REPORT NO. FRA/ORD-78/52

PB 300969/AS

TDOP

TRUCK DESIGN OPTIMIZATION PROJECT PHASE II

PHASE I DATA EVALUATION AND ANALYSIS REPORT

WYLE LABORATORIES
SCIENTIFIC SERVICES & SYSTEMS GROUP

Colorado Springs Division
4620 Edison Avenue
Colorado Springs, Colorado 80915

DEPARTMENT OF TRANSPORTATION · UNITED STATES OF AMERICA

AUGUST 1979

Document is available to the U.S. public through the National Technical Information Service Springfield, Virginia 22161

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
Federal Railroad Administration
Office of Research and Development
Washington, D.C. 20590

NOTICE

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FRA/ORD-78/52		

4. Title and Subtitle	5. Report Date
TRUCK DESIGN OPTIMIZATION PROJECT (TDOP) PHASE II Phase I Data Evaluation and Analysis Report	August 1979
	6. Performing Organization Code
7. Author(s) David W. Gibson and Robert J. Glaser	8. Performing Organization Report No. TDOP TR-02
9. Performing Organization Name and Address Wyle Laboratories Scientific Services & Systems Group 4620 Edison Avenue Colorado Springs, CO 80915	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DOT-FR-742-4277
12. Sponsoring Agency Name and Address Department of Transportation Federal Railroad Administration (FRA) Office of Research and Development Washington, DC 20590	13. Type of Report and Period Covered Technical Report Dec. 1977 - April 1979 14. Sponsoring Agency Code FRA/RRD-12

15. Supplementary Notes

See FRA Report No. FRA/ORD-70/34, Phase I Data Evaluation and Analysis Plan, September 1978

16. Abstract

As part of the TDOP Phase II project, the FRA directed Wyle Laboratories to evaluate and analyze the test data acquired during TDOP Phase I for use in Phase II model validation and specification of performance indices. These data were contained on 204 magnetic tapes and computer printouts.

The applicability of the Phase I test data to Phase II was evaluated from three points of view. The first was completeness of the test matrix. Most Phase I tests were conducted using the 70 ton refrigerator car on an ASF ride control truck with new wheel profiles. Although this over-emphasis on one configuration will necessitate additional testing of the Type I truck, it was possible to derive useful information from the Phase I test data. The second was measurement accuracy. The quality of measurements was acceptable except for measurements of lateral wheel force at the wheel/rail interface and in the detection of ALD targets. The third point of view was the Phase I data's adequacy to perform the Type I truck model validation and specification of performance indices. The data in the regimes of ride quality and lateral stability appear to be adequate. In the regimes of curve negotiation and trackability, the lack of adequate measurements of wheel/rail forces makes it difficult to extract meaningful information from the data.

17. Key Words	18. Distribution Statement
Truck Design Optimization Project (TDOP), Phase II, Phase I Data Evaluation and Analysis, Freight Car Trucks (Type I), Railroad Technology	Document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	82	

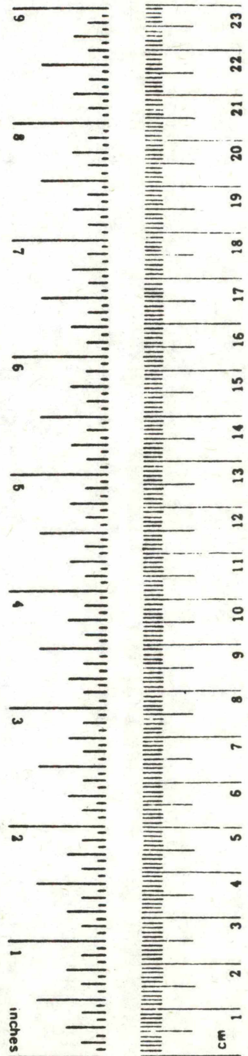
Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

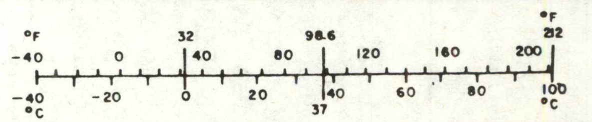
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



EXECUTIVE SUMMARY

The purpose of this report is to evaluate and analyze the TDOP Phase I test data for its applicability to the TDOP Phase II project. Specifically, the evaluation will determine if the Phase I data can be used in Phase II model validation and performance indices specification.

The report discusses the three approaches used to determine the usefulness of the Phase I data. First, the quantity and scope of the data was evaluated. Using a data sorting routine, a series of matrices was developed. This analysis showed that the preponderance of Phase I testing was conducted on the 70-ton refrigerator car with the ASF truck and new wheels. Since the refrigerator car is not typical of most cars in service, reliance on the data may well bias the results of the Phase II analytical work.

Secondly, the evaluation determined if the Phase I measurements accurately represent the quantity measured. For example, did the vertical accelerometers on the carbody give an accurate representation of car bounce? The conclusion was that the measurements was satisfactory except in two areas: the measurement of lateral wheel forces at the wheel/rail interface, and the detection of automatic location detector (ALD) devices. The first deficiency is of major significance. Without the data on the lateral wheel forces, the Phase I data cannot be used in validating the various curving models or in assessing the curve negotiation performance indices of the Type I truck. The lack of precise ALD target locations limits the usefulness of the Phase I data for trackability regime analysis and, to a lesser degree, ride quality analysis.

Finally, the Phase I data were evaluated for its adequacy in performing the Type I truck model validation and specification of performance indices. In other words, what data are required versus what data are available from TDOP Phase I. For the lateral stability and ride quality regimes, the data appear to be adequate; however, the lack of accurate measurements on the lateral forces at the wheel/rail interface will make it difficult to extract from the data meaningful information for the curve negotiation and trackability regimes.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1 - INTRODUCTION

1.1 BACKGROUND

As part of the Truck Design Optimization Project (TDOP) Phase II study, the Federal Railroad Administration (FRA) directed Wyle Laboratories to evaluate and analyze the test data acquired during Phase I of TDOP for use in Phase II model validation and specification of performance indices.

Prior to commencing this work, Wyle Laboratories prepared a TDOP Phase I Data Evaluation and Analysis Plan which the FRA approved (Reference 1). The plan describes what will be accomplished during the Phase I data evaluation and analysis and how the task will be implemented. It contains a description of the hardware and software to be used, the specific analytical techniques to be employed, and the selection and format of the data to be reduced. The plan also defines the expected results of this effort and the format for this report.

1.2 REPORT ORGANIZATION

The remainder of the report is divided into these sections: Section 2 summarizes what data were available for this effort and the computer programs used in the study. Section 3 provides an evaluation of the data and their applicability to Phase II. Section 4 provides a sample of data usage in the form of a pilot program of data analysis for the ride quality regime. Section 5 summarizes the results of the data evaluation and analysis and provides recommendations for future testing.

SECTION 2 - IMPLEMENTATION

2.1 PHASE I DATA

The TDOP Phase I data, in the form of data tapes and computer printouts of analyzed data, were provided to Wyle Laboratories by the FRA. The data were categorized by a computer-based inventory and stored in boxes. The boxes contain 204 magnetic data tapes from the five test series in Phase I, analyzed data from the car response measurements, and the track geometry. The analyzed data included the ENSCO Track Geometry Data Report, and reduced data from various test runs consisting of power spectral densities (PSDs), time histories, and statistical summaries. The complete catalog of the FRA-supplied Phase I data is contained in Appendix A.

Wyle initially explored the idea of reformatting the Phase I data to permit selection by the railroad industry of a particular phenomenon, characteristic, or parameter variation. However, a survey of the railroad industry revealed little appeal for reformatting. Furthermore, the need for a summary of TDOP Phase I data has been met by these FRA documents: the Freight Car Truck Design Optimization Phase I Executive Summary, the Test Results Reports, and the FRA Critique of the Test Results Reports (Reference 4).

2.2 DESCRIPTION OF DATA ANALYSIS SOFTWARE

2.2.1 TDOP Data Sorting Routine

Because of the vast amount of Phase I data generated, a TDOP data sorting routine was developed by Wyle which provides ready access to these data. The sorting routine allows for the specification of a given set of test conditions; the routine then lists all test runs which meet that set of requirements. Details of this sorting routine and the parameters on which it sorts are contained in Appendix B. This sorting routine was used extensively in the evaluation of the Phase I data as discussed in Section 3.2.

2.2.2 Post Processing Program

The analysis of the Phase I data was accomplished by utilizing the Post Processing Program developed by the Southern Pacific Transportation Company (SPTCo.). The Post Processing Program was received from the FRA on magnetic tape and converted for use on Wyle's Interdata 8/32 computer system. Documentation on the program was provided by the Post Processing Program manual (Reference 2). The effort required to convert this program to the Interdata computer system proved to be considerably more difficult than originally anticipated (see Appendix B). The program, as revised and implemented for Phase II analytical work, is described in Reference 3.

