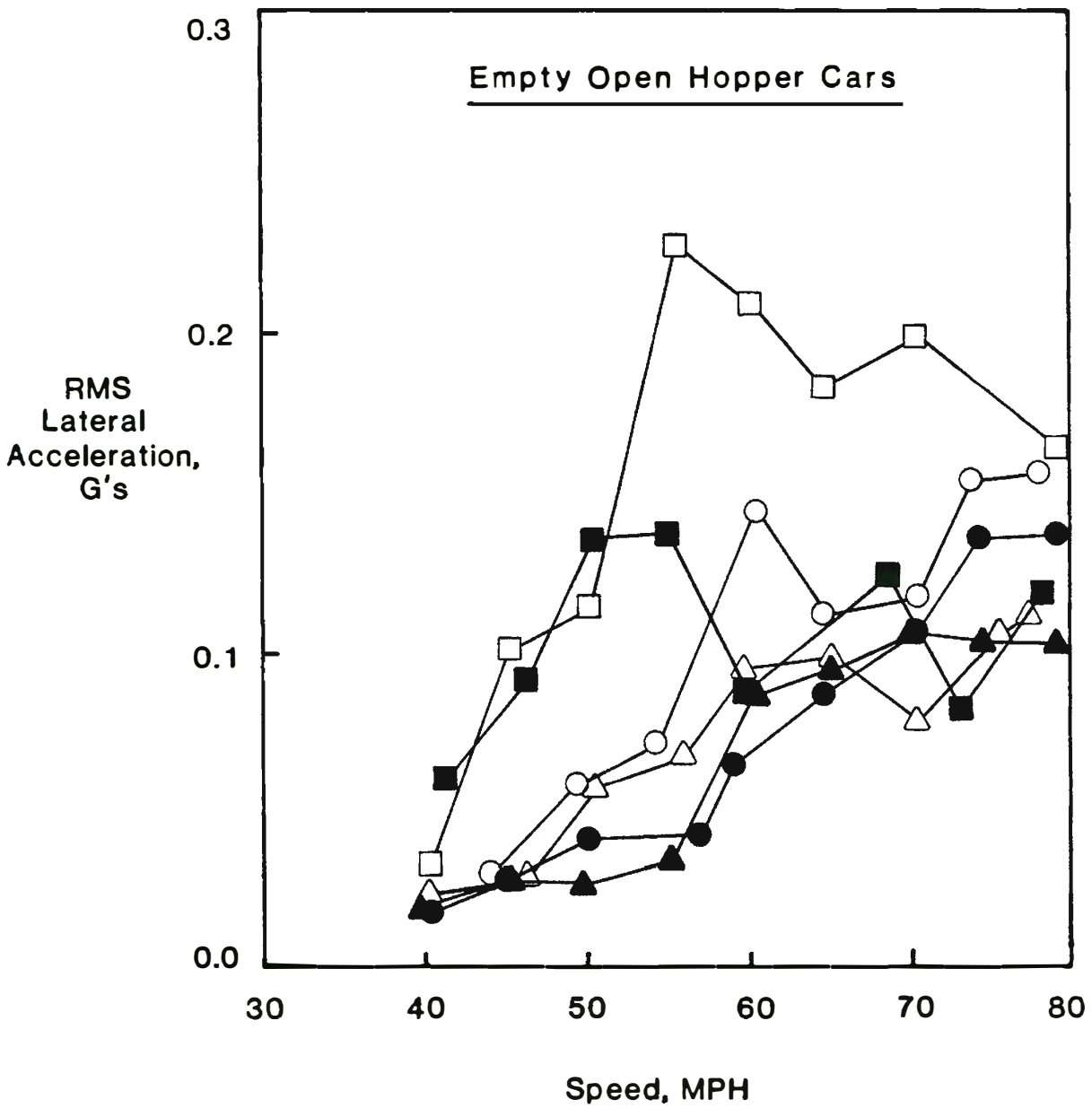


WYLE LABORATORIES

PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

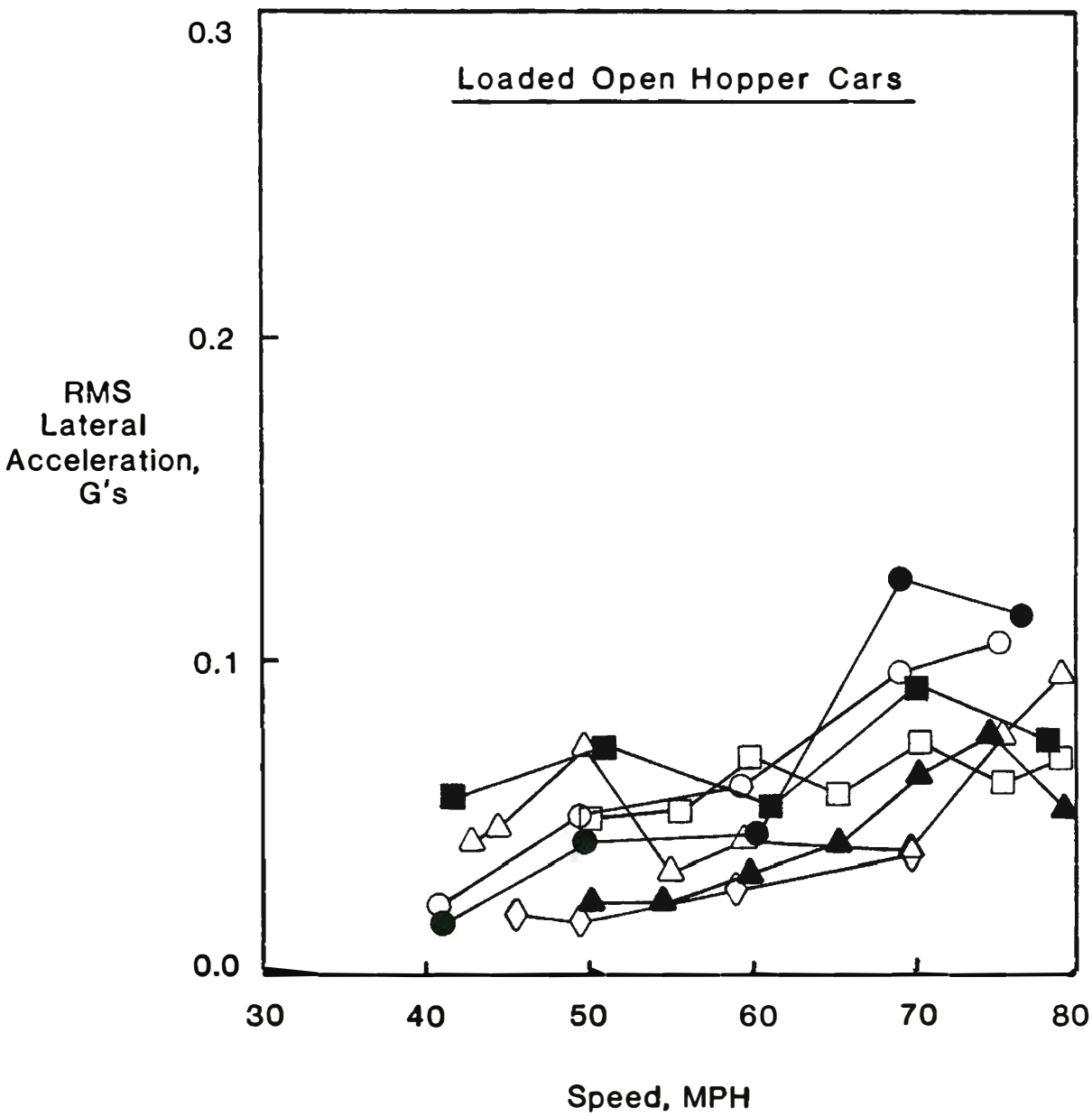
Lateral Stability

RMS Lateral Acceleration



PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Lateral Stability
RMS Lateral Acceleration



PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS - LATERAL STABILITY
EMPTY CARS - RADIAL TRUCKS

Radial Trucks	Phenomenological Behavior	Average Amplitude of Lateral Acceleration (g's)	Range of Critical Speed(mph)	Percentage of Time of Occurrence of Observed Phenomenon
△	Moderate Amplitude Intermittent Hunting	.50-.55	60-65	60-65
□	Moderate Amplitude Intermittent Hunting	.60-.70	45	65-70
	Sustained Hunting	1.0-1.3	55-60	100
○	Moderate Amplitude Intermittent Hunting	.60-.70	60	60-65
	Sustained Hunting	.80-.90	79	100

PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS - LATERAL STABILITY

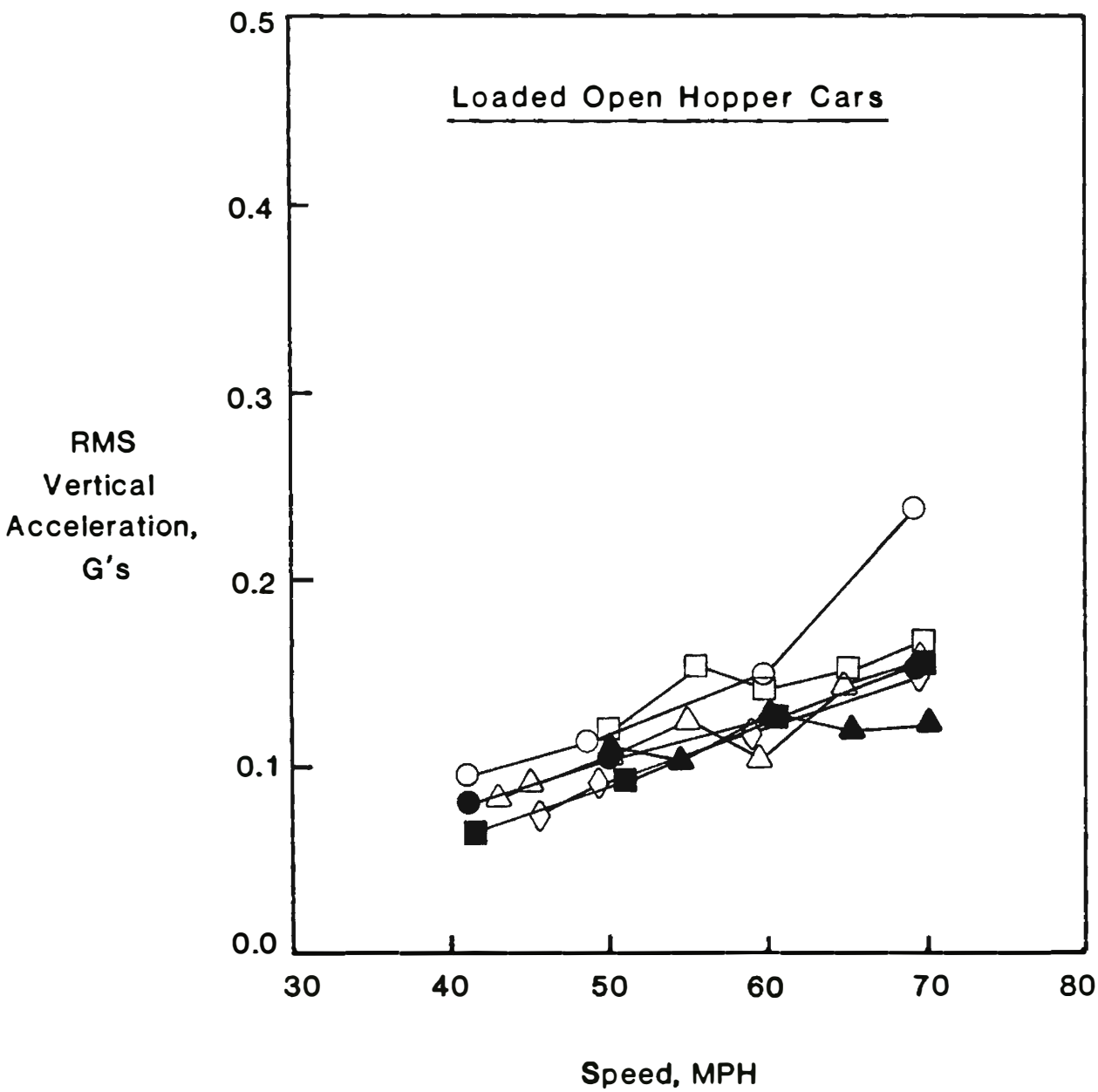
EMPTY CARS - RIGID TRUCKS

Rigid Trucks	Phenomenological Behavior	Average Amplitude of Lateral Acceleration (g's)	Range of Critical Speed(mph)	Percentage of Time of Occurrence of Observed Phenomenon
▲	Moderate Amplitude Intermittent Hunting	.60-.65	60-65	60-65
●	Moderate Amplitude Intermittent Hunting	.75-.80	65-70	60-65
	High Amplitude Intermittent Hunting	0.90-1.0	79	75-80
■	Moderate Amplitude Intermittent Hunting	.55-.65	60-65	60-65

PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Ride Quality

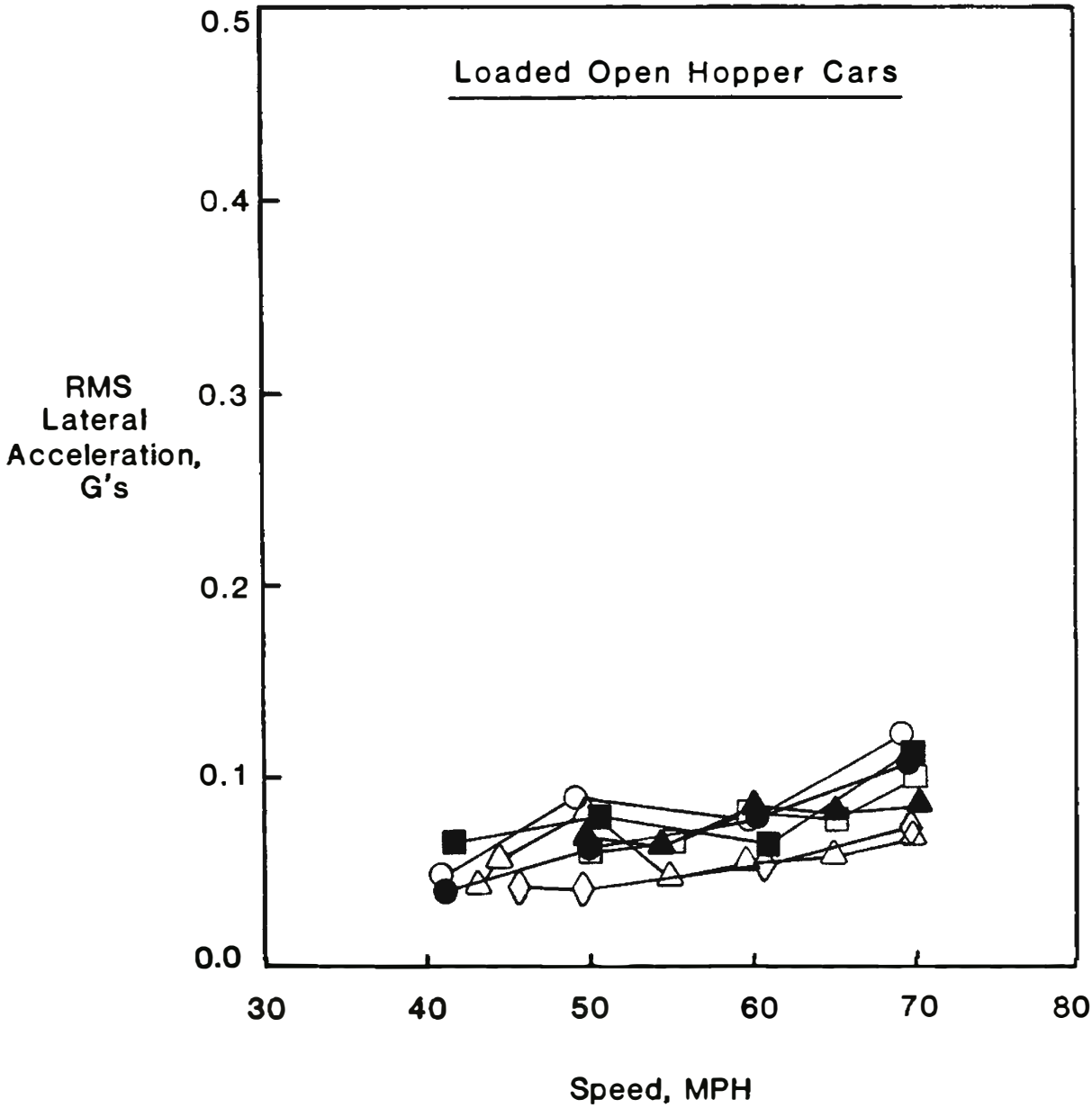
RMS Vertical Acceleration (0 - 20 Hz)



PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Ride Quality

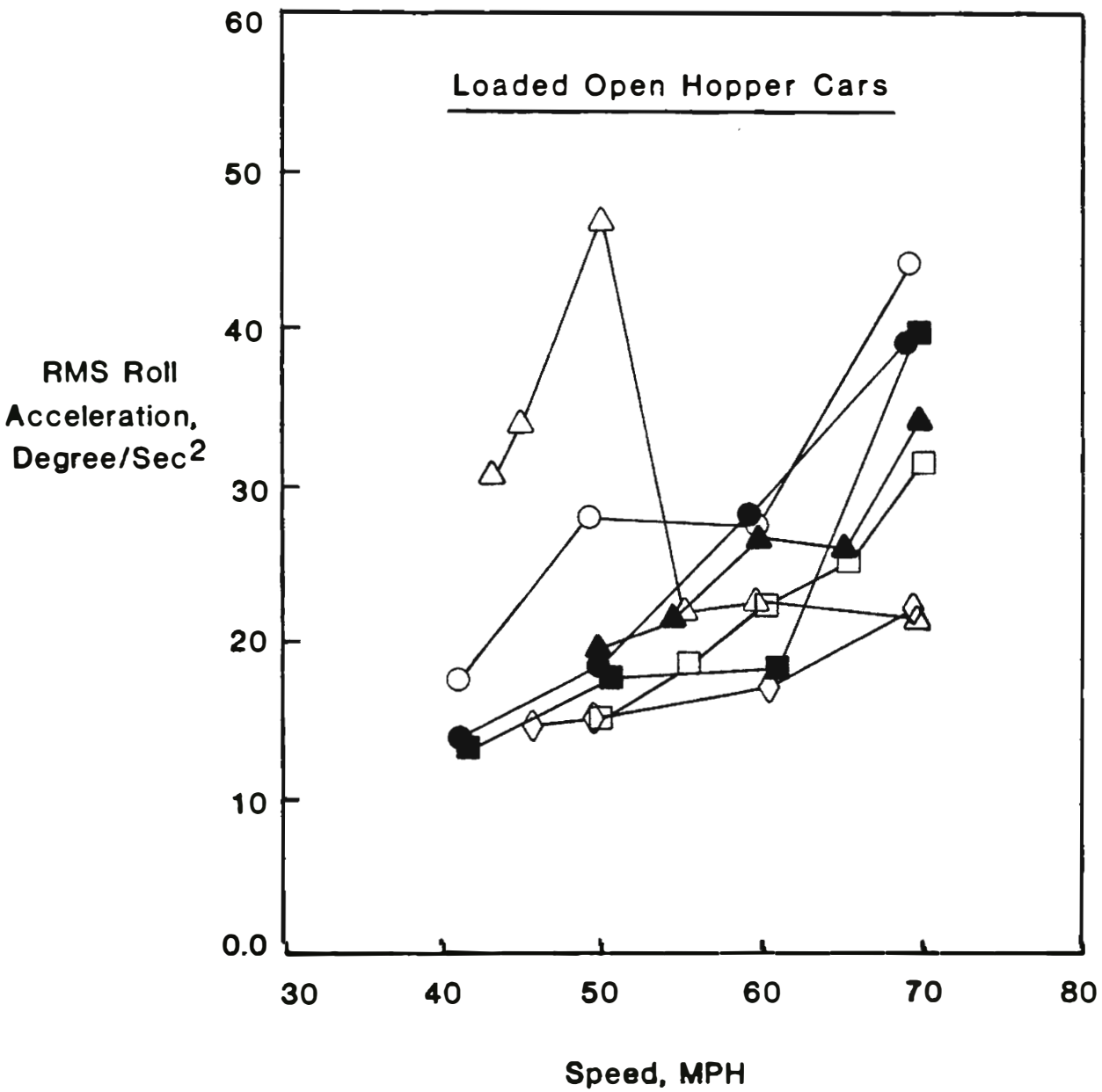
RMS Lateral Acceleration (0 - 20 Hz)



PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

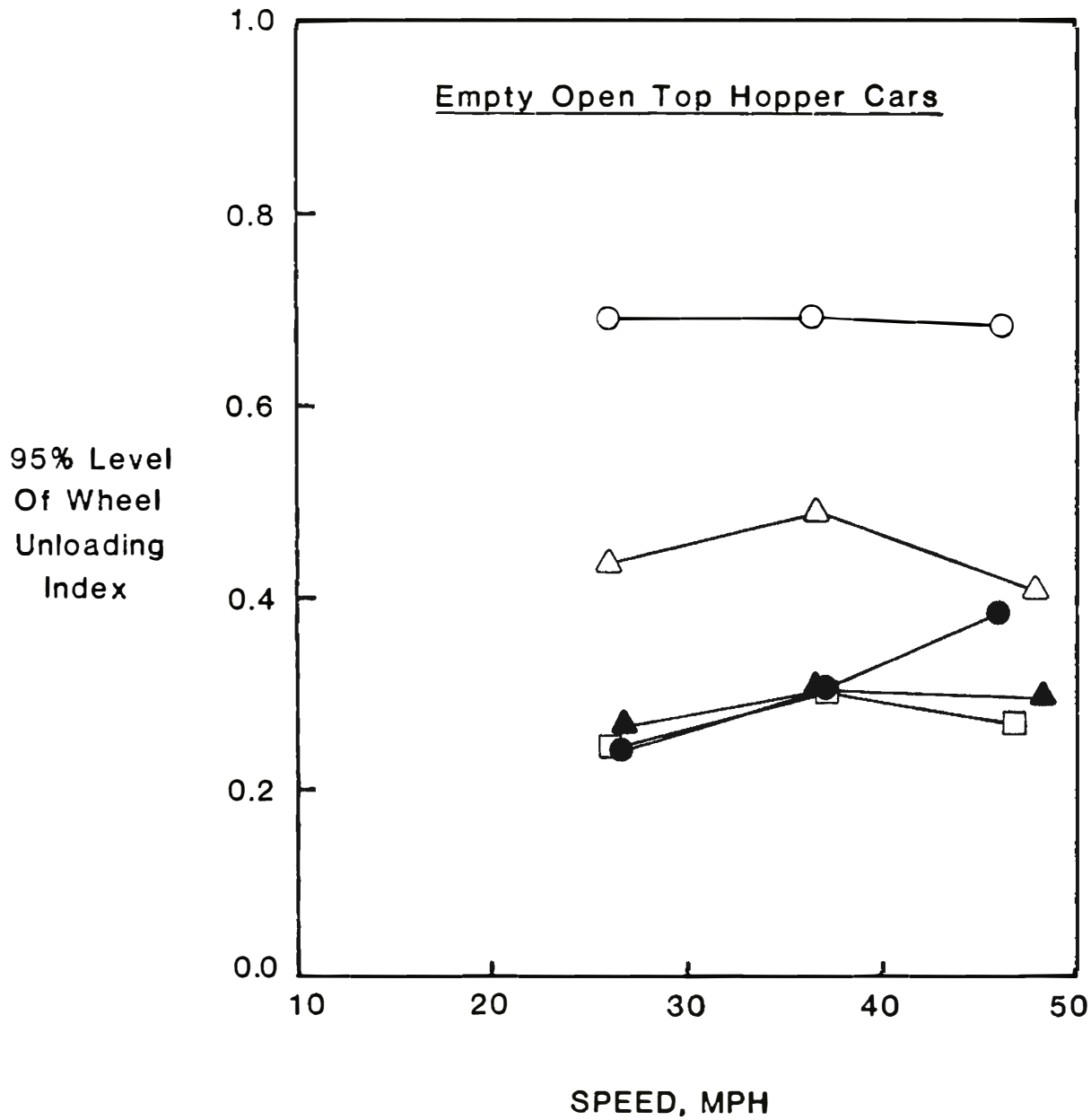
Ride Quality

RMS Roll Acceleration (0 - 20 Hz)



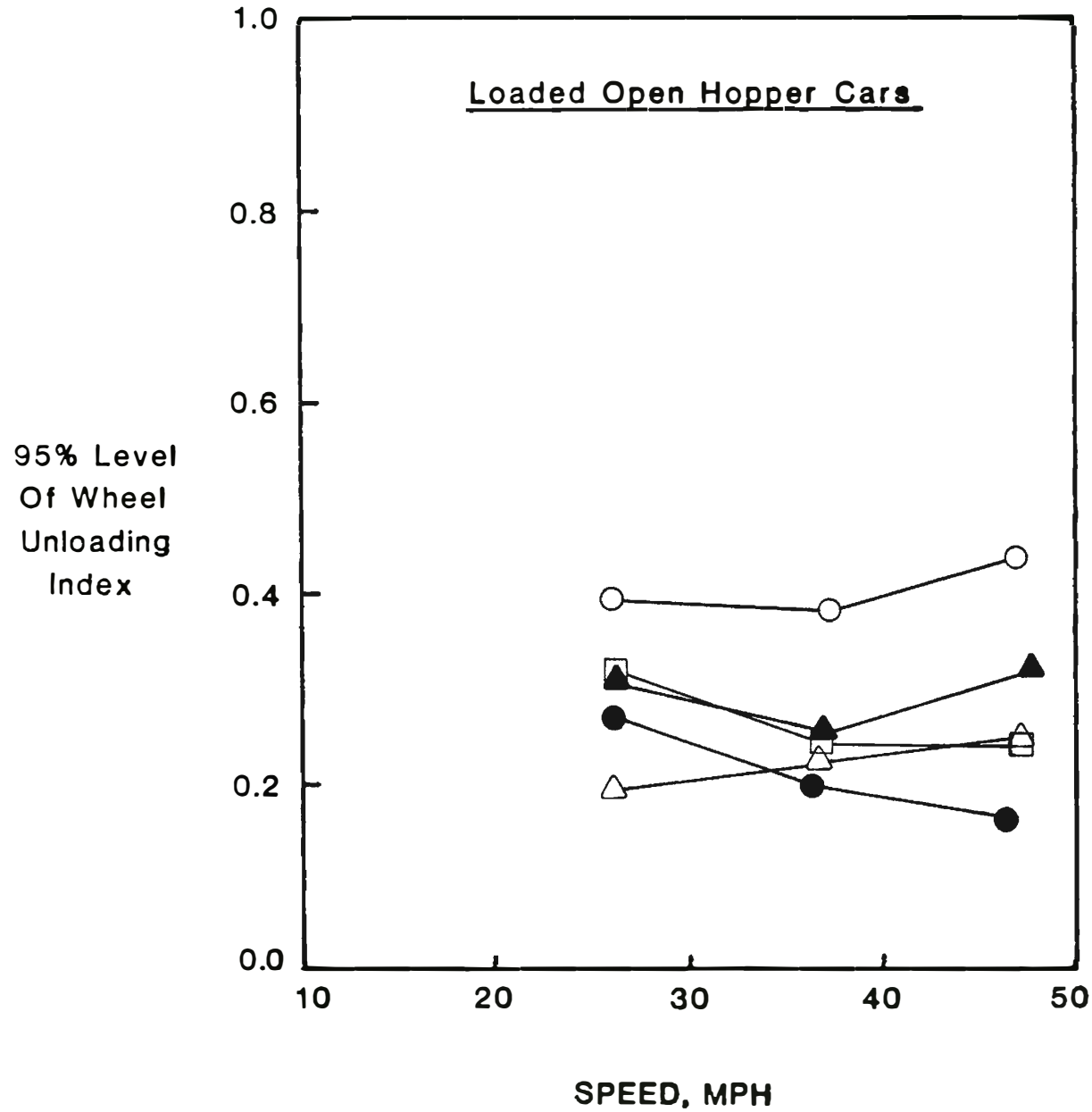
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Trackability
Wheel Unloading Index
Track Curvature: 2.5 Degrees



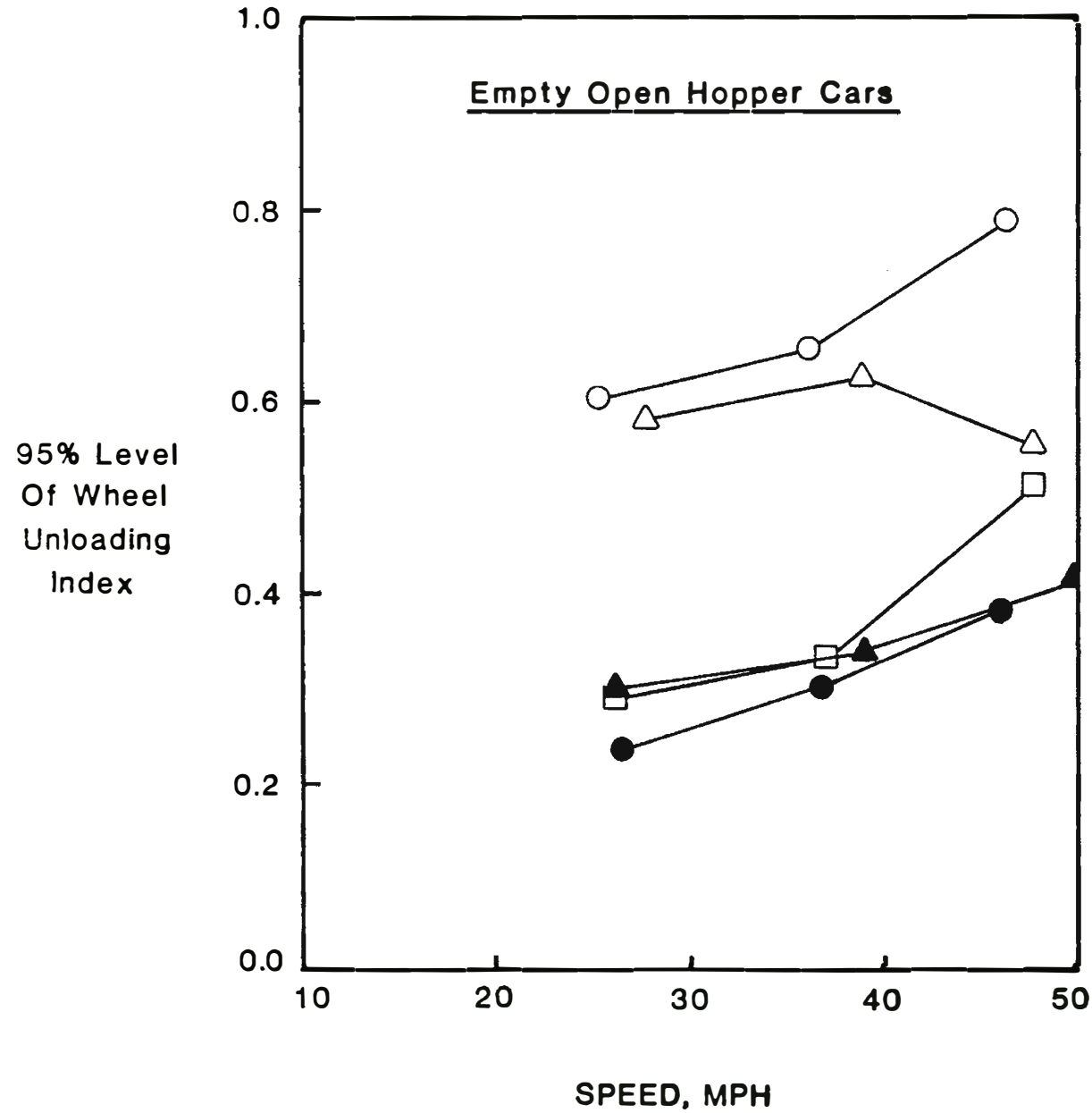
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Trackability
Wheel Unloading Index
Track Curvature: 2.5 Degrees