2.2.2.1 Program Validation. To assure the accuracy of analyzed data using the Post Processing Program, a series of steps was executed to validate the operation of the program on the Interdata computer. The first step involved running test cases on the Interdata computer and comparing results with those obtained by the SPTCo. The second step involved evaluation of the equations used in the program to determine their accuracy. The only problems experienced were in the PSD calculation. The results of the validation effort are also described in Appendix B.

2.2.2.2 Enhancements. The only modifications made to the Post Processing Program were those associated with the PSD package to enable it to give the correct results. These consisted of removing the mean from the signal before any PSD calculation, calculating the area under the PSD curve, removing an erroneous factor of two, and printing the gravity root-mean-square (g rms) level on the plot.

The Post Processing Program from Phase I provided plots of up to a maximum of 20 seconds in duration. A need was identified in connection with the automatic location detector (ALD) problem (see Section 3.3.2) to provide time history plots of greater than 20 seconds. This capability was implemented by writing a new program which takes the Phase I tapes and produces a reformatted tape compatible with the Wyle library of analysis routines. These routines provide the capability to produce a time history plot for one channel at a time for any duration.

SECTION 3 - DATA EVALUATION

3.1 INTRODUCTION

The data evaluation task first determined the quantity and scope of test data provided by Phase I. The trucks, the carbody types, and track conditions were identified. Secondly, the evaluation determined which measurements taken during Phase I provided useful and accurate representations of the quantity measured. For example, did the vertical accelerometers on the carbody give an accurate representation of car bounce; did the pins on which the strain gages were mounted in the adapter give an accurate representation of the lateral load at the wheel/rail interface, etc.? If the measured data did give a valid quantification of the desired parameter, they are considered acceptable for the model validation and specification of performance indices.

Thirdly, the completeness of the Phase I measurements in providing the required data was evaluated. It is not the purpose of this evaluation to judge if the data will perform the actual model validation or specification of performance indices. This determination will be made part of the analytical and engineering task areas.

The original plan for this report called for an appendix which would catalog all reduced data. However, at the completion of this task, the volume of the reduced data would have resulted in an appendix of several thousand pages. No useful purpose would have been served by publishing a report of this size. However, header sheets describing the test conditions for each run which was reduced are contained in Appendix C. All the data has been cataloged and stored at Wyle in a manner which permits ready access.

3.2 DATA SORTING ANALYSIS

The data sorting routine was used to assess the number of test runs made during the Type I truck testing conducted during the TDOP Phase I test. The parameters used during this sort sequence were car type, truck type, percent load, wheel profile, and track type. The first sort is shown in Table 3-1 and shows the number of runs by car, truck and wheel type. Note that a test run in this discussion includes a number of different speeds and thus may encompass several entries in the data sorting catalog.

Table 3-1 shows that the preponderance of test runs was made with a refrigerator car on ASF 70-ton ride control trucks with new wheels. This emphasis made the data more difficult to use because the refrigerator car is not considered a typical freight car; its uneven weight distribution and very high empty weight tends to bias the data and give misleading answers. The empty weight of the 70-ton capacity refrigerator car is 89,600 pounds compared with 61,200 pounds for the empty 70-ton box car. This is approximately a 46% greater empty weight. The A-end of the empty refrigerator car weighs 49,300 pounds compared to 40,200 pounds on the B-end. This is approximately a 10% difference in the weights of the two ends. Because of these two factors, most of the analysis described in this report was accomplished using test data for the other carbody types shown.

Table 3-1. Number of Test Runs by Body, Truck and Wheel Type

By car type:	Refrigerator Car	234	(86%)
	70-ton Box	9	(3%)
	100-ton Box	12	(4.5%)
	89-ft. Flat	10	(3.5%)
	100-ton Hopper	8	(3%)
	Total Test Runs:	273	
By truck type:	ASF 70-ton Ride Control	225	(82%)
	ASF 100-ton Ride Control	6	(2%)
	Barber 70-ton	18	(7%)
	Barber 100-ton	14	(5%)
	ASF 70-ton Low Level	10	(4%)
	Total Test Runs:	273	
By wheel type:	1/20 (new)	195	(72%)
	1/40 (new)	11	(4%)
	Cylindrical	34	(12%)
	Half Worn	5	(2%)
	Worn	28	(10%)
	Total Test Runs:	273	

While the test data acquired on the test runs using the refrigerator car are considered valid, with the exceptions noted for the other data (see Section 3.3), there is a concern that using the test data from the refrigerator car may tend to skew the analytical results. As previously noted, the car's uneven weight distribution and the high empty weight can give analytical results which will not be typical for other freight cars. For this reason, Wyle decided not to include the refrigerator car in this analysis of the Phase I data. However, the data acquired from these tests are of good quality and can be used in the analytical and engineering effort should it be required.

A more detailed breakdown by track type was conducted as shown in Table 3-2 for the refrigerator car and Table 3-3 for the other four carbody types. Again, this shows the heavy emphasis on the refrigerator car tests. On the other carbody types, only one test run was conducted for each track type. This makes any assessment of repeatability difficult.

The test data sorting information is summarized in Tables 3-4 through 3-8 which show a matrix of test combinations with a dot noting those which were tested during Phase I. Each table refers to one kind of track condition and shows the tests run by the SPTCo according to carbody type, loading condition, truck type, and wheel type and condition.

Table 3-2. Number of Runs of 70-ton Mechanical Refrigerator Car

	CURVED 25, 35 MPH	Hi-Speed Jointed 30, 40, 50, 60, 70, 79 MPH	Hi-Speed CWR 30, 40, 50, 60, 70, 79 MPH	Med-Speed Jointed	Shimmed
ASF 70-ton Refrigerator Car Trucks					
Empty, 1/20 (new) wheels	10	29	28	23	
Empty, 1/40 (new) wheels	1	1	1	2	1
Empty, cylindrical	3	4	3	2	3
Empty, half worn		1	2	2	
Empty, worn	1	4	4	4	
Half Full, 1/20 (new) wheels	1	2	2	2	
Fully loaded, 1/20 (new) wheels	11	16	16	14	
Fully loaded, 1/40 (new) wheels	1	1	1	1	1
Fully loaded, cylindrical	3	3	3	3	3
	1	4	4	4	
Barber 70-ton trucks					
Empty, 1/20 (new) wheels	1	1	1	1	
Fully loaded, 1/20 (new) wheels	1	1	1	2	

Table 3-3. Number of Runs by Car Configuration (All Car Body Types Except Mechanical Refrigerator)

	CURVED 25, 35 MPH	Hi-Speed Jointed 30, 40, 50, 60, 70, 79 MPH	Hi-Speed CWR 30, 40, 50, 60, 70, 79 MPH	Med.-Speed Jointed	Shimmed
100-ton box, Barber trucks, new wheels, empty	1	1	1	1	
100-ton box, Barber trucks, new wheels, loaded	1	1	1	1	
100-ton box, Barber trucks, cylindrical, empty				1	1
100-ton box, Barber trucks, cylindrical, loaded				1	1
70-ton box, Barber trucks, new wheels, empty	1	1	1	1	
70-ton box, Barber trucks, new wheels, loaded	2	1	1	1	
89' flat, ASF trucks, new wheels, empty	1	1	1	1	
89' flat, ASF trucks, new wheels, loaded	1	1	1	1	
89' flat, ASF trucks, worn wheels, empty		1	1		
100-ton hopper, Barber truck, new wheels, empty	1				
100-ton hopper, Barber truck, new wheels, loaded	1				
100-ton hopper, ASF truck, new wheels, empty		1	1	1	
100-ton hopper, ASF truck, new wheels, loaded		1	1	1	

Table 3-4. Curved Track Test Matrix

TDOP PHASE I TEST MATRIX

● TEST DATA AVAILABLE
☐ NO TEST CONDUCTED
☒ NON-APPLICABLE TEST CONDITION

TRACK TYPE : CURVED

CAR BODY	TRUCK / LOAD COND.	ASF 70-TON RIDE CONTROL					ASF 100-TON RIDE CONTROL					BARBER 70-TON					BARBER 100-TON					ASF 70-TON LOW LEVEL				
	WHEELS *	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
REFRIGERATOR	EMPTY	●	●	●		●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED	●	●	●		●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
70-TON BOXCAR	EMPTY						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
100-TON BOXCAR	EMPTY	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X
89-FT FLATCAR	EMPTY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				
	HALF FULL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	LOADED	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				
100-TON HOPPERCAR	EMPTY	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X

* A - NEW 1/20 B - NEW 1/40 C - CYLINDRICAL D - HALF WORN E - WORN

Table 3-5. High Speed Jointed Track Test Matrix

TDOP PHASE I TEST MATRIX

TRACK TYPE : HIGH-SPEED JOINTED

Legend: ● TEST DATA AVAILABLE; ☐ NO TEST CONDUCTED; ☒ NON-APPLICABLE TEST CONDITION

CAR BODY	TRUCK	ASF 70-TON RIDE CONTROL					ASF 100-TON RIDE CONTROL					BARBER 70-TON					BARBER 100-TON					ASF 70-TON LOW LEVEL				
	LOAD COND.	WHEELS * A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
REFRIGERATOR	EMPTY	●	●	●	●	●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL	●					X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED	●	●	●		●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
70-TON BOXCAR	EMPTY						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
100-TON BOXCAR	EMPTY	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X
89-FT FLATCAR	EMPTY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				●
	HALF FULL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	LOADED	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				
100-TON HOPPERCAR	EMPTY	X	X	X	X	X	●					X	X	X	X	X						X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X	●					X	X	X	X	X						X	X	X	X	X

* A - NEW 1/20 B - NEW 1/40 C - CYLINDRICAL D - HALF WORN E - WORN

Table 3-6. High Speed CWR Track Test Matrix

TDOP PHASE I TEST MATRIX

TRACK TYPE : HIGH-SPEED CWR

Legend: ● TEST DATA AVAILABLE; ☐ NO TEST CONDUCTED; ☒ NON-APPLICABLE TEST CONDITION

CAR BODY	TRUCK	ASF 70-TON RIDE CONTROL					ASF 100-TON RIDE CONTROL					BARBER 70-TON					BARBER 100-TON					ASF 70-TON LOW LEVEL				
	LOAD COND.	WHEELS * A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
REFRIGERATOR	EMPTY	●	●	●	●	●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL	●					X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED	●	●	●		●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
70-TON BOXCAR	EMPTY						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
100-TON BOXCAR	EMPTY	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X						X	X	X	X	X	●					X	X	X	X	X
89-FT FLATCAR	EMPTY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				●
	HALF FULL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	LOADED	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				
100-TON HOPPERCAR	EMPTY	X	X	X	X	X	●					X	X	X	X	X						X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X	●					X	X	X	X	X						X	X	X	X	X

* A - NEW 1/20 B - NEW 1/40 C - CYLINDRICAL D - HALF WORN E - WORN

Table 3-7. Medium-Speed Jointed Track Test Matrix

TDOP PHASE I TEST MATRIX

TRACK TYPE : MEDIUM-SPEED JOINTED

Legend: ● TEST DATA AVAILABLE; ☐ NO TEST CONDUCTED; ☒ NON-APPLICABLE TEST CONDITION

CAR BODY	TRUCK	ASF 70-TON RIDE CONTROL					ASF 100-TON RIDE CONTROL					BARBER 70-TON					BARBER 100-TON					ASF 70-TON LOW LEVEL				
	LOAD COND.	WHEELS *																								
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
REFRIGERATOR	EMPTY	●	●	●	●	●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL	●					X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED	●	●	●		●	X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
70-TON BOXCAR	EMPTY						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
	HALF FULL						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED						X	X	X	X	X	●					X	X	X	X	X	X	X	X	X	X
100-TON BOXCAR	EMPTY	X	X	X	X	X						X	X	X	X	X	●		●			X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X						X	X	X	X	X	●		●			X	X	X	X	X
89-FT FLATCAR	EMPTY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				
	HALF FULL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	LOADED	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	●				
100-TON HOPPERCAR	EMPTY	X	X	X	X	X	●					X	X	X	X	X						X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X	●					X	X	X	X	X						X	X	X	X	X

* A - NEW 1/20 B - NEW 1/40 C - CYLINDRICAL D - HALF WORN E - WORN

Table 3-8. Shimmed Track Test Matrix

TDOP PHASE I TEST MATRIX

TRACK TYPE : SHIMMED

Legend: ● TEST DATA AVAILABLE; ☐ NO TEST CONDUCTED; ☒ NON-APPLICABLE TEST CONDITION

CAR BODY	TRUCK	ASF 70-TON RIDE CONTROL					ASF 100-TON RIDE CONTROL					BARBER 70 TON					BARBER 100 TON					ASF 70-TON LOW LEVEL				
	LOAD COND.	WHEELS *																								
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
REFRIGERATOR	EMPTY		●	●			X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	HALF FULL						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED		●	●			X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
70-TON BOXCAR	EMPTY						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	HALF FULL						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
	LOADED						X	X	X	X	X						X	X	X	X	X	X	X	X	X	X
100-TON BOXCAR	EMPTY	X	X	X	X	X						X	X	X	X	X			●			X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X						X	X	X	X	X			●			X	X	X	X	X
89-FT FLATCAR	EMPTY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	HALF FULL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	LOADED	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
100-TON HOPPERCAR	EMPTY	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	HALF FULL	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X
	LOADED	X	X	X	X	X						X	X	X	X	X						X	X	X	X	X

* A - NEW 1/20 B - NEW 1/40 C - CYLINDRICAL D - HALF WORN E - WORN

3.2.1 Test Matrix Omissions

While it is not claimed that the test matrix need to be completely filled in for the purposes of Phase II analysis, the following omissions are considered most significant:

a. No curving tests were run on 100-ton box cars and hopper cars with the ASF ride control truck. Since there are significant differences between the ASF and Barber trucks related to warp stiffness, a curving test should have been run with both trucks.

b. No curving tests were run with worn wheels on any car except the refrigerator car. Wheel wear has some effect on curving performance.

c. The curving test runs and the conditions omitted have no significance because of the improper measurement of lateral wheel loads.

d. No high-speed CWR tests were run with the 100-ton box car on an ASF truck, or the 100-ton hopper car with the Barber truck.

e. No tangent track tests were run with worn wheels except for the refrigerator car, and the empty 89-foot flat car. Thus, data on lateral stability appear to be inadequate.

f. There were no medium-speed jointed rail test runs on a 100-ton box car on an ASF truck, or the 100-ton hopper car with the Barber truck. Since this type of track exercises the friction snubber, this omission makes it difficult to compare the two types of snubbing systems.

g. Shimmed track tests with other than cylindrical wheels were run only with the refrigerator car. This abbreviated test does not reflect the variety of devices present in the suspension system. An evaluation of the shimmed track tests thus requires more detailed scrutiny.

3.2.2 Ride Quality Data

In terms of ride quality, the only deficiency of the Phase I data is the lack of correlation between measured track geometry and response data as discussed in Section 3.3. This should not significantly hinder the ride quality analysis as shown in the pilot program. When test data become available during the Phase II testing of Type I trucks, it can be used to further validate the results from the Phase I data.

3.2.3 Impact on TDOP Phase II

The Phase I data omissions discussed in Sections 3.2.1 and 3.2.2 will necessitate additional testing during Phase II of the Type I truck. The extent of this testing will be directly related to the amount of data required by the model validation and engineering task requirements. After each of these tasks has been reviewed, a preliminary matrix of tests for the Type I truck will be prepared. These matrices will be reviewed and consolidated by the testing group and an integrated test plan developed to perform the desired tests.

3.3 MEASUREMENT EVALUATION

3.3.1 Lateral Wheel Load Measurements

In Phase I, lateral wheel loads due to creep and flange forces were improperly measured. During Phase I, lateral forces between the side frame pedestals and the roller bearing adapters were measured by strain gages on pins that were located on both sides of the roller bearing adapters.

As generally known, lateral forces applied to truck components are of two types:

a. The first consists of external and inertial forces, such as those applied by angled couplers, centrifugal forces during curve negotiation at other than balance speed, and forces due to periodic car body accelerations having lateral components. These lateral forces are eventually reacted between the wheel and rail, and the load path passes through the bearing adapter and side frame, which justifies the method of measurement used in Phase I.

b. The second comprises creep and flange forces which are partly reacted between wheels of the same wheelset, and partly between wheelsets through the track structure; only the lateral components of the latter can be measured by the adapter pins on which strain gages were mounted. However, during curving with flange contact, a large part of the lateral load on the outer leading wheel is due to the creep forces on the forward wheelset; the load path is confined to the wheels and axle, thus it bypasses the adapter which transmits only the lateral creep forces from the rear wheelset (if it is not in flange contact). Therefore, lateral wheel loads measured by this method during curving at equilibrium speed are bound to be low, and the contribution of dynamic loads as coupler forces cannot be separated from those of the creep forces.