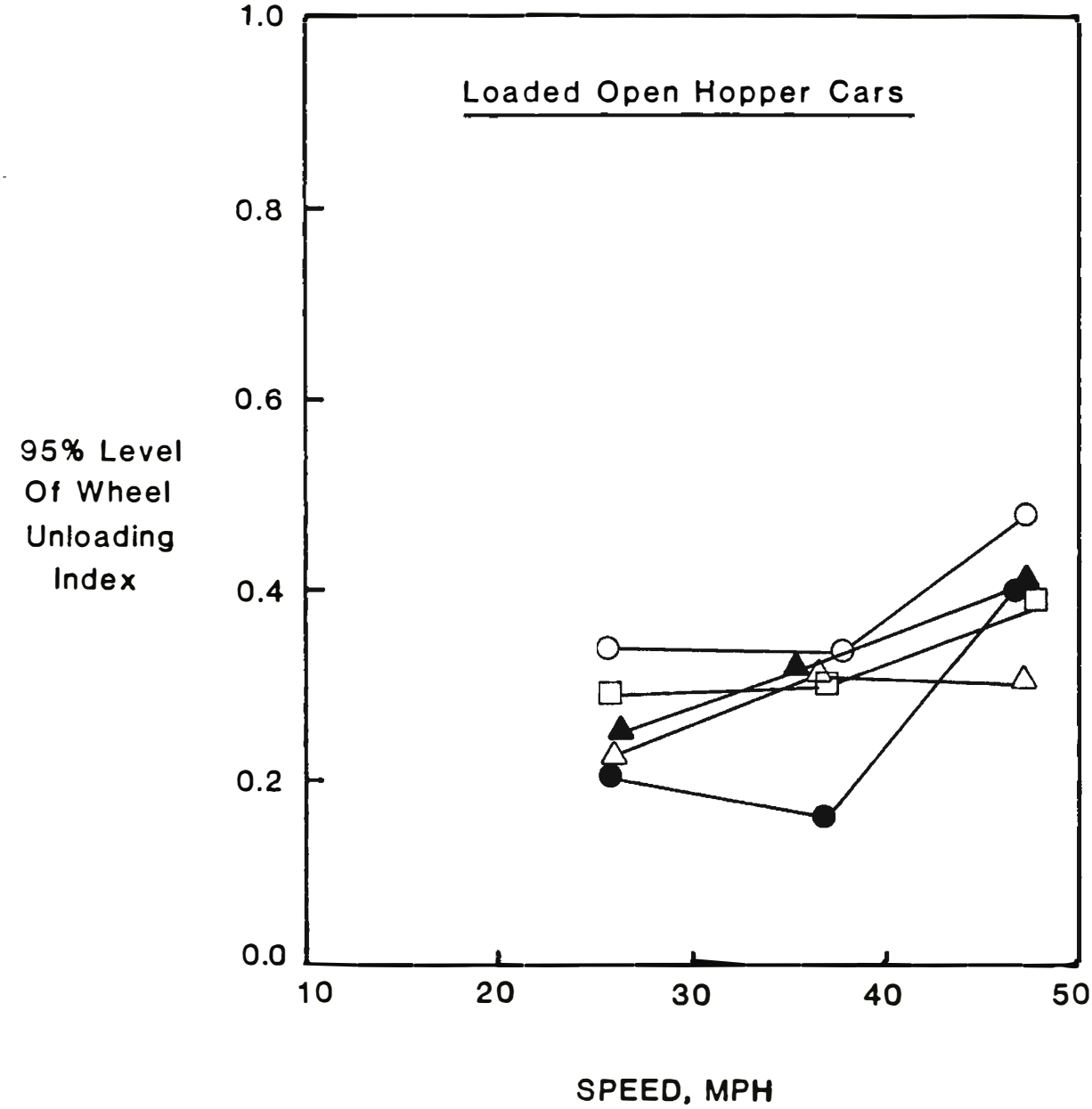
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Trackability
Wheel Unloading Index
Track Curvature: 6.2 Degrees



PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Trackability
Wheel Unloading Index
Track Curvature: 6.2 Degrees

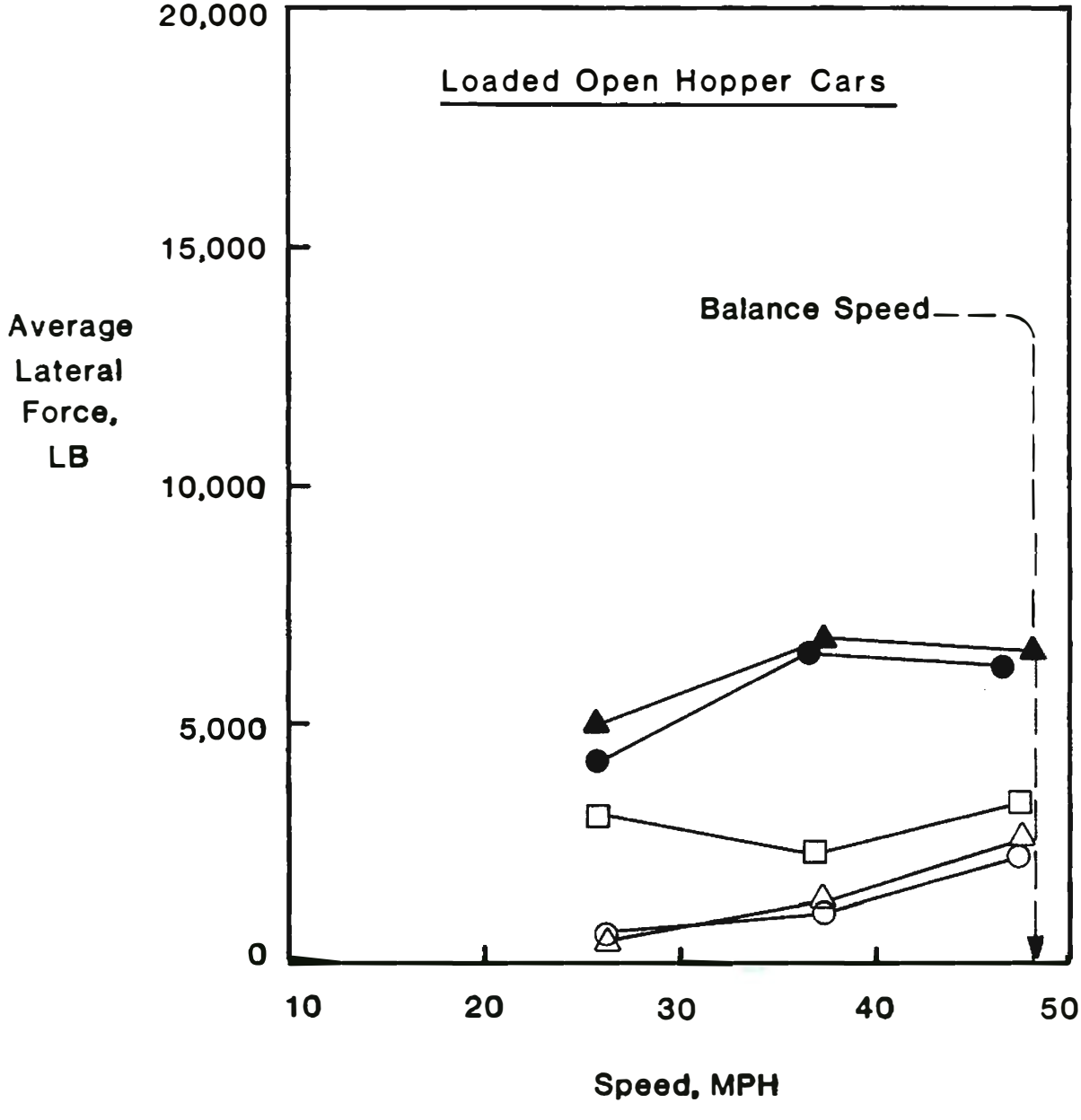


WHEEL UNLOADING INDEX (WUI) LEVELS
(Track Twist)

Truck	Empty Car WUI_{95}	Loaded Car WUI_{95}
Radial Trucks △	0.783	0.281
Radial Trucks □	0.343	0.400
Radial Trucks ○	0.744	0.512
Rigid Trucks ▲	0.553	0.368
Rigid Trucks ●	0.297	0.307

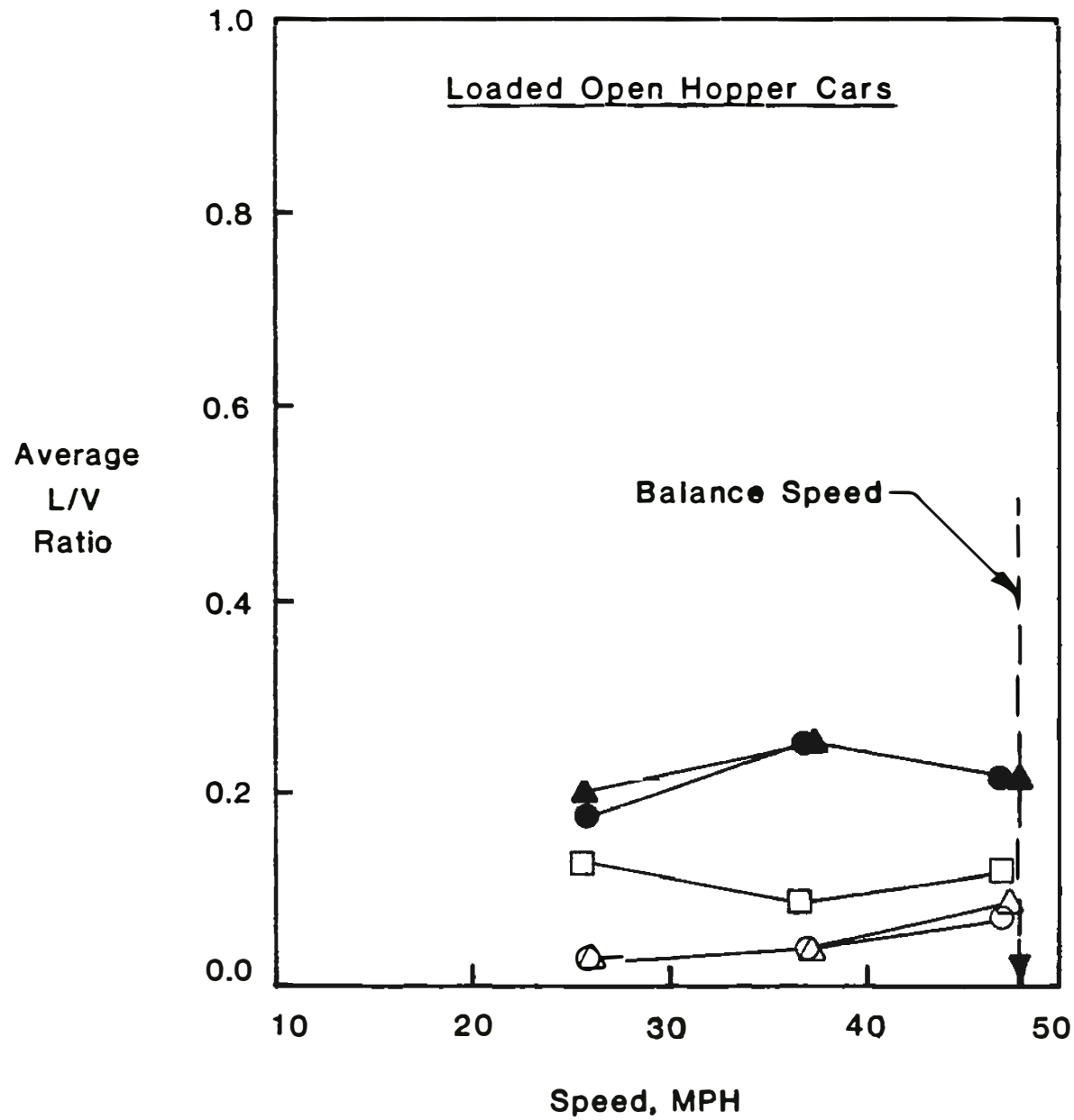
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
Lateral Force
Track Curvature: 2.5 Degrees



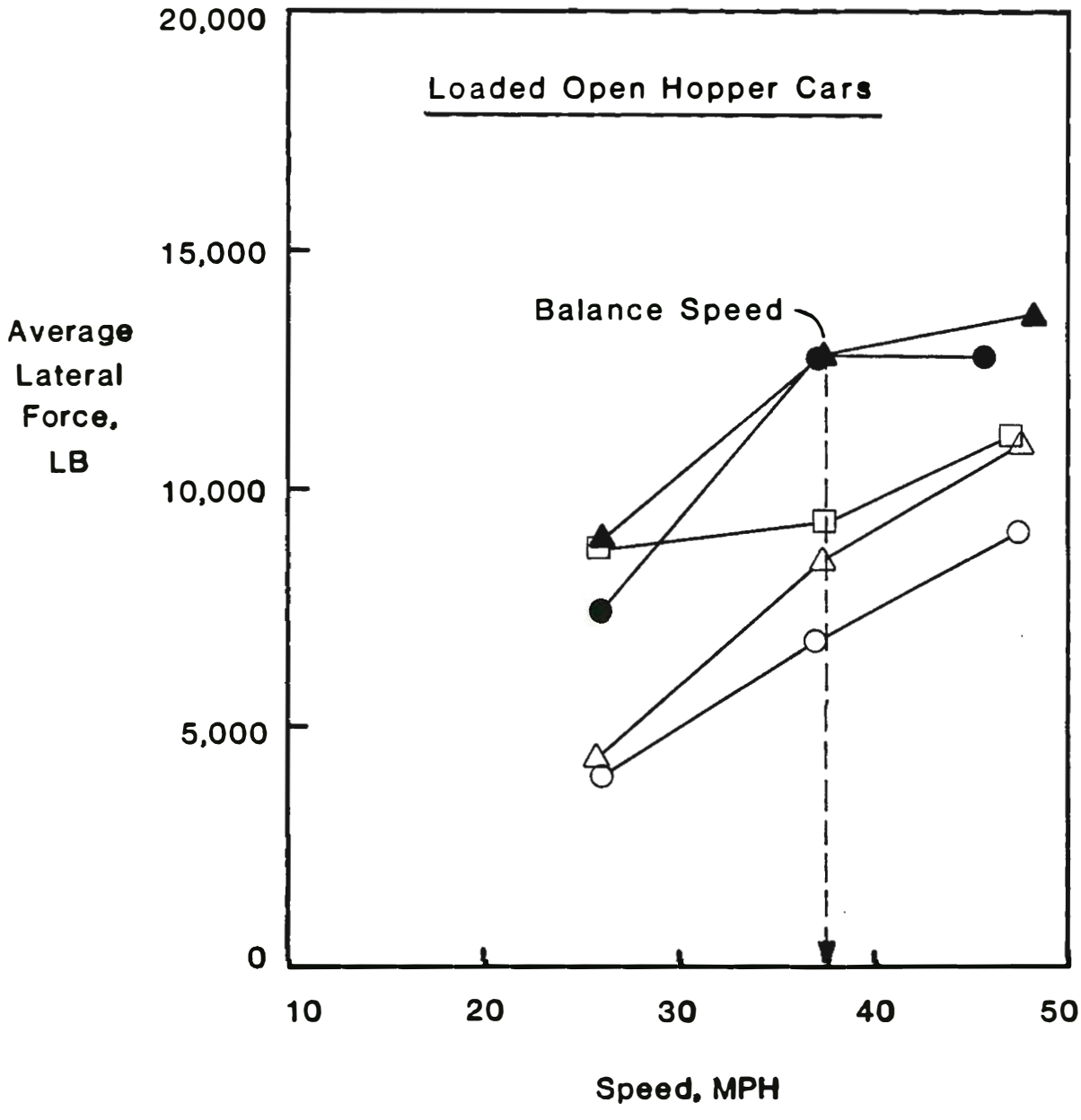
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
L/V Ratio
Track Curvature: 2.5 Degrees



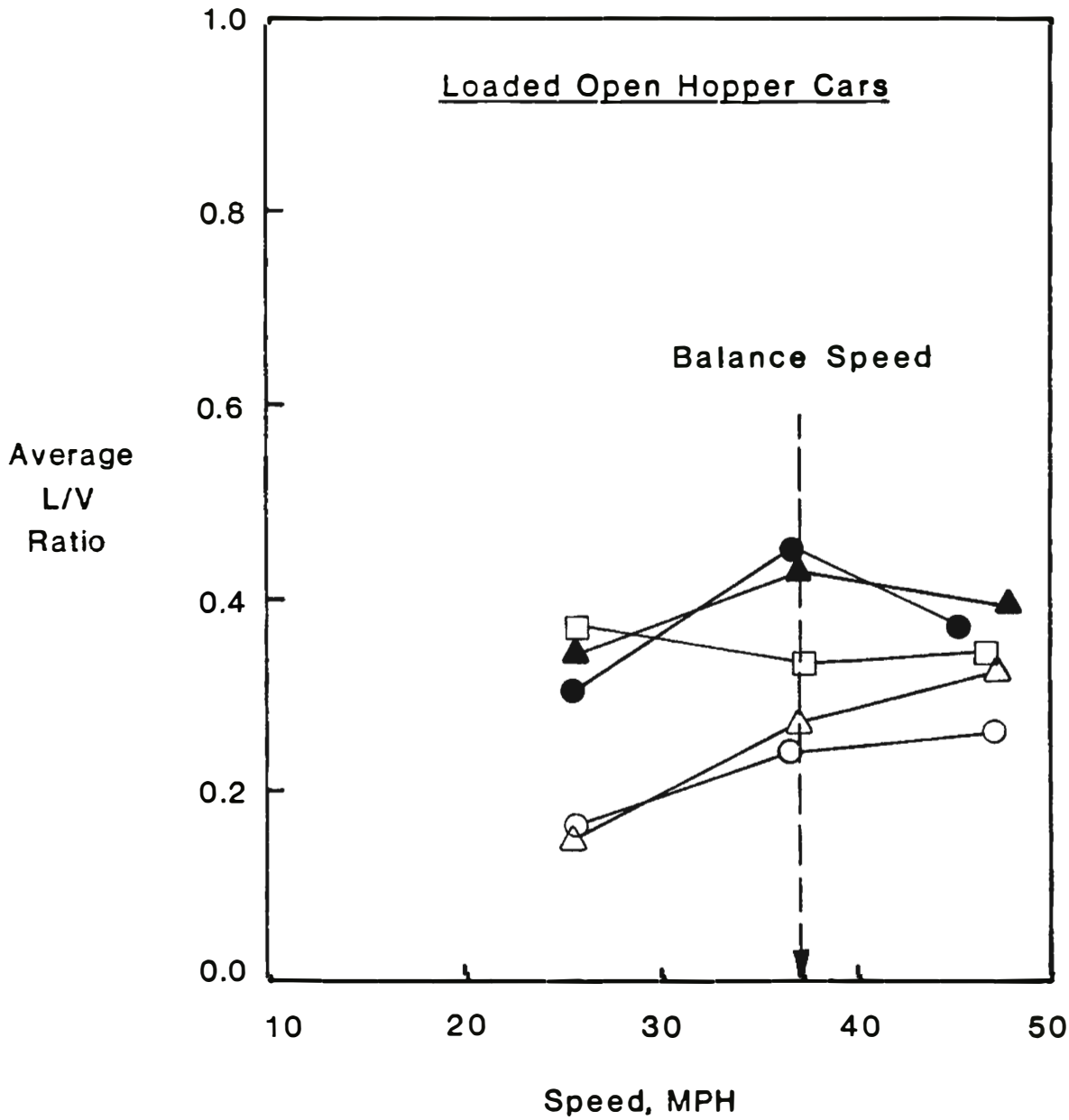
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
Lateral Force
Track Curvature: 5.2 Degrees