The lack of lateral wheel/rail force measurements particularly affects the curving data where the most important parameter is the lateral force at the wheel/rail interface, since this directly relates to the amount of rail and wheel wear which occurs during curving. Thus, in Phase II these missing curving tests may have to be run (hopper car with ASF truck, trucks with worn wheels), and some Phase I tests repeated to provide an adequate matrix of data to characterize the Type I truck in curve negotiation. The data available from Phase I are not sufficient for validation of any meaningful curve negotiation model since the primary quantity to be derived from the model would be the lateral force. Also, the data do not provide sufficient information to quantify any performance indices relative to curving. However, some preliminary work can be done in the area of truck motions related to degree of curvature and superelevation.

The measurement of the lateral wheel/rail force is also of importance in lateral stability (hunting), since again it relates directly to wear. The importance of lateral force/vertical force (L/V) ratio is related primarily to dynamic regimes involving contact between the throat or flange of the wheel and the rail, either when the lateral force is high (such as occurs during hunting), or when the vertical force is low (which occurs during harmonic roll). Both situations produce a high L/V ratio and thus pose the risk of derailment.

There is no question that a better method of measuring lateral wheel loads would have been preferable than that used in Phase I. However, in the case of hunting, some very useful information may be extracted from the Phase I data by combining the vertical forces measured by the strain gages mounted in the bearing adapters with the known wheel contours, the inertial properties of the wheels and side frames, and the vertical accelerations of the pedestals to calculate the lateral loads on the wheels with a level of accuracy acceptable for engineering purposes.

Also, much model validation may be done from the Phase I data in relating critical speed to the model parameters. As several test configurations are being instrumented for curving tests, it is planned that hunting tests will be run at the same time as the curving tests with the same test configurations. Thus, some additional lateral force data will also be provided for the lateral stability regime.

3.3.2 Track Geometry Correlation

A problem area discussed in the TDOP Phase I Data Evaluation and Analysis Plan (Reference 1) is the difficulty of correlating response measurements with the track geometry location. The automatic location detector (ALD) used by the SPTCo. during Phase I picked up numerous extraneous signals which made determining the exact location of the test car difficult. The technique used during Phase I for determining the exact milepost location of the test car, so that the car response data may be correlated to the track geometry measurements, was to place metal targets at known locations along the track. A detector on the train sensed the targets as the train passed over them. In theory, this method would then identify the exact location of the train; the milepost location between targets could then be obtained by integration of train speed. In practice, however, this technique did not work because the target detector also picked up extraneous signals in addition to detecting the targets.

This problem is illustrated in Figure 3-1 from test run 030201TWA001 which shows the ALD channel (solid line) versus milepost. The milepost location was obtained by integrating train speed from the known starting milepost. A positive voltage signal indicates the ALD located a target. The dashed lines in Figure 3-1 were overlayed on the plot of ALD at those known locations at which the metal targets were placed. If the dashed lines (target location) were close to agreement with the ALD detection signal (solid lines), then it would be a relatively simple matter to put some small adjustments into the speed integration to get the dashed and solid lines to match exactly. However, the discrepancy between the two signals is so great that it is not possible to determine what corrections should be made to line them up.

The problem of knowing the exact track input which corresponds to a given response is particularly critical in time-domain analysis. In this type of analysis, the model must be given exactly the same input as the test car if the response data are to be compared.

During the Phase I Data Evaluation and Analysis, the ALD signals from several runs spanning the duration of Phase I testing were plotted. Figure 3-2 is a plot of one of the first tests; the ALD system, was not operating satisfactorily at that time. After the first few test runs, the ALD signal was improved. The remaining plots show a great degree of similarity. Figures 3-3 through 3-5 all show almost exactly the same pattern. This probably indicates that some fixed object (such as a switch or crossing) causes the ALD to register and the problem that now remains is to sort these occurrences out from the actual ALD target detections. One approach to correlating the signals could be to try to relate each ALD signal with a known object and then to determine the actual ALD signals. If the ALD signal can be made to line up with the car response data, then it will be possible to use Phase I data in conjunction with the time-domain models.

At present, no additional effort is planned in attempting to correlate the track geometry and milepost location because it is not critical to perform an analysis of the data. If in the future, the track geometry/response data correlation is required, additional effort may be expended on the task.

The problem associated with the ALD was caused by the detector sensing any metal object including the desired target. This problem will be corrected during Phase II by using an alternate technique. The two techniques currently under evaluation consist of either a tuned coil or magnet buried in the ballast and an appropriate detection circuit attached to the instrumentation car. This approach should eliminate the problem of spurious signals.

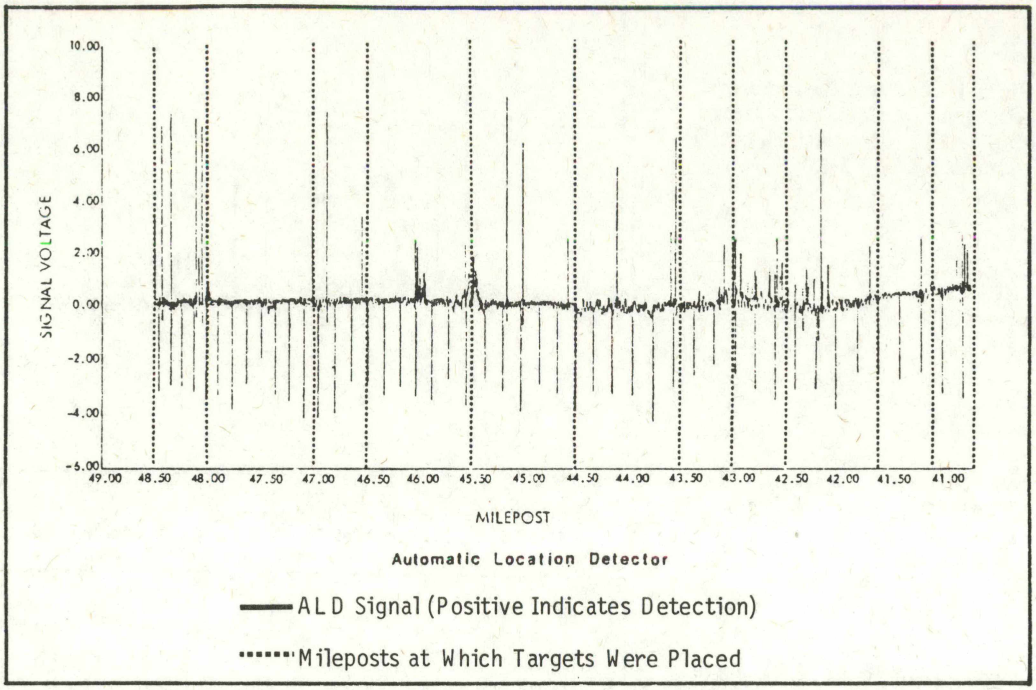


Figure 3-1. ALD Location Plot

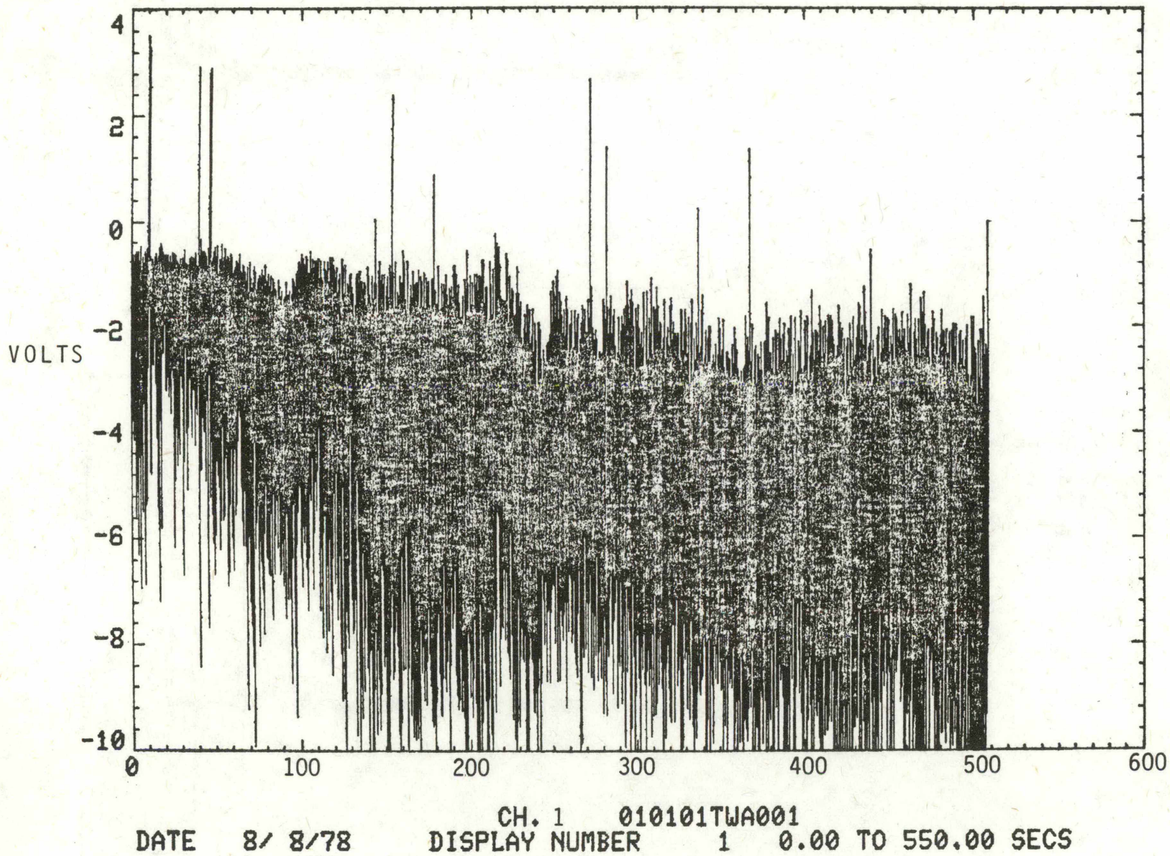


Figure 3-2. Plot of One of the First Tests, ALD System Inoperative

Figure 3-3. Plots from First Test Series, ALD System Operative (Note similarity of patterns in Figures 3-4 and 3-5.)

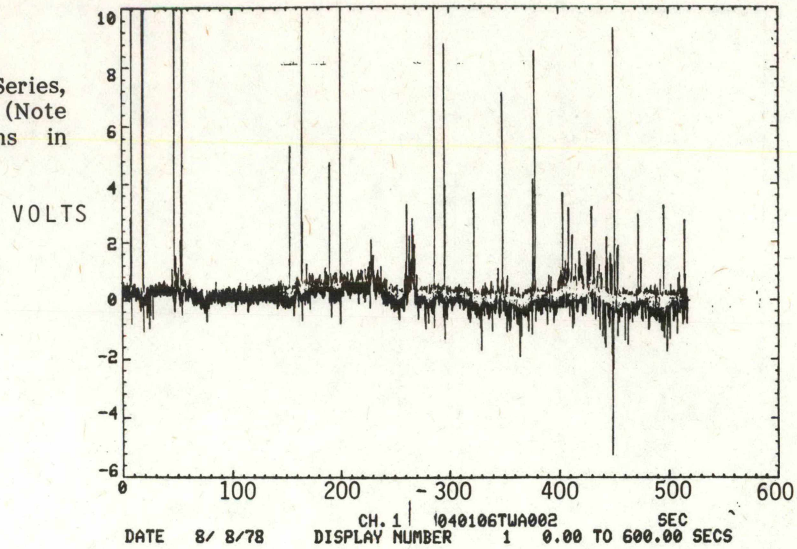


Figure 3-4. Plots from First Test Series, ALD System Operative (Note similarity of patterns in Figures 3-3 and 3-5.)

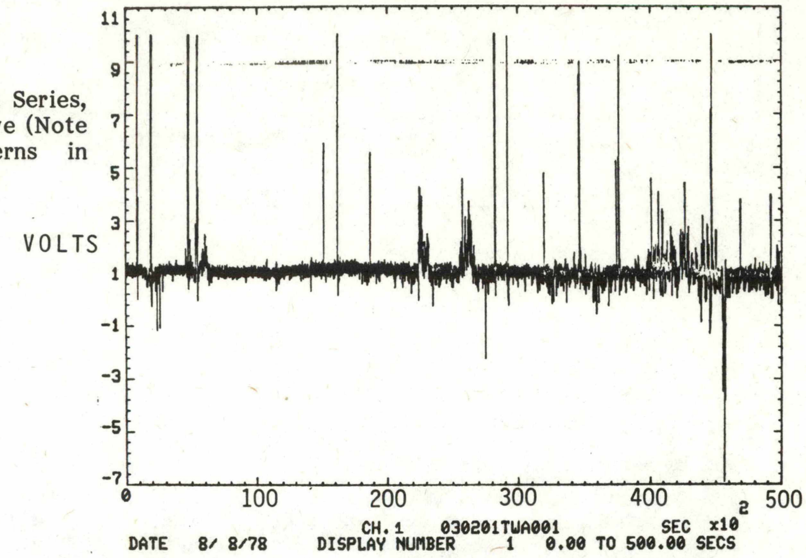
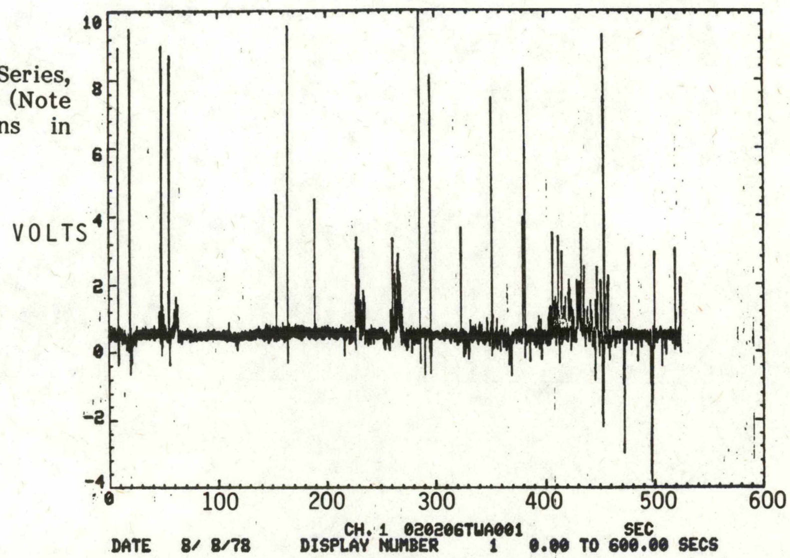


Figure 3-5. Plots from First Test Series, ALD System Operative (Note similarity of patterns in Figures 3-3 and 3-4.)



3.3.3 Quality of Measurements

The measured data from Phase I proved to be of acceptable quality in the evaluation of performance parameters, with the exception of the inability of the ALD measurement to correlate to track location, the improper technique used to measure lateral wheel loads, and the lack of friction snubber force measurements.

3.3.3.1 Measurements Made Incorrectly. During TDOP Phase I, a strain gage mounted on a pin was used in the adapter to measure lateral force. The data acquired were accurate measurements of the lateral force at the adapter but cannot be correlated to lateral forces at the wheel/rail interface as previously discussed in Section 3.3.1. Thus, the data cannot be used in calculating L/V values. Several alternate techniques for measuring wheel lateral force are being investigated during Phase II and the most promising approach will be adopted.

The signal conditioning during the Phase I testing used a calibration technique which introduces a small error in the data depending upon the length of the cable from the signal conditioner to the transducer and the bridge resistance of the transducer. Ectron signal conditioning was used which has the excitation voltage sensing at the signal conditioner. Thus, the voltage drop it senses includes not only the transducer bridge, but also the line drop in the cable. For a 300-foot cable, this results in a two to five percent error in the calibration voltage, depending upon the transducer type. This amount of error does not significantly affect the data; however, it does introduce a slight bias on the low side to all data acquired during Phase I. Without knowing the length of cable used for each transducer on each run, it is not possible to correct for it and thus the bias is left in the data. During TDOP Phase II, the voltage sensing is being moved to the junction box on the test car. This decreases the maximum cable length to about 30 feet and the resultant error will be of a lesser order of magnitude.

3.3.3.2 Measurements Not Made. The lack of friction snubber force measurements was identified early in Phase I and plans were developed independently by Wyle Laboratories to design a device which will measure these forces. However, development of the device was not completed until the end of Phase I, and no over-the-road data were ever acquired. Hence, a test program using the Friction Snubber Force Measurement System (FSFMS) was conducted in Phase II to obtain the desired characterization of friction snubber forces (reference 5).

3.4 APPLICABILITY OF DATA TO PHASE II

3.4.1 Analysis

The Phase I data were evaluated to determine their applicability to the validation of analytical tools. This evaluation consisted of a listing, by regime, of the planned models for the Phase II analysis work, the test data requirements for each model, and the quality of the Phase I data. This survey is contained in Tables 3-9 through 3-12 for the four performance regimes planned for Phase II.

Significant data are available in the lateral stability regime for model validation as shown in Table 3-9. The primary shortcomings were the lack of wheel/rail force measurements and the lack of tests on wheels with worn profiles other than for the refrigerator car. The data required for the ride quality regime are generally complete. A few minor exceptions shown in Table 3-10 were some carbody and truck motion measurements. However, these deficiencies are not considered critical.