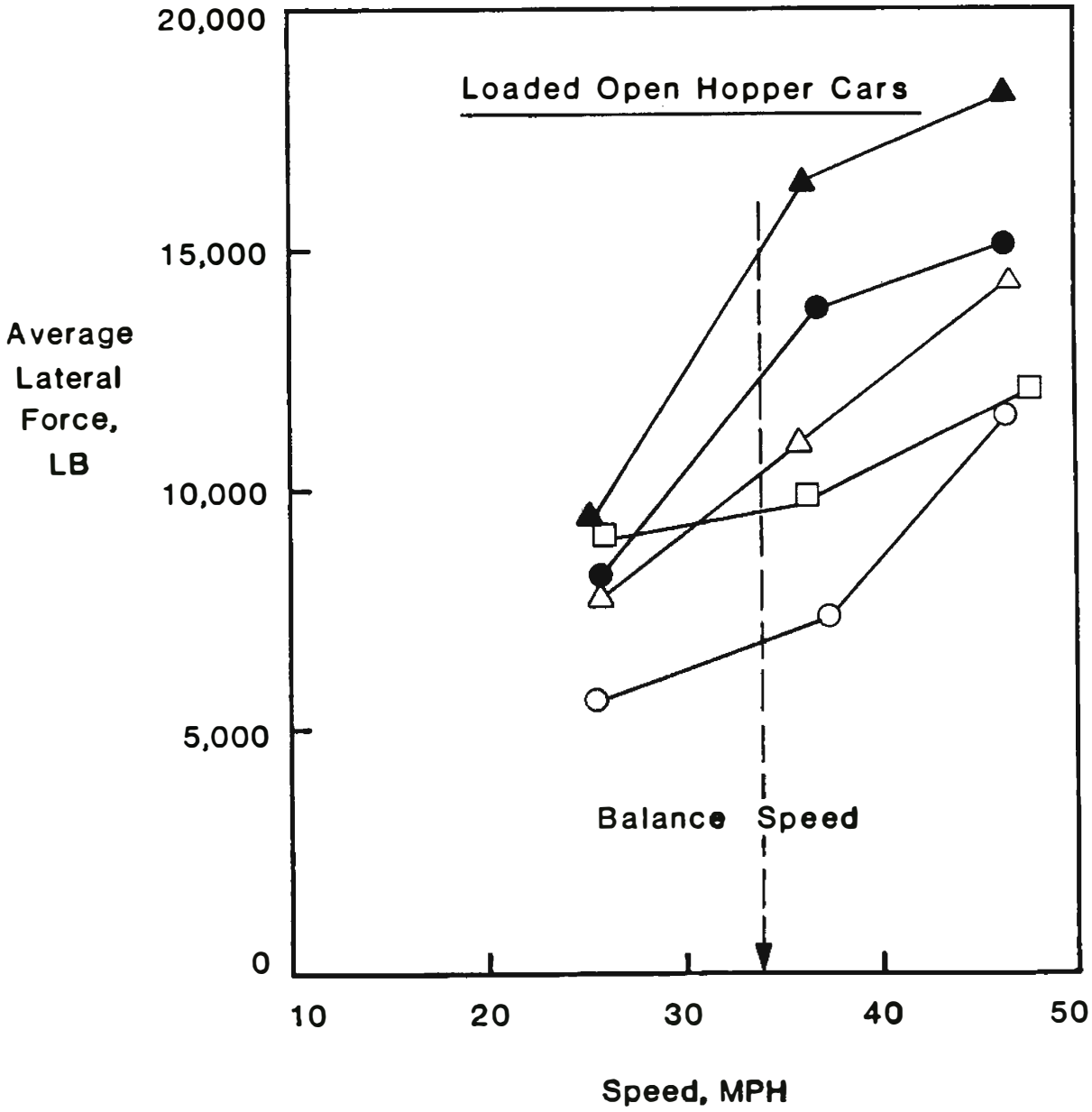
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
L/V Ratio
Track Curvature: 5.2 Degrees



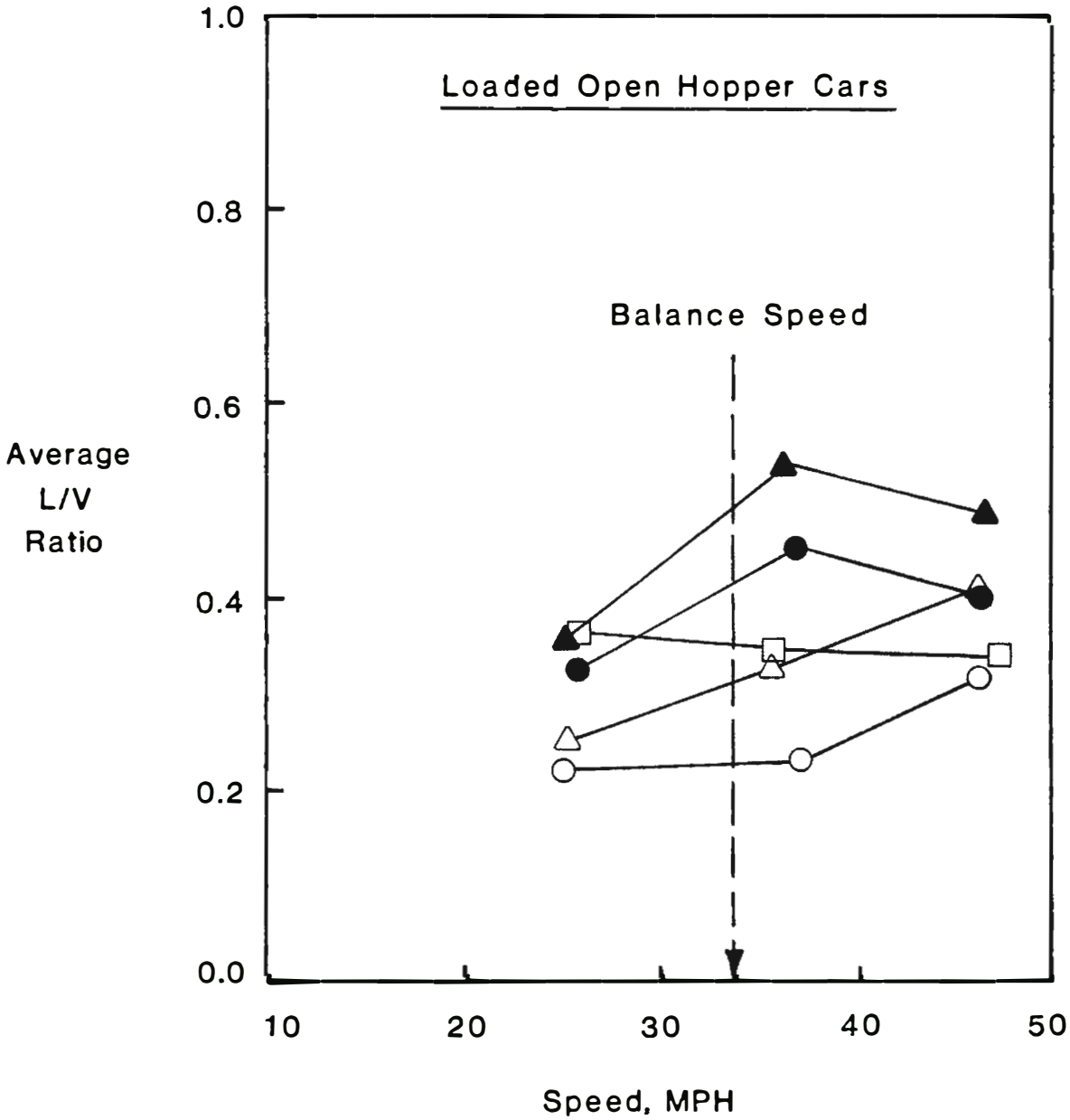
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
Lateral Force
Track Curvature: 6.2 Degrees



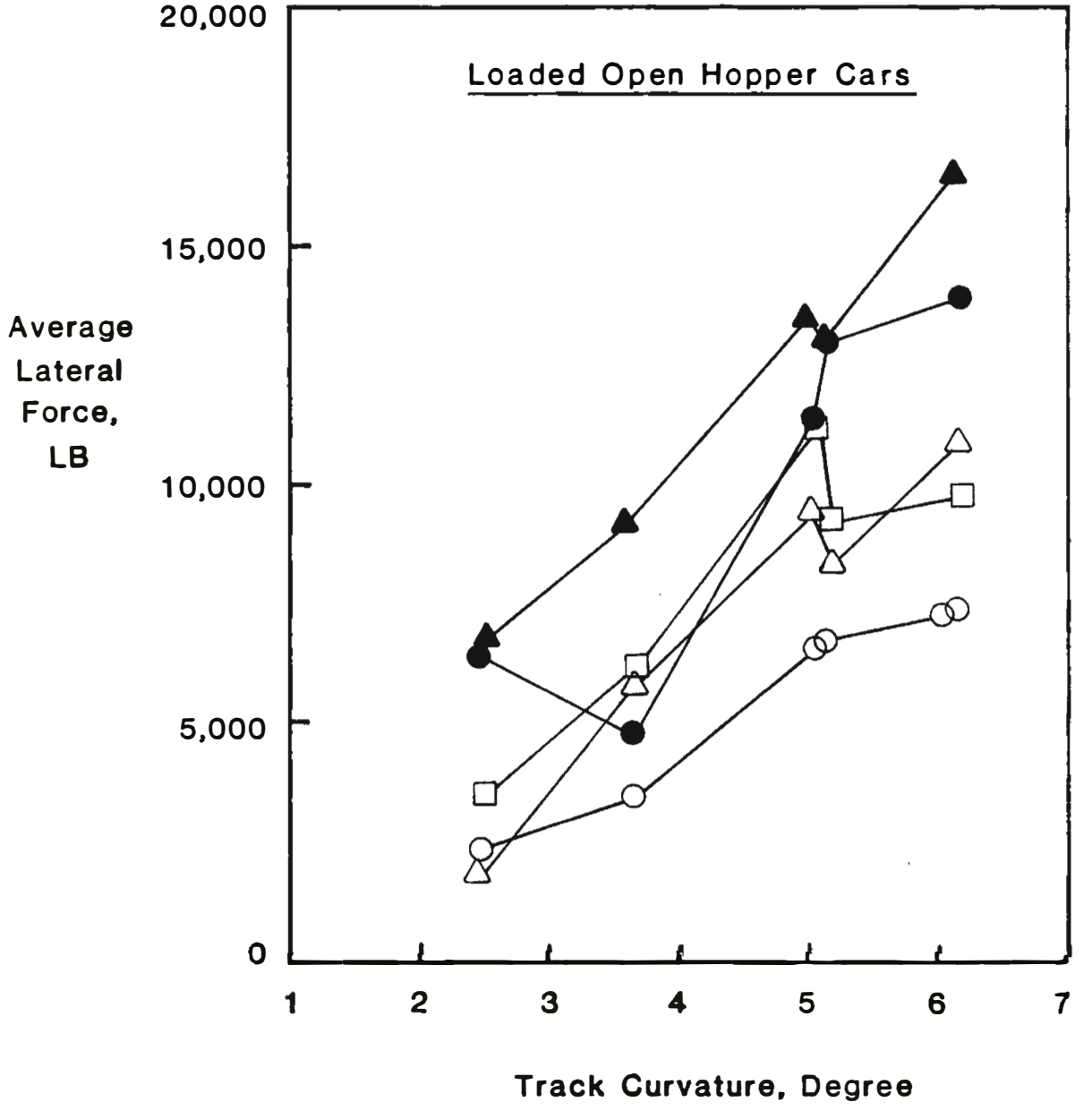
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
L/V Ratio
Track Curvature: 6.2 Degrees



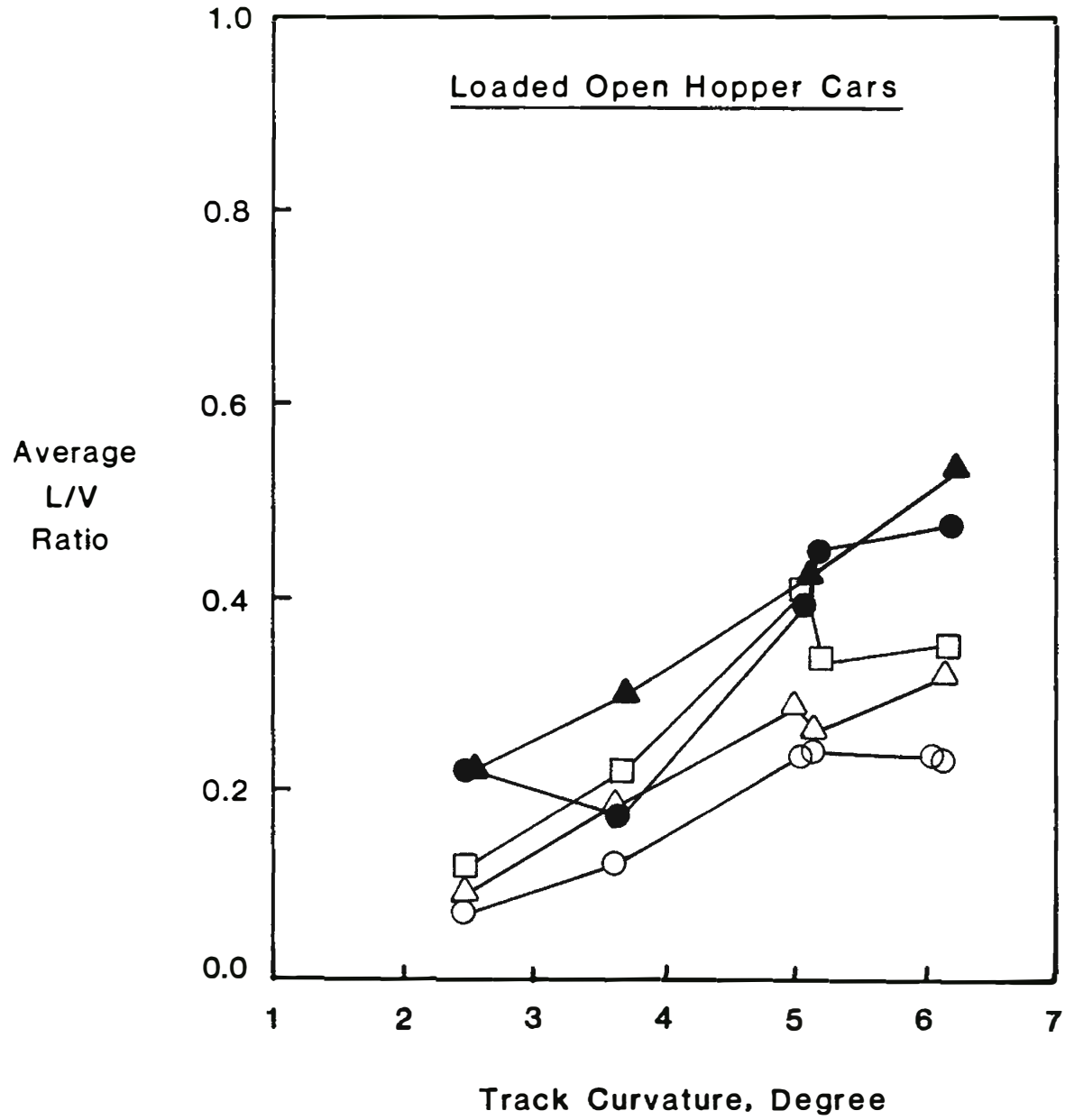
PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
Lateral Force At Balance Speed