In the curve negotiation regime, the two most critical measurements (lateral force and angle of attack) were not measured (see Table 3-11). This makes extraction of meaningful information from the other data difficult. The data available for the trackability regime is shown in Table 3-12. There are sufficient data for the linear models; however, the nonlinear models lack adequate measurement of wheel/rail forces and of correlatable track geometry.

As previously discussed in paragraph 3.2, even when adequate data channels were acquired during Phase I, the matrix of configurations which were tested is often inadequate. Thus, additional data may be required on other carbodies and wheel profiles.

3.4.2 Engineering

The Phase I data were evaluated to determine their applicability to the specification of performance indices. This evaluation is shown in Table 3-13 which lists the performance index for each of the four regimes and the necessary test data required to specify the performance index. The right-hand column in Table 3-13 defines the availability of test data from Phase I for the given performance index. The data available in the ride quality and lateral stability are sufficiently complete and adequate. Limited data are available to handle portions of the trackability regime. In the curve negotiation regime, the measurements are completely lacking.

Table 3-9. Lateral Stability Validation Requirements

Type of Model	Test Data Requirements	Phase I Data Availability	Quality of Data
Engineering Models	• Kinematic frequency versus speed	Measured	Satisfactory
Simple Kinematic Models	• Car body rigid body modes	Five rigid body modes available.	Longitudinal mode not measured
Eigenvalue Analysis Models	• Hunting at some critical speed for various wheel profiles. (Linearized models of the car/truck combination stability will be compared to the predicted critical speeds.)	Hunting tests with various profiles limited to refrigerator car.	Satisfactory
Nonlinear time-domain models	• Truck kinematics vs. speed	Measured	Satisfactory
	• Car body dynamics vs. speed	Measured	Satisfactory
	• Time histories of the vertical and lateral forces at the wheel/rail interface.	Not Measured	N/A
	• Mode shapes of the car/truck during limit cycle hunting motions for primary (body hunting).	Measured	Limited to rigid body modes

Table 3-10. Ride Quality Validation Requirements

Type of Model	Test Data Requirements	Phase I Data Availability	Quality of Data
Linear Frequency Domain Models	• Nominal truck and car body vibration response data while running over tangent track on both continuous welded and jointed rail.	Measured	Satisfactory
	• Duration of recorded data should be at least 100 seconds at a given constant speed in order to obtain sufficient statistical confidence in the measured PSD and transmissabilities.	Runs at most speeds averaged 60 sec. of data	Satisfactory
	• Track geometry shall be correlatable over the test section to within $\pm$100 feet. (Since the work will be in the frequency domain only, the position accuracy is not as stringent as it is for the trackability regime.)	Track geometry measured.	Correlation difficult. Providing estimate of accuracy also difficult, $\pm$100 ft. may not be possible.
	• Required truck response measurements shall include:		
	- Vertical and lateral accelerations at each of the four bearing adapters.	Vertical accel. each end of both axles, lateral accel. on each axle.	Satisfactory
	- Two vertical acceleration measurements sufficient to determine vertical and roll motion.	Not measured (displacement data can be used to derive roll motion).	N/A
	- Lateral acceleration measurement	Measured	Satisfactory
	• Car body		
	- Vertical and lateral	Measured	Satisfactory
	- Center A end and B end	Measured	Satisfactory
	- Both corners A and B end top and bottom	Not Measured (measurement is required to locate center of roll)	N/A
	- Lateral and vertical at car body center	Not Measured (required for flexible car bodies).	N/A

Table 3-11. Curve Negotiation Validation Requirements

Type of Model	Test Data Requirements	Phase I Data Availability	Quality of Data
Simple Engineering Models	Required data should provide the set up and wheel/rail forces during curving.	Not Measured	N/A
Kinematic Models	Measurements to include:		
	• Truck to car body yaw	Measured	Satisfactory
	• Truck tram angle	Measured	Satisfactory
	• Angle of attack at each wheelset	Not Measured (critical deficiency)	N/A
	• Wheel/rail forces, particularly during flanging	Not Measured (critical deficiency	N/A
Steady-State Curving Models*	• Wheel/rail lateral force	Not Measured	N/A
	• Wheel/rail lateral displacement	Not Measured	N/A
Dynamic Curving Models	Data during curve entry and exit in addition to the above measurements should include time history responses of:		
	• Car body dynamics in the form of acceleration measurements sufficient to determine car body roll, roll center, car body yaw, sway and pitch.	Measured	Satisfactory
	• Accelerometers on the truck sufficient to determine the truck component motions for:		
	- Truck bolster - Side frame - Wheelsets	Lateral only measured Measured Measured	Satisfactory

*Data acquired during the steady-state portion of the curve. (Filtering or averaging of the data will be required to extract the steady-state forces and positions.)

Table 3-12. Trackability Validation Requirements

Type of Model	Test Data Requirements	Phase I Data Availability	Quality of Data
Engineering Models	Data required should be sufficient to extract truck/car resonances and mode shapes	Data available for rigid body resonances and modes.	Satisfactory
Linear Spring Mass Models	Small vehicle responses (which minimize the nonlinear reactions) over both regular and perturbed track.	Tests run on both regular and perturbed track.	Satisfactory
	Harmonic roll critical speed on perturbed track (linear models will be used as a means of estimating the critical speed before the more costly nonlinear simulations are run).	Harmonic roll available on shimmed track	Available only in two mph increments
Nonlinear Time-Domain Models	In addition to the above data, validation of the nonlinear time-domain models will require:		
	• Wheel/rail vertical and lateral forces.	Not Measured	N/A
	• Measurements prior to and during wheel lift off.	Not Measured	N/A
	• Extreme center plate dynamics during - Harmonic Roll - Bounce	Measured	Satisfactory
	• Truck component relative motions during perturbed track tests. (Required for validation of the large signal responses.)	Measured	Satisfactory
	• All measured car truck responses shall be correlatable with the track geometry within ± 6 inches.	Track geometry measured	Track geometry and response data cannot be correlated.

Table 3-13. Test Data Required for Engineering Analysis

Performance Regime	Performance Index	Necessary Test Data	Availability of Test Data from Phase I
Lateral Stability	• Critical Speed	Lateral Acceleration of one or more representative points on the truck measured as a function of speed and such variables as: wheel/rail contour, rail surface conditions, car bodies (truck spacing, stiffness), and lading (empty, full, ...)	Lateral acceleration available on axle and car body. Data are taken at constant speeds of 40, 50, 60, 70, and 79 mph. Varying speeds exist between these constant speeds. Variables such as wheel profile, rail surface conditions, car body parameters, and lading is noted in the test header. No rail contour data are available. Tests were not run for a full matrix of variables.
	• Magnitude of Lateral Acceleration	Magnitude of lateral acceleration at or near the hunting speed, for the same set of variables mentioned above.	Lateral acceleration data on axles.
Curve Negotiation	• Lateral force on leading outer wheel per 1000 pounds axle load per degree of curve under, at and over balance speed.	Lateral force on leading outer wheel as a function of lading, degree of curvature at, under, and above balance speed.	No measurements made of lateral force.
	• Wear Index	Angle of attack as a function of lading, and degree of curvature under, at, and above balance speed.	No measurements made of angle of attack.
	• Derailment Potential	L/V ratio as a function of speed, lading, wheel/rail contour.	No measurements made from which to calculate L/V.
Trackability	• Wheel Unloading Index	Simultaneous loads under the wheels as a function of track twist in degrees as a function of lading.	No measurements made of vertical load at wheel. Vertical loads measured at bearing adapters, but cannot be correlated to track geometry.
	• Max. Roll Amplitude	Max. roll amplitude as a function of excitation (amp. and frequency) for different lading conditions.	Roll angle of car body/truck bolster and roll acceleration of car body were measured, however, they cannot be correlated to track geometry.
	• Rate of Energy Dissipation	Level of friction force, displacement (i.e., spring travel), rate of increase of friction level with spring compression, as a function of lading.	No friction snubber force measurements were made.
	• Derailment Potential	L/V ratio as a function of speed, lading, wheel/rail contour.	No measurements made from which to calculate L/V.
Ride Quality	• Transmissibility	Acceleration response, referred to one or more specific locations on the car body, as a function of speed, track quality and lading within the normal operating range of speeds.	Vertical acceleration made on car body. Speed, trackability, and lading were varied, however, a complete matrix of these variables was not tested.