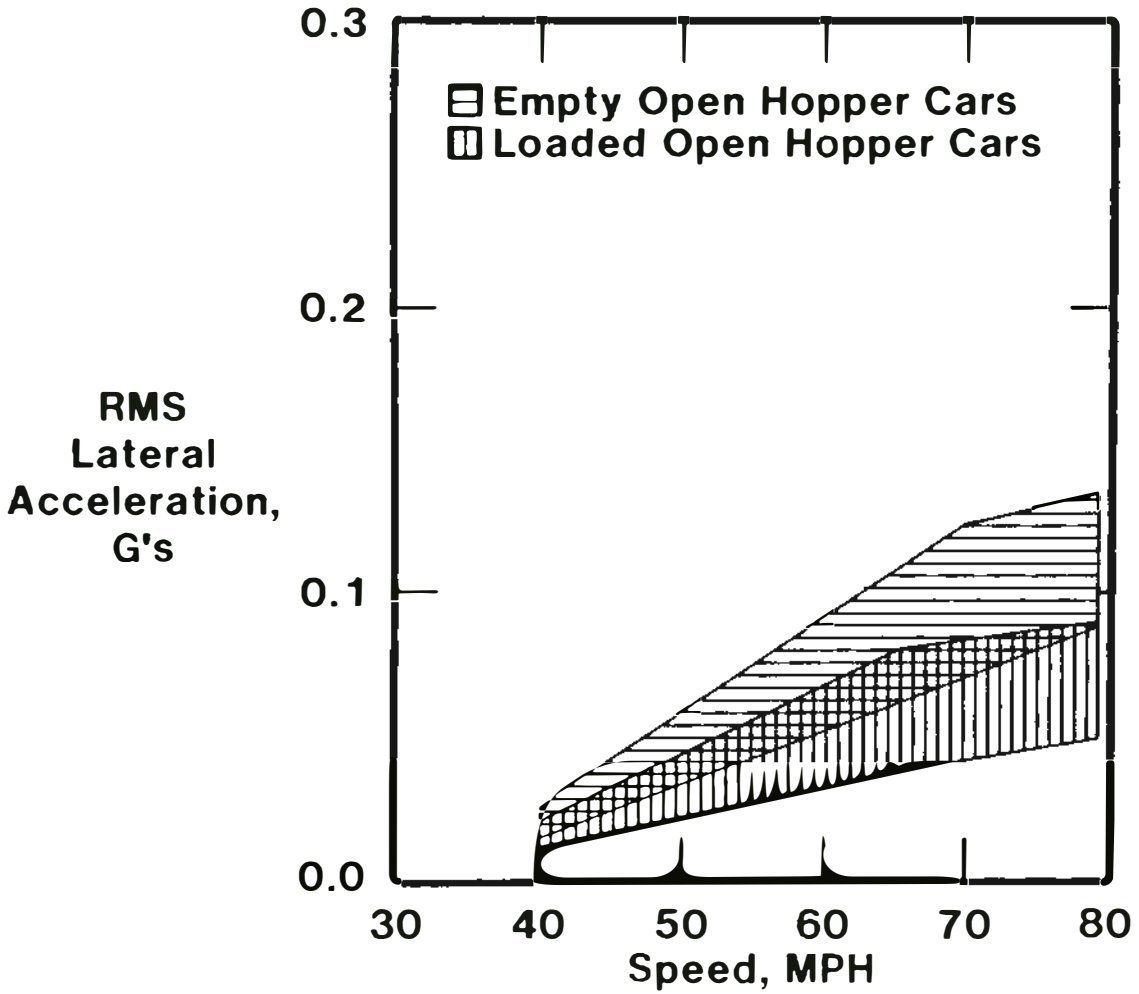


PERFORMANCE CHARACTERISTICS OF TYPE II TRUCKS

Curve Negotiation
L/V Ratio At Balance Speed

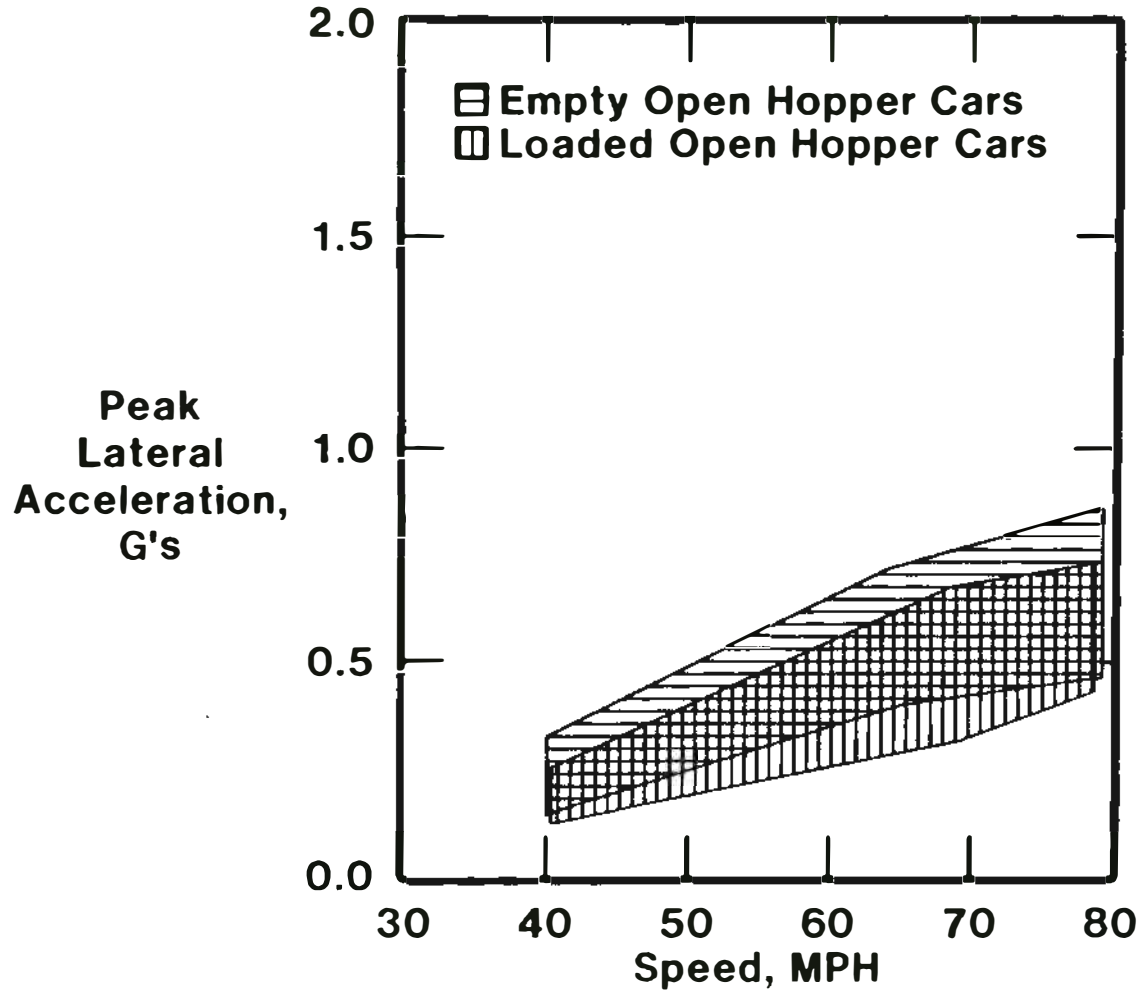


PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Lateral Stability
RMS Lateral Acceleration



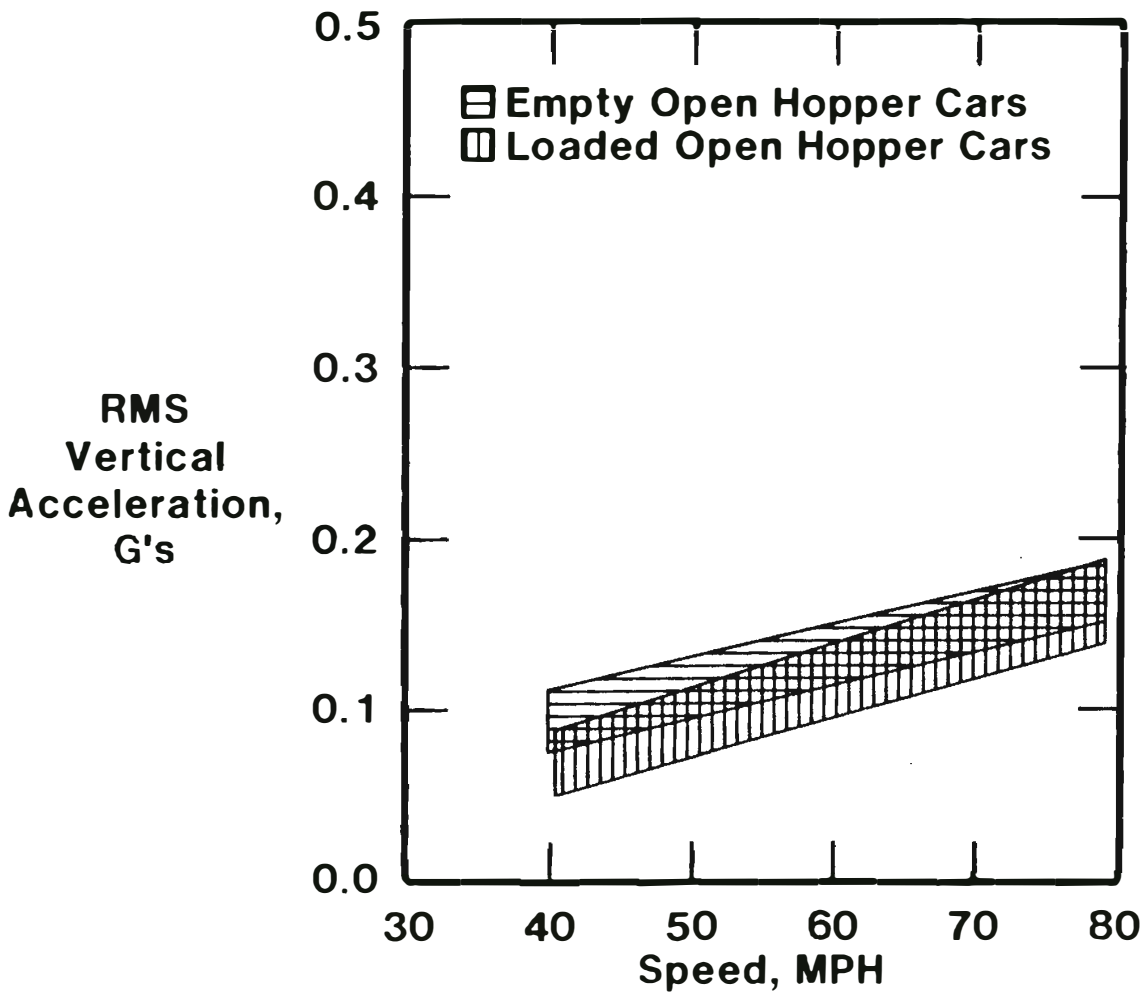
WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Lateral Stability
Peak Lateral Acceleration



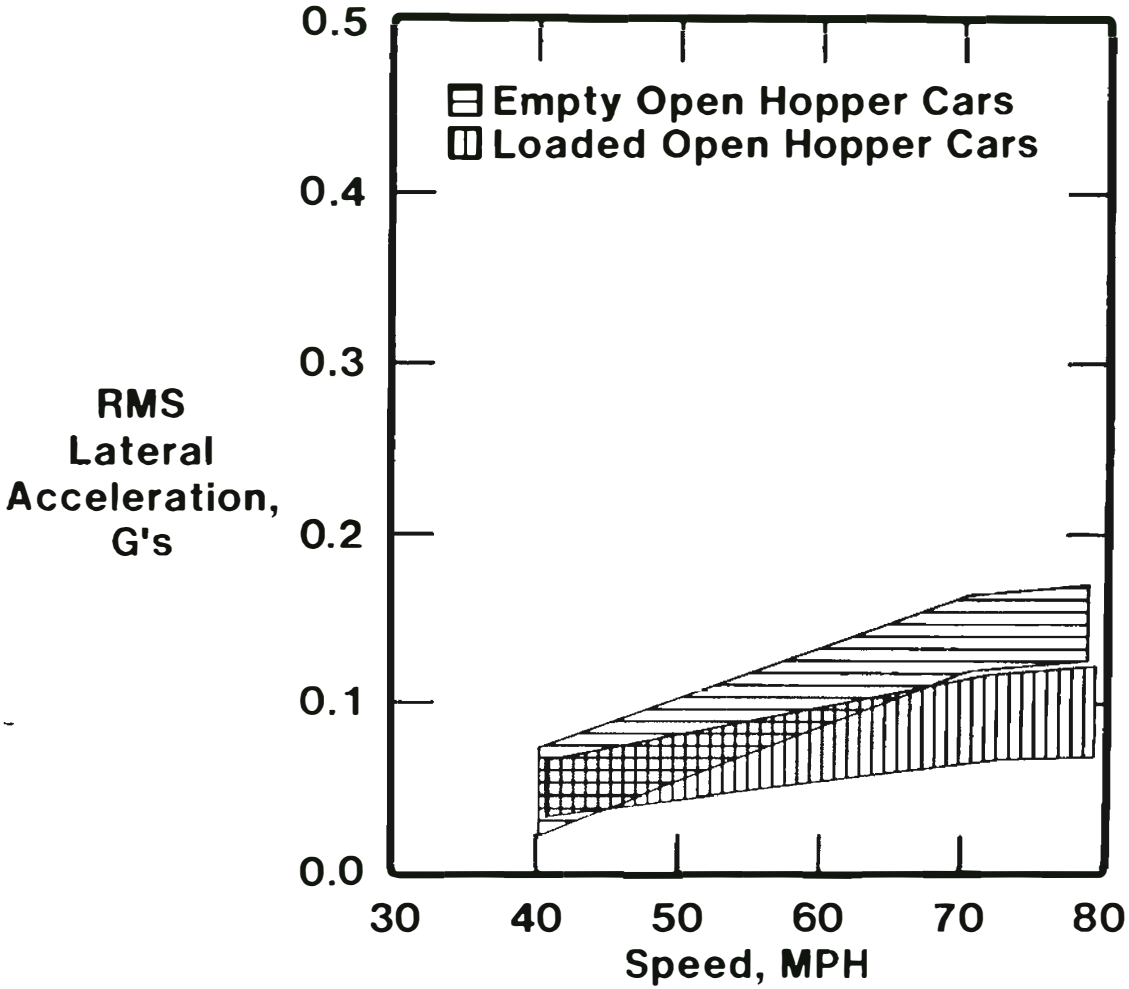
WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Ride Quality
RMS Vertical Acceleration (0-20 Hz)



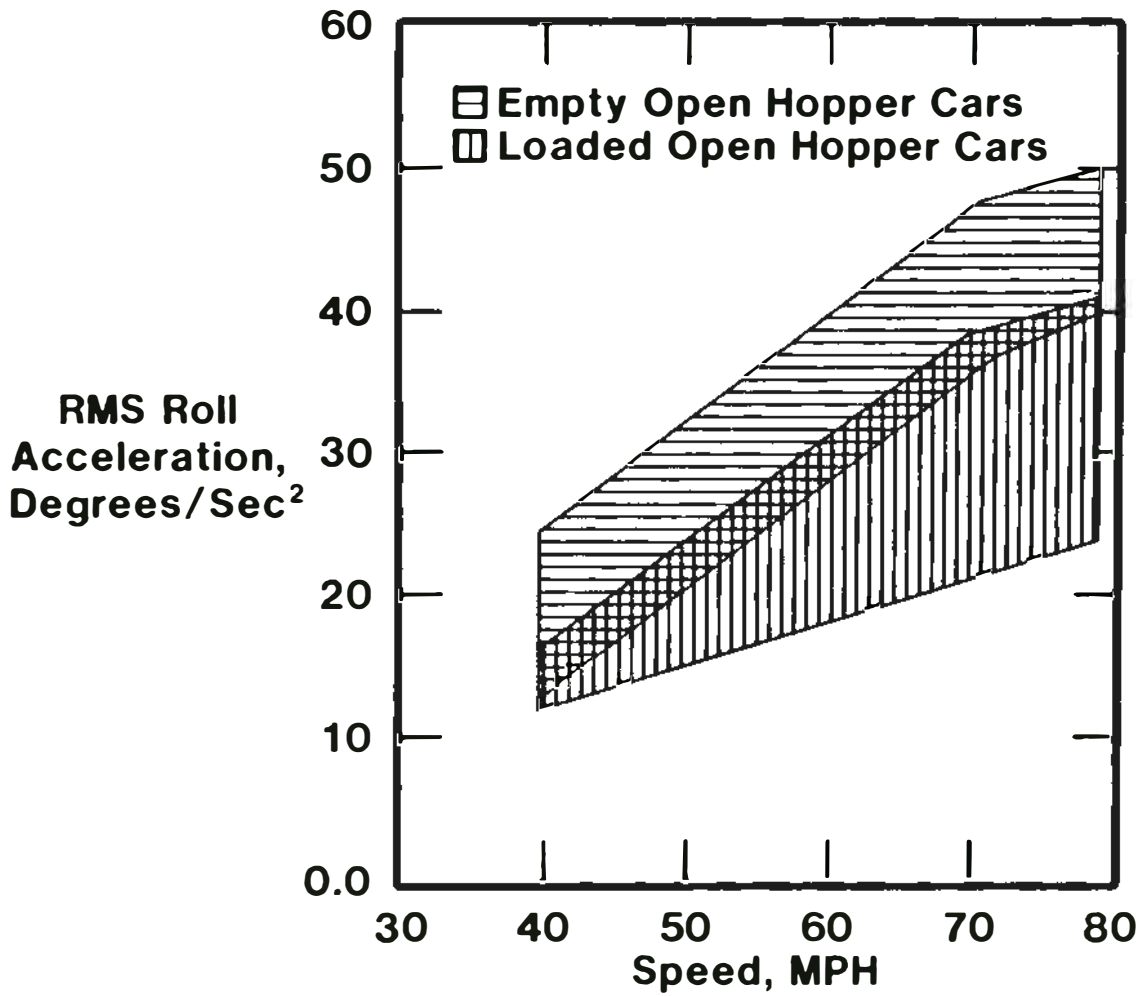
WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Ride Quality
RMS Lateral Acceleration (0-20 Hz)



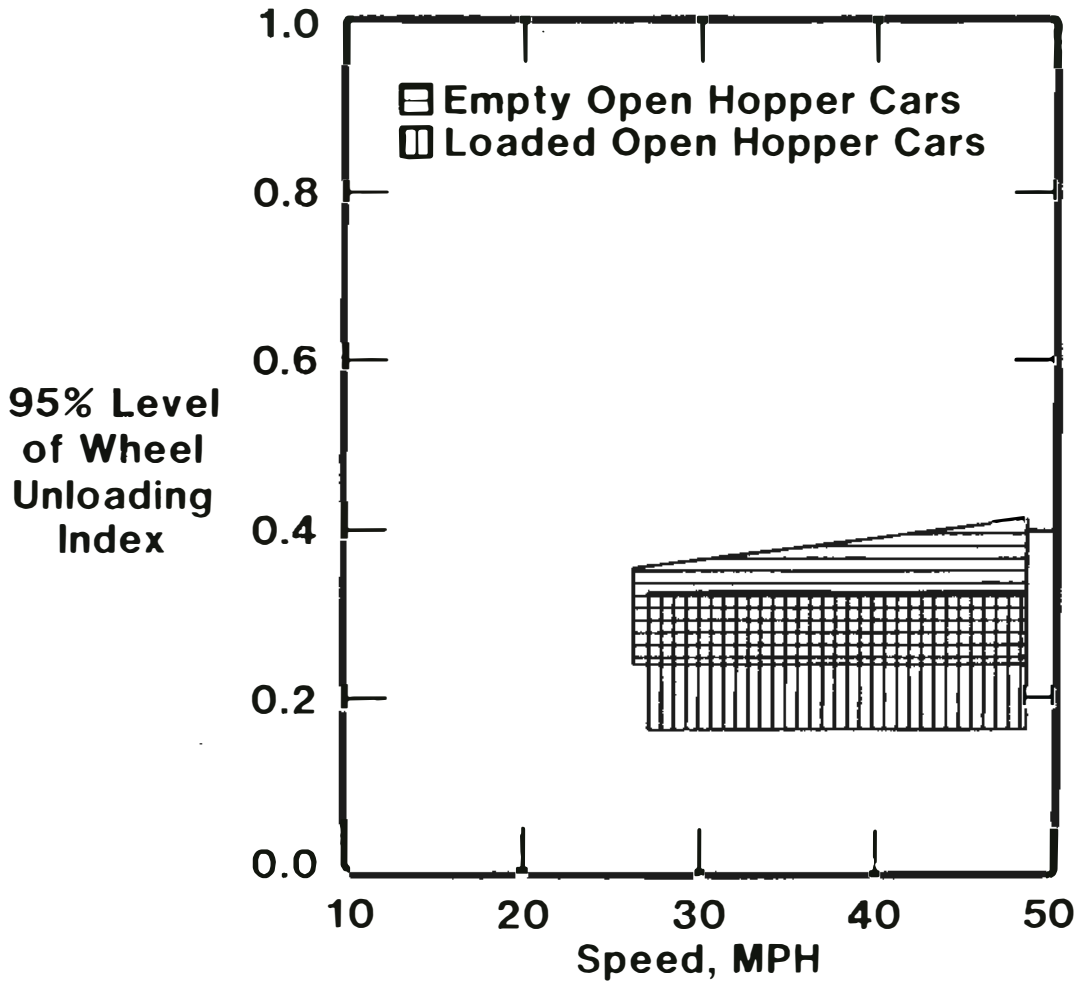
WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Ride Quality
RMS Roll Acceleration (0-20 Hz)



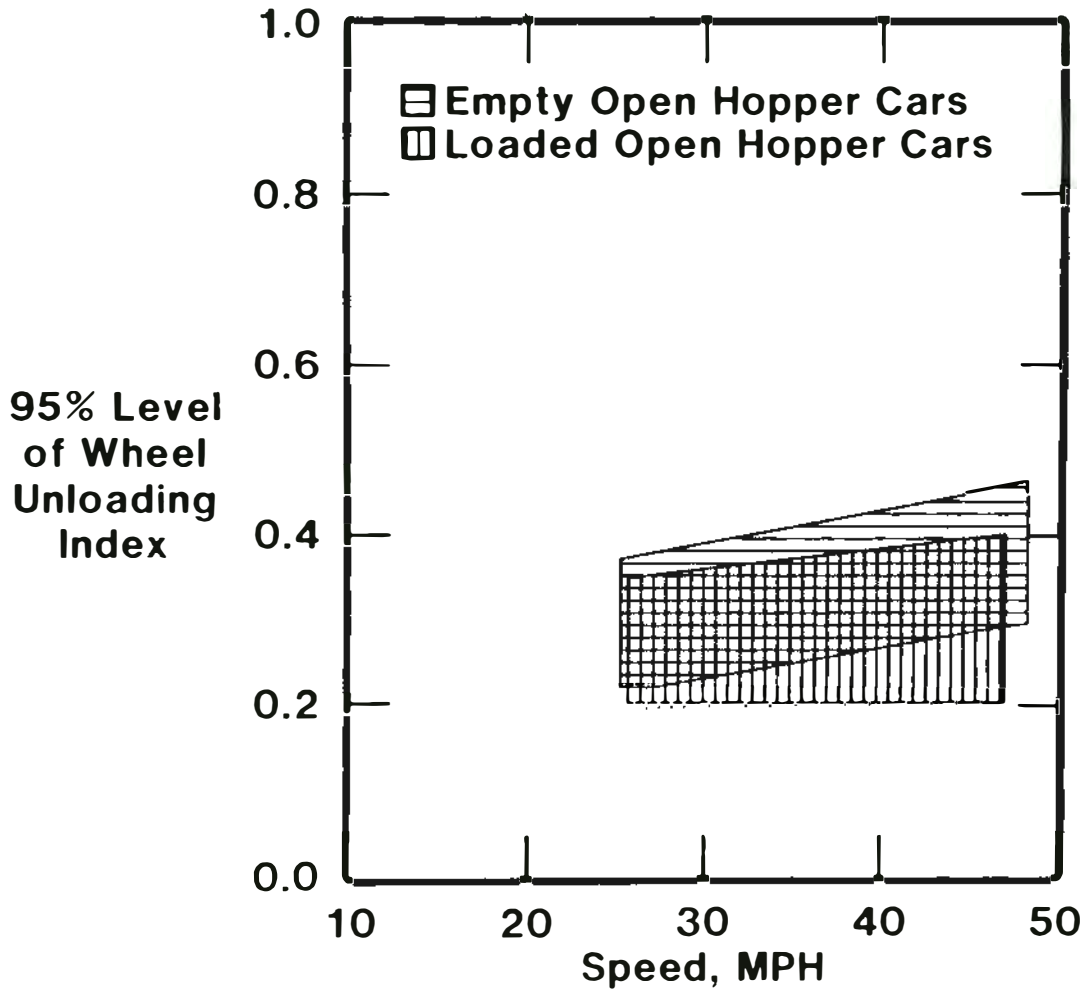
WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Trackability
Track Curvature: 2.5 Degrees



WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Trackability
Track Curvature: 6.2 Degrees



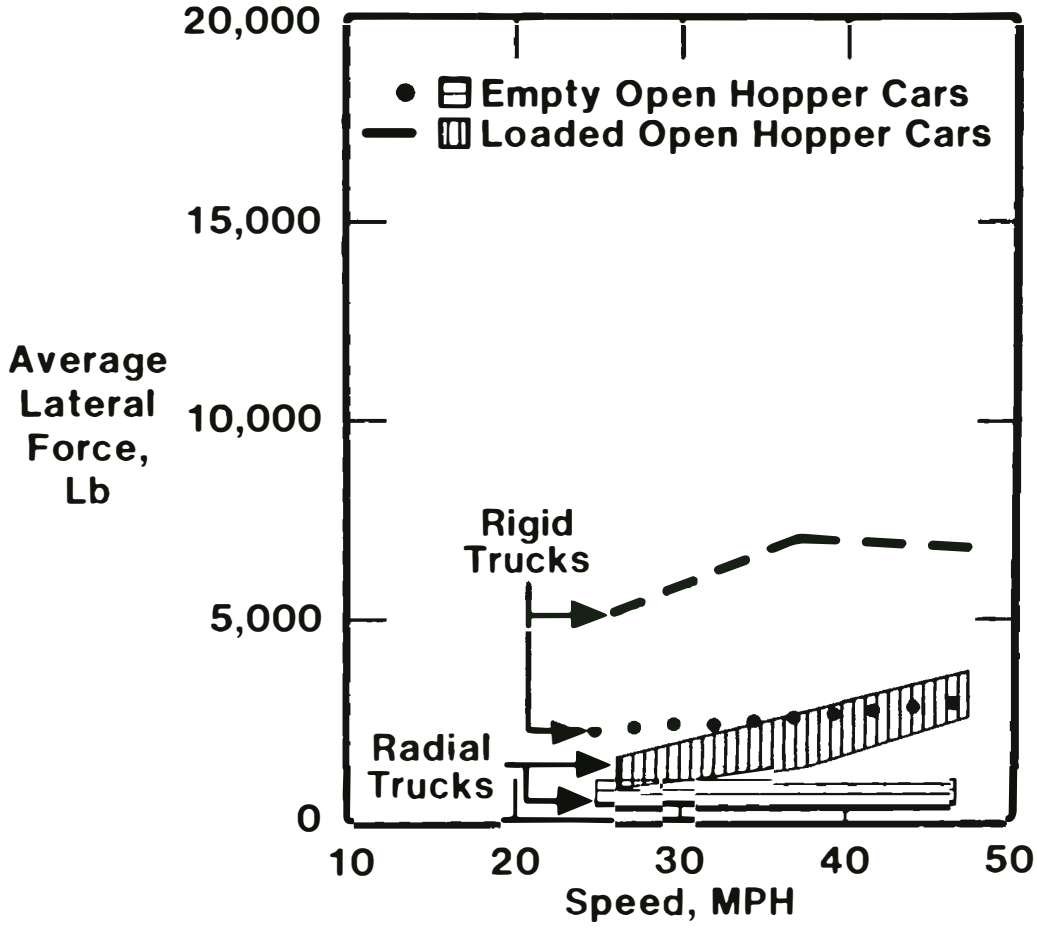
WYLE LABORATORIES

WUI_{95} Levels For
Type II Freight Car Trucks
(Track Twist)

Performance Index	Premium Trucks Empty Cars	Premium Trucks Loaded Cars
Wheel Unloading Index (95% Level)	0.30 - 0.55	0.28 - 0.37

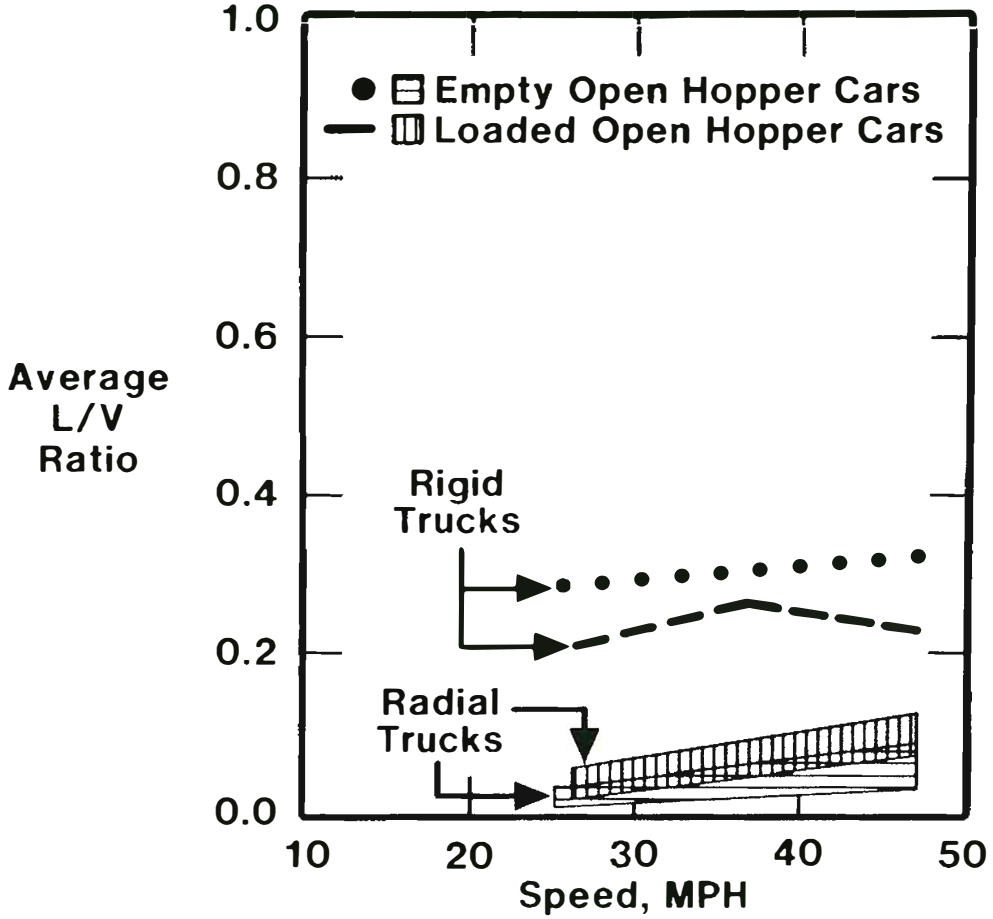
PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS

Curve Negotiation
Lateral Force
Track Curvature: 2.5 Degrees



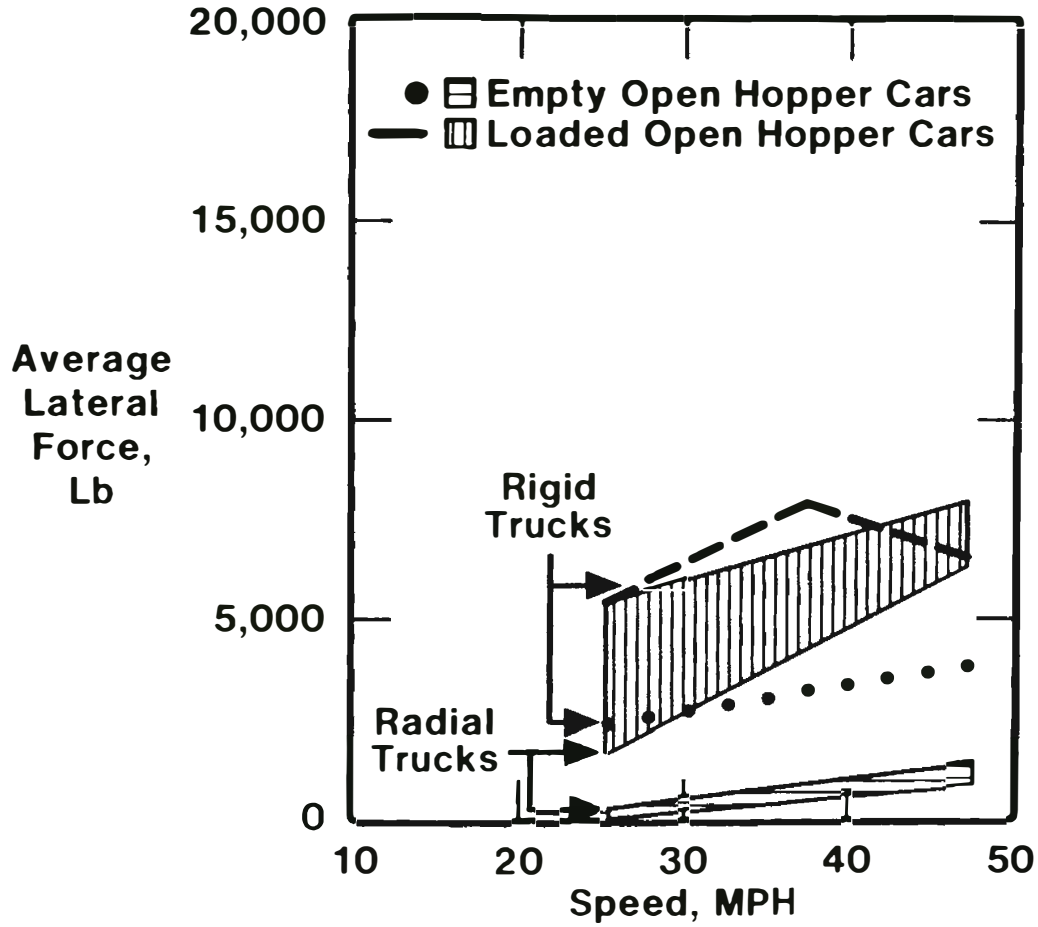
WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
L/V Ratio
Track Curvature: 2.5 Degrees