SECTION 4 - PILOT PROGRAM

Phase I data will be used as part of the analytical and engineering tasks in model validation and quantification of performance indices. To gain familiarity and confidence in the data and to demonstrate a technique for data analysis, a small pilot program was conducted during the Phase I data evaluation and analysis. This pilot study, which was intended to show how the data are to be used, was limited to one specific performance regime, ride quality.

A number of test runs were analyzed to investigate ride quality. The pilot program used rms acceleration versus speed plots to provide a visual display of the data, and regression analysis to quantify the relative magnitude of the various parameters considered during Phase I testing. A large number of variables were tested during Phase I (e.g., loading condition, carbody, rail type, wheel profiles, and truck type). This analysis attempted to address which variables had significant impact on the ride quality level.

4.1 DATA ANALYSIS METHODOLOGY

For the purposes of this analysis, the rms versus speed analysis capability from the Phase I Post Processing Program was used. The Post Processing Program was given a specific series of track sections and asked to calculate the rms acceleration value. In each case, two test zones were chosen at the speed rating indicated in Table 4-1. The purpose of dividing the speed zone in half was to give some indication of the amount of spread which could occur in the results from one track section to the next.

The test runs to be considered were selected using the TDOP data sorting routine. The intent is to analyze as wide a variation of parameters as available from the Phase I testing. After much discussion, Wyle decided to concentrate on carbodies other than the 70-ton refrigerator car because there was considerable criticism of Phase I for using this test car so extensively. This limited our analysis to a workable number of runs without severely compromising the number of variables to be considered. Later in the program, the refrigerator car was included in some of the regression runs to help separate the effects of wheel profile from those of carbody types. This had little effect on the results, however.

4.2 METHODOLOGY FOR SUMMARY REGRESSIONS

Wyle used a descriptive regression to summarize the results of the investigation of the TDOP Phase I data with respect to ride quality. A descriptive regression quantifies the relative effects of a number of variables. For the purposes of this study, ride quality was quantified by rms acceleration (i.e., acceleration was taken as the ride quality performance index). This was then considered a function of a number of variables such as train speed, load conditions, carbody, etc. The slope of the acceleration with respect to the train speed was estimated for speeds in the range of 30 to 79 mph. Other influences such as car loaded, car empty, jointed rail, CWR rail, etc., were represented by dummy variables, e.g., a variable whose value is either 0 or 1 depending upon which category the measurement fell into. The average change in rms level for each category was estimated. The results of this analysis are indicated in Table 4-2.

It was discovered early in the analysis that the response data measured on the axles was different from the response data measured on the carbody. This results from the fact that the axle measurements are made on the unsprung portion of the truck while the remainder of the measurements were made on the truck component and carbody which are separated from the rail input by the truck suspension system. As the rail inputs feed directly into the axle-mounted accelerometers, it is reasonable that they would have much higher accelerations than the accelerometers mounted elsewhere. It was decided to separate the axle measurements into one regression analysis and the remainder of the measurements into their own regression analysis. An analysis of variance was run with the early regressions. This analysis showed that the cross effects between the axle and the other parameters were larger than most of the primary effects which strongly suggested that this was an appropriate division to make.

It is important to note that a descriptive regression does not attempt a curve fit of the data. Individual curves could be fitted using the least-square techniques, each curve having a separate equation. Individually fitted curves would provide a more accurate representation of the data. However, information regarding the relative size of the effects would be obscured. Since the purpose of this analysis is to determine the relative importance of the various parameters, we have chosen to describe the data with the regression, obtaining an indication of the average size of each effect. Similarly, the equations used do not force the acceleration to go through zero when the train speed is zero. The equations should be regarded as linear approximations to the "real" function in the range of the train speed variable considered (e.g., 30 to 79 mph).

The following example clarifies the use of the data in Table 4-2. Suppose it were desired to estimate the rms acceleration level in the lateral direction at the A-end roof of a fully loaded 70-ton box car traveling at a train speed of 40 mph on CWR with new wheels and a Barber truck. The total rms acceleration is calculated by adding the rms acceleration contribution of each of the variables, as shown in the following equation:

> g rms acceleration = g rms/mph x speed + g rms (acceleration location) + g rms (loading) + g rms (carbody) + g rms (rail type) + g rms (acceleration direction) + g rms (wheel profile) + g rms (truck type) + constant rms acceleration = .00172 g rms/mph x 40 mph + .0609 g rms + 0.0 + .0189 g rms - .0186 g rms - .0185 g rms + 0.0 + 0.0 - .0188 g rms = .0927 g rms.

This predicted value of .0927 g rms based upon the regression analysis may be compared to measured test values taken on the above configuration of .0728 g rms and .0702 g rms. The error here is typical, 68% of the data may be expected to have an error within $\pm$ .0329 g rms.

However, the importance of the analysis is not so much a quantitative prediction of the g rms levels, but a qualitative prediction of how the variables affect the measured g rms level. While it is an accepted practice in the railroad industry to report ride quality as an rms level, this is not necessarily appropriate for all modes of deterioration. Rms is an average level. It may be that certain types of lading can accept an rms level of around 1 g rms, but suffer damage if some peak accelerations is exceeded (e.g., 10 g peak).

Table 4-1. Track Sections

Speed-mph	Mile Post Numbers Jointed	CWR
30	48.5 - 48.25	42.5 - 42.75
30	48.25 - 48.0	42.75 - 43.0
40	47.75 - 47.5	43.25 - 43.625
40	47.5 - 47.25	43.625 - 44.0
50	46.75 - 46.38	44.5 - 45.0
60	46.38 - 46.0	45.0 - 45.5
60	45.0 - 44.75	46.94 - 47.37
70	43.75 - 48.38	42.5 - 43.38
70	43.38 - 43.0	43.38 - 44.25
79	41.6 - 41.15	45.5 - 46.44
79	41.15 - 40.7	46.44 - 47.37

Note: Samples per zone: 3000 to 9300

Table 4-2. Summary Regressions

	Measurement Not On Axle	Measurement On Axle
Slope of Speed	.00172 ± .00008 g rms/mph	.00376 ± .00025 g rms/mph
Accelerometer Location		
Axle	N/A	Nominal
Truck Side Frame	.0884 ± .0062 g rms	N/A
Roof of Car	.0609 ± .0064 g rms	N/A
Car Center	.0029 ± .0061 *g rms	N/A
Center Sill	Nominal	N/A
Empty as Opposed to Loaded:	.0287 ± .0085 g rms	No Data
Car Body		
70-ton box	.0189 ± .0045 g rms	.0242 ± .0107 g rms
89-ft flat	-.0004 ± .0079 *g rms	No Data
100-ton Hopper	-.0115 ± .0105 *g rms	No Data
100-ton box	Nominal	Nominal
CWR as Opposed to Jointed:	-.0186 ± .0041 g rms	-.0496 ± .0107 g rms
Lateral as Opp. to Vertical Accel:	-.0185 ± .0062 g rms	-.1561 ± .0107 g rms
Worn as Opp. to New Whels:	.0131 ± .0105 *g rms	No Data
ASF as Opp. to Barber Truck:	-.0013 ± .0105 *g rms	No Data
Constant:	-0.188 ± .0066 g rms	.1109 ± .0164 g rms
R^2**	72.6%	82.8%
Std. Error	.0329 g rms	.0545 g rms
Number of Samples	338	104

*Cannot be distinguished from nominal at 5% significance level.

**Ratio of explained variance to total variance.

To demonstrate what information may be extracted from Table 4-2, consider the following: as the speed goes up, so does the g rms acceleration level; the empty car has a rougher ride than the loaded; the 100-ton hopper gives the best ride; wheel profile and truck type have too small an effect to be distinguished from zero, based upon these data.

4.3 PRIMARY INFLUENCES ON RIDE QUALITY

The primary influence on ride quality, as measured by rms acceleration readings from the TDOP Phase I data, was train speed. As the train speed increased, the g rms level increased. Another major difference in the measurements was the significantly higher g rms levels measured on the truck axle, as opposed to measurements made elsewhere on the truck and carbody. Train speed was expected to play a major role in determining ride quality. As the train moves faster, there is more kinetic energy available to excite the car. Thus, one expects the accelerometer readings to increase roughly as the square of the train speed. Similarly, the distinction between measurements on the car and measurements on the truck were expected because the truck is designed to cushion the car from the rail. The unsprung mass at the wheelsets should respond more violently than the much heavier carbody. The difference in level between axle and car measurements merely indicates that the truck is operating as expected.