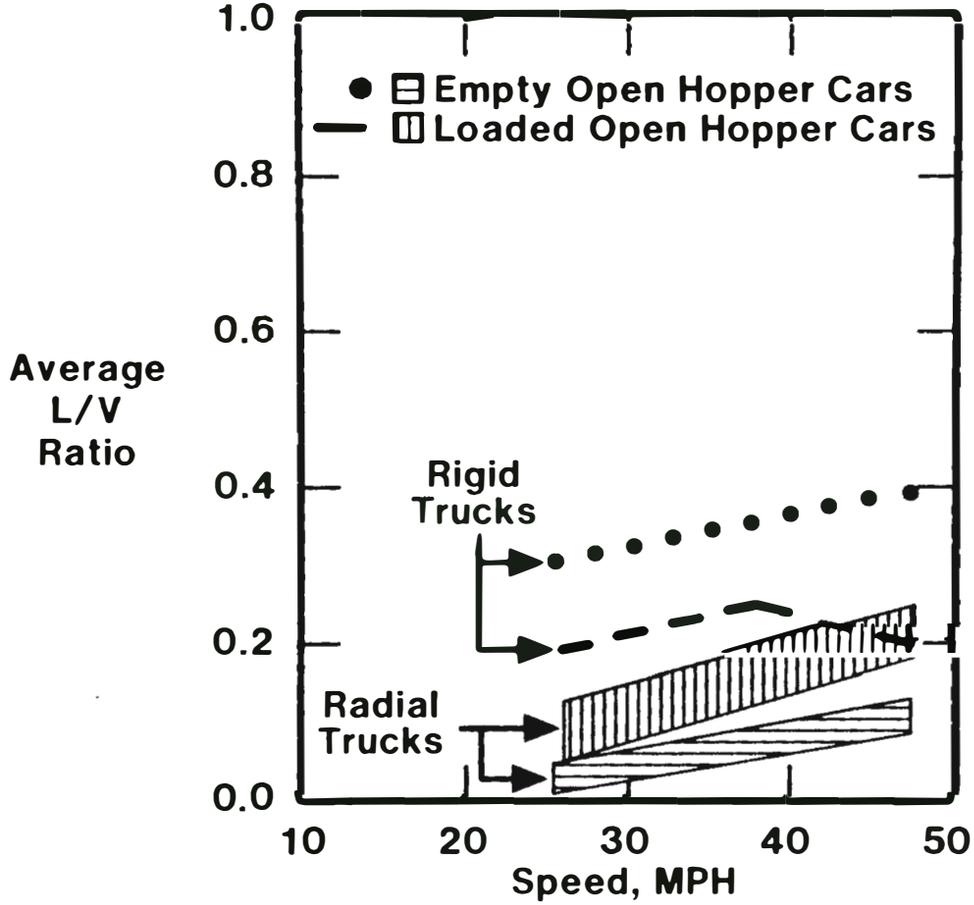
WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Curve Negotiation
Lateral Force
Track Curvature: 3.7 Degrees



WYLE LABORATORIES

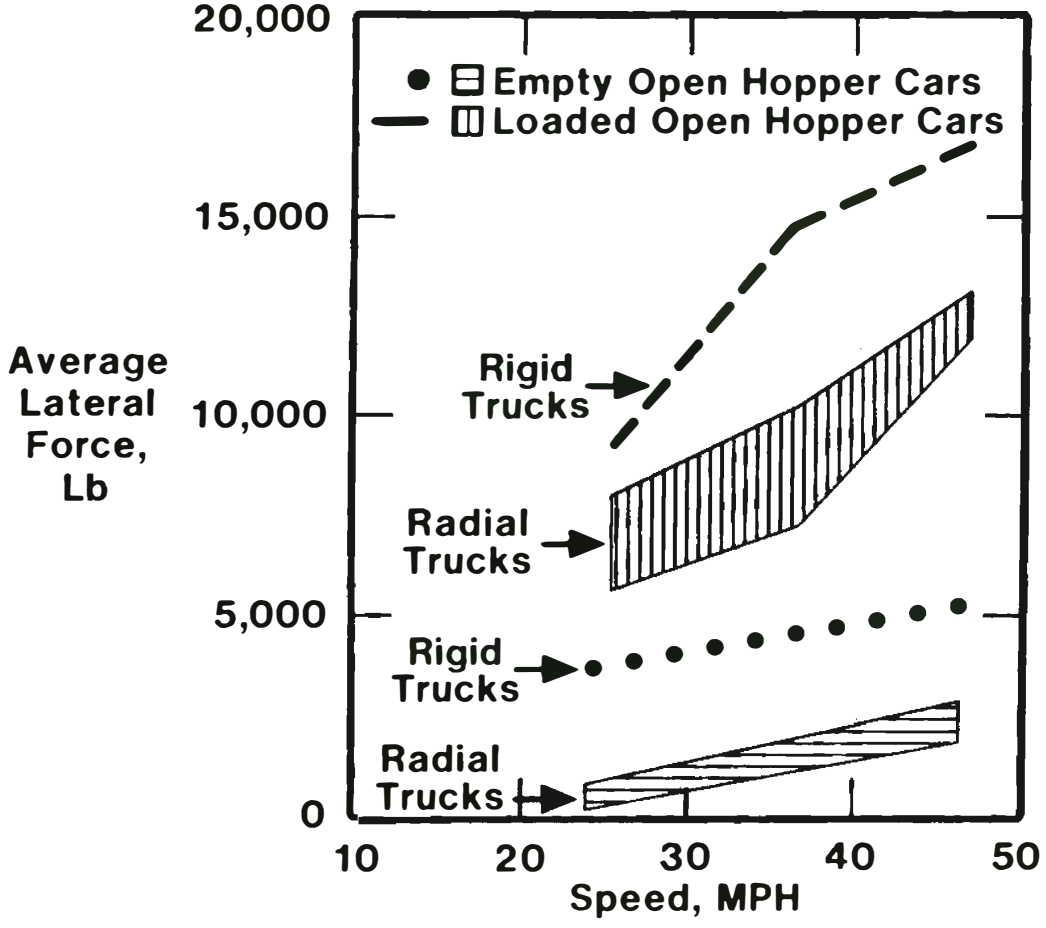
PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Curve Negotiation
L/V Ratio
Track Curvature: 3.7 Degrees



WYLE LABORATORIES

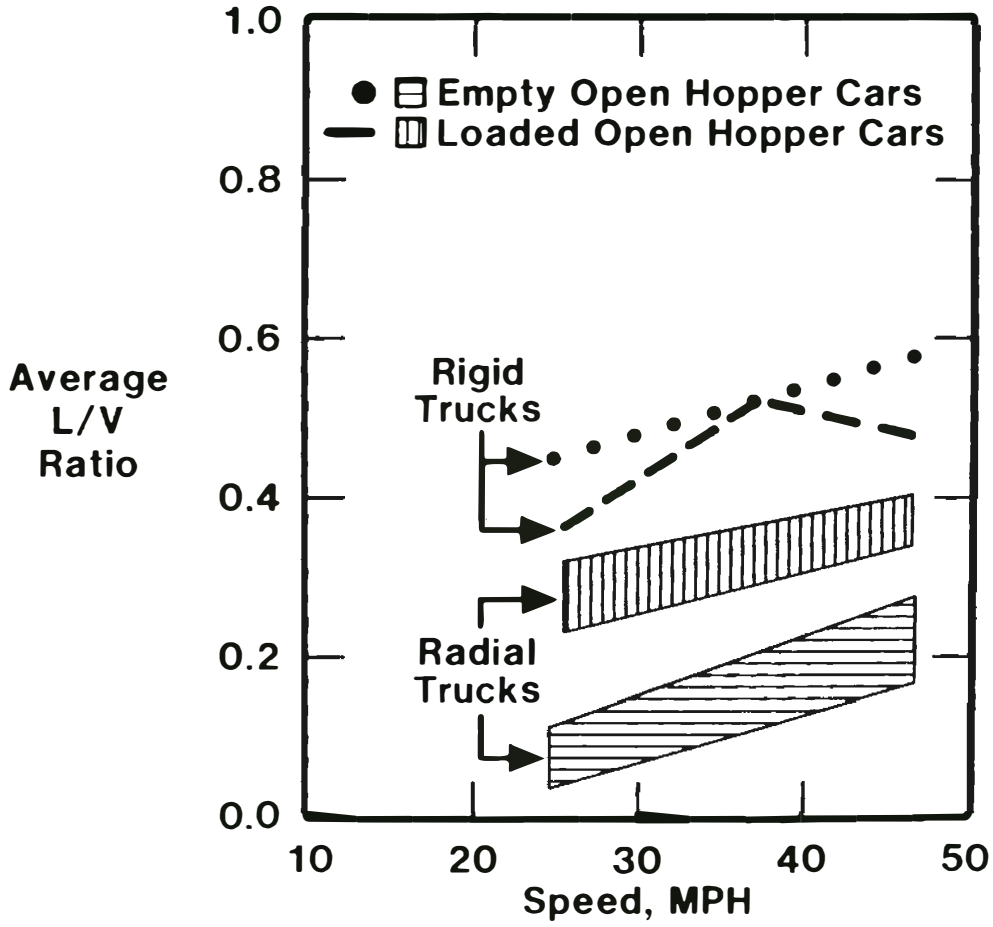
PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS

Curve Negotiation
Lateral Force
Track Curvature: 6.2 Degrees



WYLE LABORATORIES

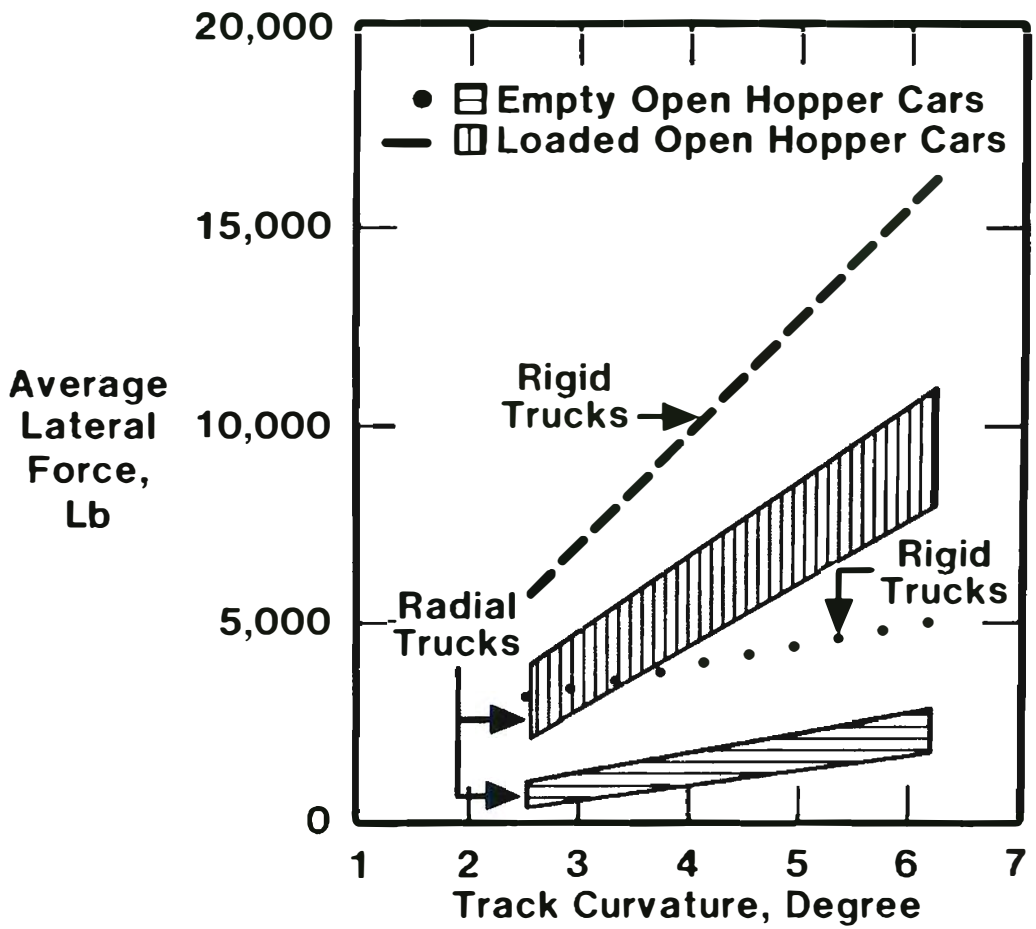
PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS
Curve Negotiation
L/V Ratio
Track Curvature: 6.2 Degrees



WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS

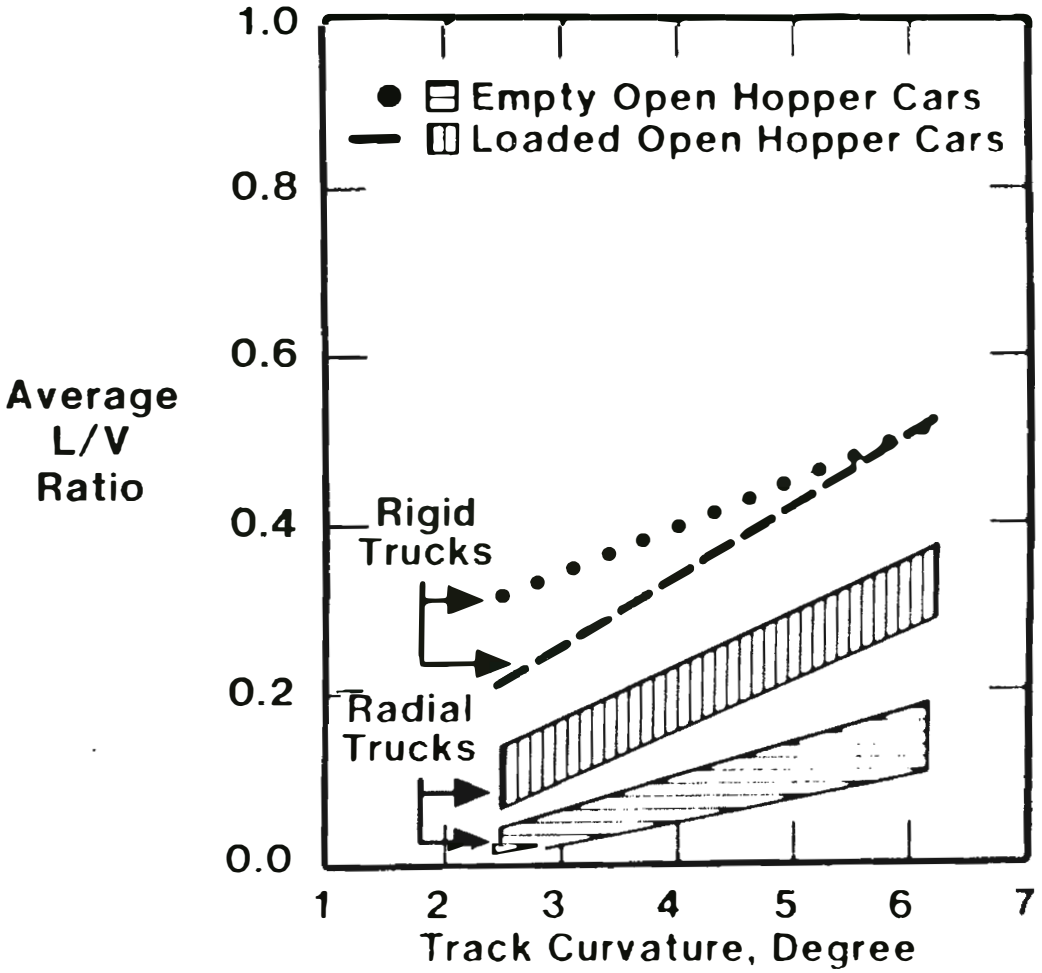
Curve Negotiation
Lateral Force
at Balance Speed



WYLE LABORATORIES

PERFORMANCE SPECIFICATION FOR TYPE II TRUCKS

Curve Negotiation
L/V Ratio
At Balance Speed



WYLE LABORATORIES

ECONOMIC ANALYSIS

OBJECTIVES

Identify Major Parameters That Govern the Profitability of Type II Trucks

Discuss the Trade-Offs Involved in Selecting Between Type I and Type II Trucks

Describe the Economic Analysis and its Relationship to Other TDOP Data

MAJOR PARAMETERS

Added Cost of the Truck

Captive Versus Interchange Service

Annual Car Mileage

Curved/Tangent Ratio

Empty to Loaded Ratio

Number of Trucks Purchased

Lading Sensitivity to Damage

GENERAL OBSERVATIONS

Savings From Following Areas:

- Roadway Maintenance
- Fuel Consumption
- Car Maintenance
- Lading Damage
- Derailment

Handling Line Receives the Benefit

Captive Service Cars

Rules Out Car Lines and Private Owners

Many Candidate Cars Owned by Car Lines/Private Owners

GENERAL OBSERVATIONS

Type I Trucks Cost 65¢/Pound

Type II Trucks Cost $1 /Pound of Non-Standard Parts
+ Any Charges for Truck Development

} Economies of Scale

Large Costs are Associated with Maintaining an Inventory of Non-Standard Parts

} Cost Due to Loss of Standardization

Benefits Greater With High Annual Mileage Cars

UNIT COAL TRAIN SCENARIO

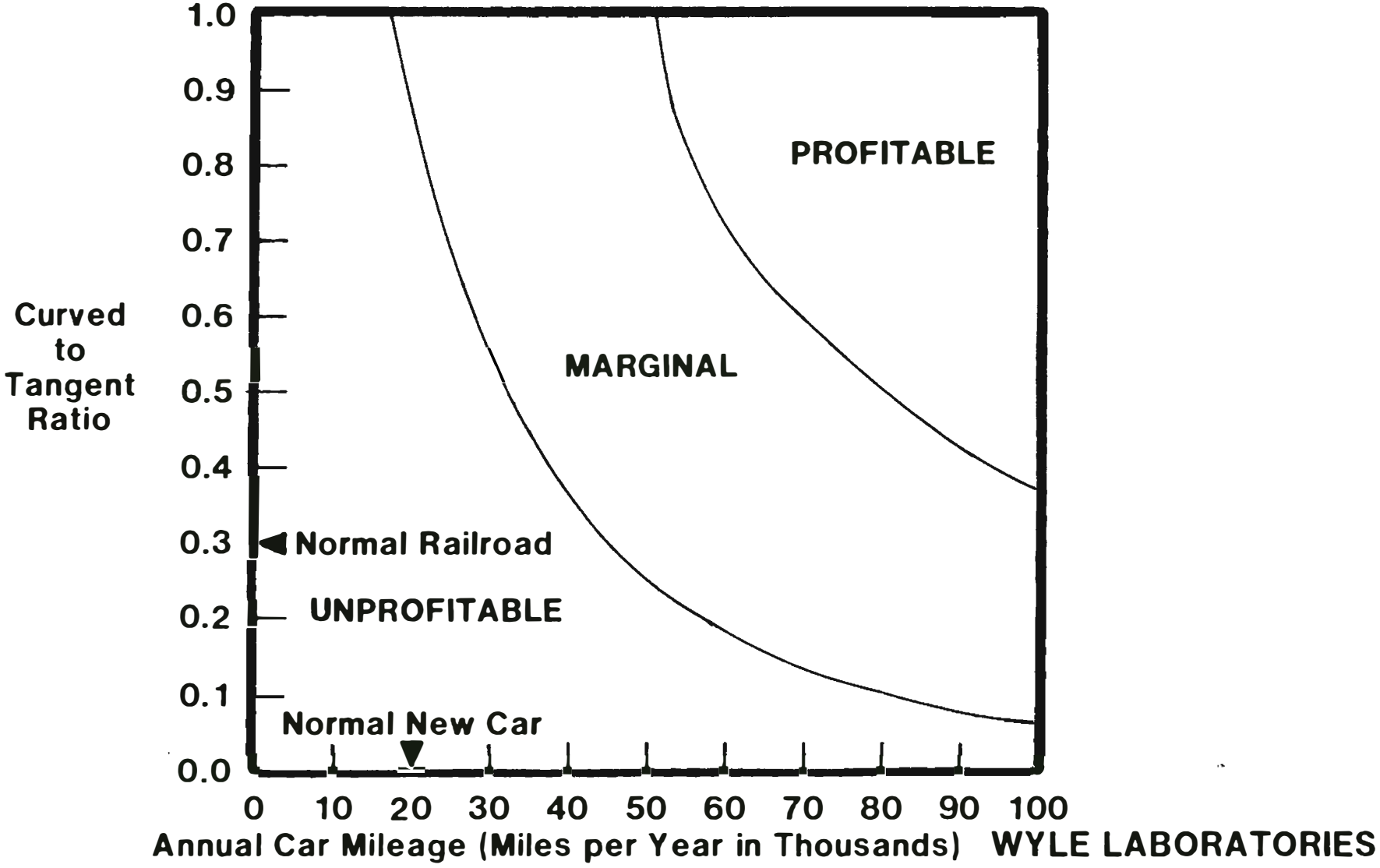
Steering Truck Savings in Curving

- Reduced Rail Wear
- Reduced Fuel Consumption
- Increased Wheelset Life

Curved/Tangent Ratio Important

Two Unit Trains Running With Steering Trucks

BOUNDARIES FOR STEERING
TRUCK SCENARIO



INTERMODAL SCENARIO

Primary Suspension Truck Savings From:

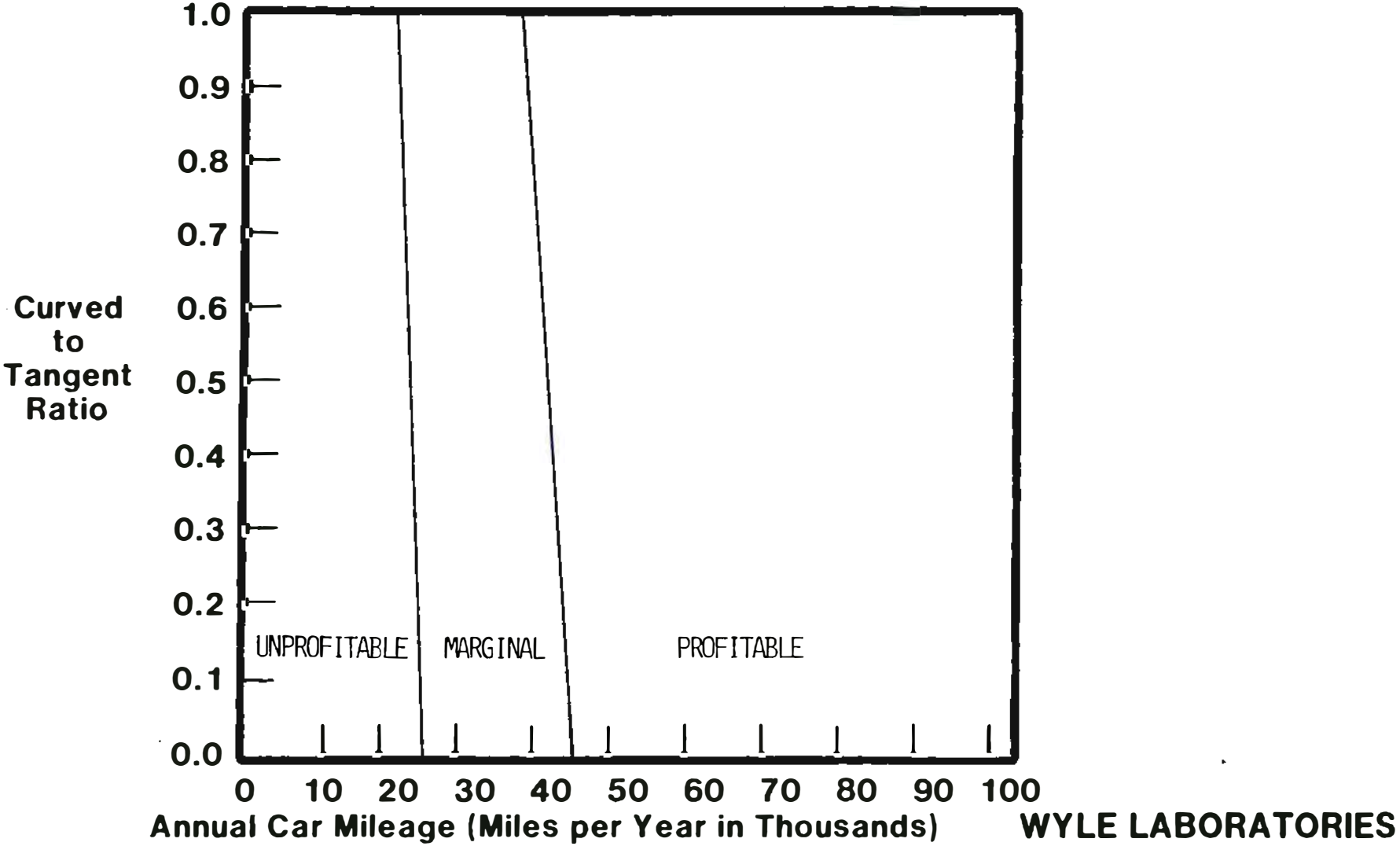
- Reduced Rail Wear (Tangent & Curved)
- Lading Damage due to Hunting

Boundary with Curved/Tangent Ratio Not Important

Boundary with Loaded Car Weight Affects Lading Damage

No Unit Trains Match This Scenario

BOUNDARIES FOR PRIMARY SUSPENSION TRUCK SCENARIO



BOUNDARIES FOR PRIMARY SUSPENSION TRUCK SCENARIO

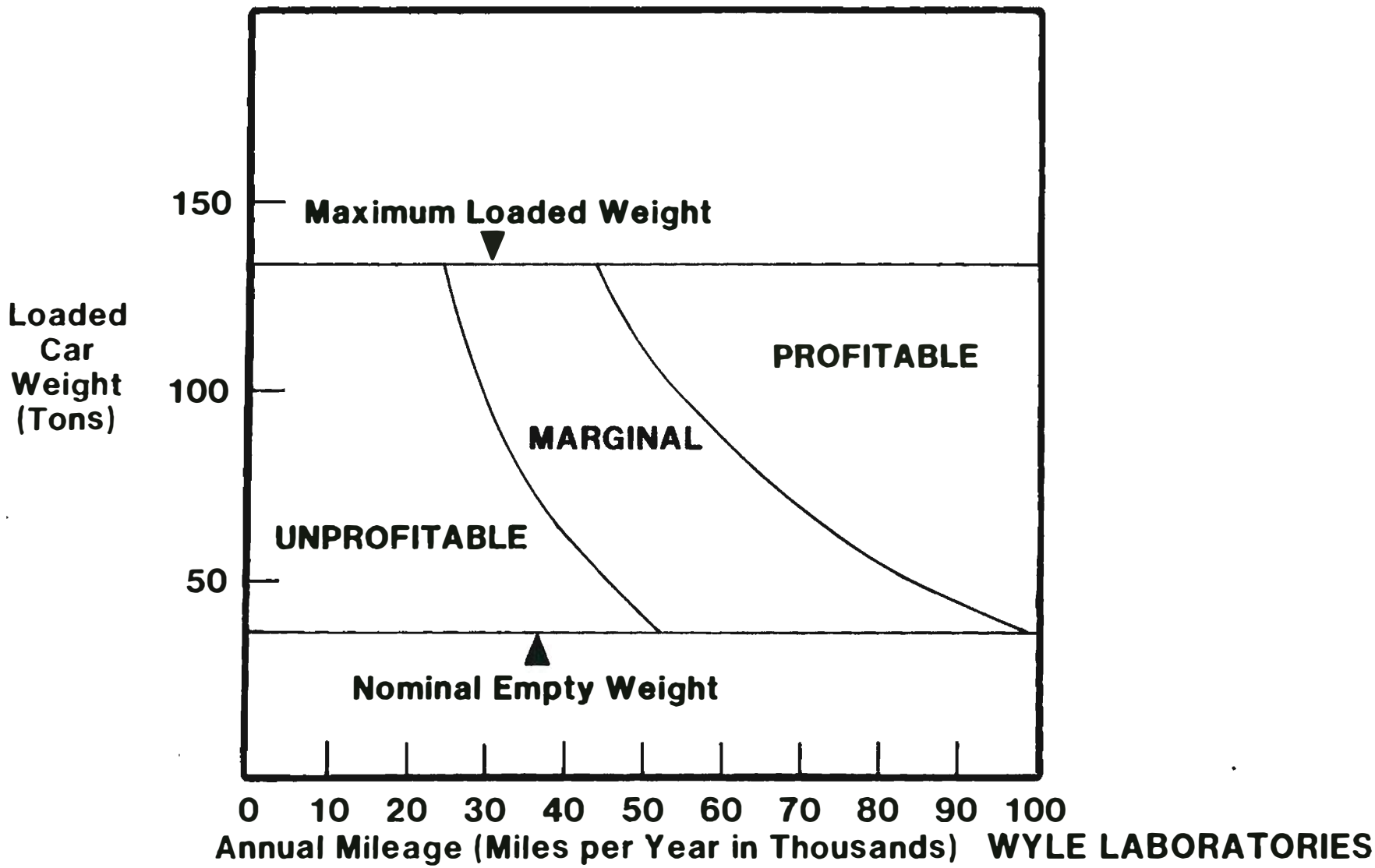


ILLUSTRATION OF PROCEDURE

Assumptions

Empty Weight	32 Tons
Loaded Weight	132 Tons
Empty to Loaded Ratio	0.5
Curved to Tangent Ratio	0.667
Annual Mileage	80,000 Miles/Year

Implicit Assumptions

Captive Service

Lading Insensitive

WORST-CASE BENEFIT/COST ANALYSIS OF A STEERING TRUCK

Incremental Net Cash Investment Calculation

Incremental Gross Cash Investment	$3000.00
Less: Investment Tax Credit of 10%	300.00
Incremental Net Cash Investment	2700.00

Annual Incremental Net Cash Benefits Calculation

Gross Cash Benefits Before Depreciation	566.71
Depreciation ($3000./22.6 Years) (Noncash Item)	132.58
Gross Accounting Profit	434.13
Tax at 50%	217.06
Net Accounting Profit	217.06

Gross Cash Benefits Adjusted to Net Cash		
Gross Cash Benefits	566.71	
Less Tax at 50%	217.06	
Annual Incremental Net Cash Benefits		349.64

Net Present Value Calculation

Present Value of Benefits	
($349.64 X 8.80 P.V. of $1 at 10% for 22.6 Yr)	3075.67
Less: Incremental Net Cash Investment	2700.00
Net Present Value	$ 375.67

CALCULATION OF BENEFITS

Car Maintenance Savings		
Wheel Life	$133.71	
Steering Arm	-61.35	
Sideframe	-13.76	
Adapter	-28.35	
Inventory Adjustment	-5.00	
Total	25.25	25.25
Roadway Maintenance Savings		
Vertical Forces	110.30	
Curving Forces	333.90	
Total	444.20	444.20
Fuel Savings		97.26
Gross Cash Benefits before Depreciation		$566.71

ESTIMATE OF WHEEL LIFE

Estimated Increased Wheelset Life Versus Type I Truck: 1.8 — Unit Trains Wear Program Performance Testing

Estimated % of Wheels That Fail for Wear: 41% — Car Maintenance Study

.41 x 1.8 + .59 x 1 = 1.328 Longer Life

Estimated Annual Wheelset Replacement Cost: $541.34 — Car Maintenance Study

$541.34/1.328 = $407.64 New Annual Cost
$541.34 − $407.64 = $133.70 Annual Savings

WYLE LABORATORIES

OTHER CAR MAINTENANCE

New Repair Category - Fixing & Replacing Non-Standard Steering Assembly

Example: Brake beam { Unit Trains / Worst Case

$61.35/Year ⇦ Car Maintenance Study

Changes in Wear Rates - Sideframe & Adapter Wearing Faster { Unit Trains / Wear Program

2 x Sideframe = $13.76/Year

3 x Adapter = $28.75/Year

⇦ Car Maintenance Study

WYLE LABORATORIES

INVENTORY COSTS

Example - 12 Storage Sites

$3000 Non-Standard Part Each Site

Cost - $36,000

Lost Return - 10% x $36,000 = $3,600/Year

100 Cars Involved	720 Cars Involved
$36/Year	$5/Year

Planning Can Reduce These Costs

ROADWAY SAVINGS

Vertical Dynamics	9%	Reduced ⇦	Performance Test
Annual Savings	$110.30	⇦	CIGGT
Curving Forces	33%	Reduced ⇦	Performance Test
Annual Savings	$333.90	⇦	CIGGT

CIGGT Analyzing TDOP Test Data

FUEL SAVINGS

TYPE I $\left| 0.680\ Wd + 0.081\ Wd^2 + 0.00041\ Wd\ (V^2 - V_b{}^2) \right|$

TEST TRUCK $\left| 0.327\ Wd + 0.077\ Wd^2 + 0.00056\ Wd\ (V^2 - V_b{}^2) \right|$

⌂

PERFORMANCE TEST

FUEL SAVINGS 0.000807 Gallons/Mile

⇦ FUEL CONSUMPTION SIMULATOR

DOLLAR SAVINGS $97.26/Year