The effect of train speed on ride quality is clearly visible throughout the data. This is shown in Figures 4-1 through 4-4 where rms acceleration is plotted against train speed. An rms value is plotted for the first and second half of each speed zone. The true data are represented by the symbols. The lines connecting the symbols are for visual clarity only, and are not intended to represent any information at other speeds. Figures 4-1 and 4-2 show vertical and lateral acceleration as a function of train speed for travel over jointed rail and Figures 4-3 and 4-4 are for travel over continuous welded rail (CWR). The expected trend may be seen in each of the figures where the rms level tends to increase with speed. In particular the effect becomes more pronounced as the measurement is taken at locations closer to the rail. However, it tends to be obscured by a resonance phenomenon (e.g., buildup due to rocking at 50 mph in the 100-ton box car). This caused problems in estimating a squared relationship in the summary regression. A least square curve fit of the data in Figure 4-1 will tend to bow down because of the resonance. Without the resonance points in the data, the curve would tend to bow up, which is the desired effect. Thus, it was decided to use a straight line approximation instead of a least squared curve fit.

The cushioning effect of the truck is also illustrated in Figures 4-1 to 4-4. In Figure 4-1, the highest rms accelerations are shown to occur on the axle, with lower levels occurring on the side frame, and the lowest levels on the carbody itself. This is also indicated in the summary regression from Table 4-2. As mentioned earlier, data measured on the axle were separated from data measured elsewhere to obtain a more accurate representation. The marked differences between coefficients in these regressions indicate the size of distinction in the data, e.g., a slope of .00376 g rms/mph for data measured on the axle compared with .00172 g rms/mph for the rest of the data.

The ratio between vertical and lateral accelerations on the axle is quite different from that on the carbody. The lateral acceleration is a smaller proportion of the vertical acceleration on the axle than on the carbody. The distinction between CWR and jointed rail is larger numerically but is roughly the same proportion in the axle data as in the other data, and the distinction in carbodies is even smaller in the axle data than in the other data. Finally, the accelerometer on the side frame of the truck reads higher (.0884 g rms as shown in Table 4-2) than any of the other locations considered in the carbody regression. This suggests the extent to which the truck succeeds in cushioning the car.

Considering the car alone, the major influences on rms ride quality seem to be speed, and the distinction between empty and loaded cars. The level of the measured rms is dependent on the location of the transducer. The highest rms levels were measured on the axle with significantly lower levels being measured elsewhere on the truck and the carbody.

Empty and loaded rms acceleration plots in Figures 4-5 and 4-6 for both jointed and CWR show the empty car to have consistently higher levels. There seems to be little difference between the average level on jointed versus CWR. Accelerations on the roof averaged 0.0609 g rms higher than accelerations at the A-end center sill or at the center of the carbody on the floor of the car. No significant distinction was found between the center sill and the center of the car indicating that the carbody was fairly rigid, e.g., flexible modes of the car do not play a major role in these data. On the average, empty cars rode rougher than fully loaded cars by 0.0287 g rms. This was expected when the mass of the system decreases (i.e., the car is empty) the acceleration must increase if the force causing the motion does not decrease in proportion. Another interpretation is that the friction snubbers are sized for fully loaded cars; hence, they over-damp the empty cars.

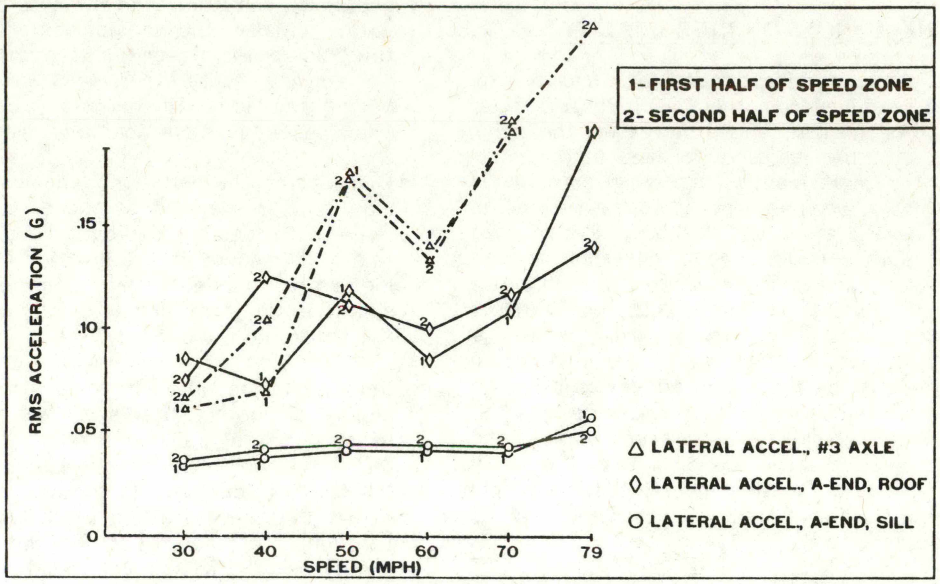


Figure 4-1. Fully Loaded, 100-Ton Box Car with Barber Trucks Over Jointed Tracks (Vertical Acceleration, R-1 Axle)

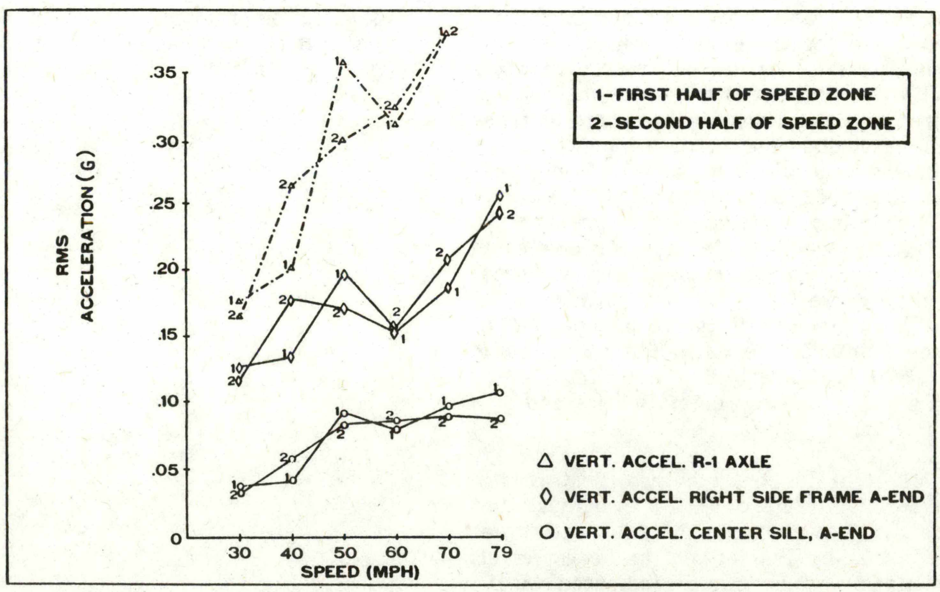


Figure 4-2. Fully Loaded, 100-Ton Box Car with Barber Trucks Over Jointed Track (Lateral Acceleration, #3 Axle)

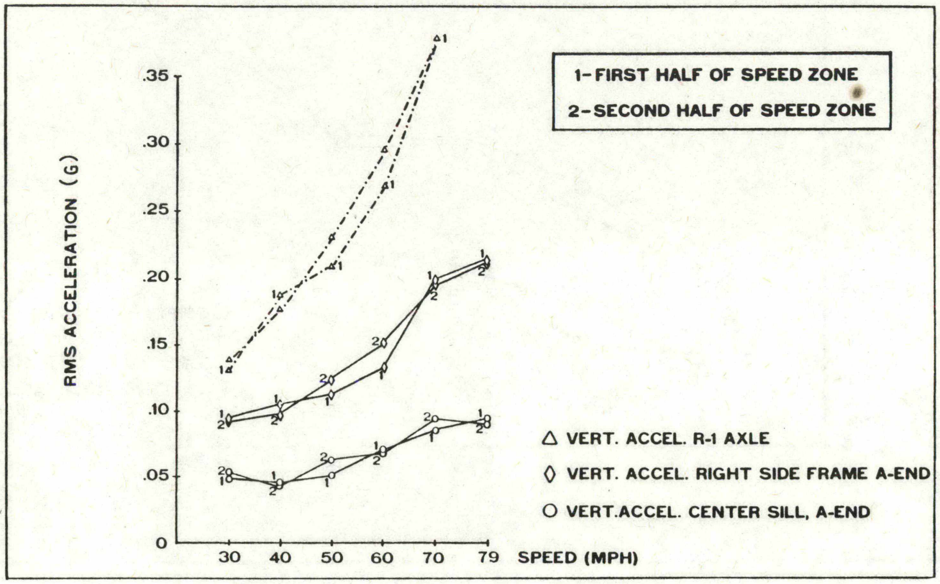


Figure 4-3. Fully Loaded, 100-Ton Box Car with Barber Trucks Over CWR Track (Vertical Acceleration, R-1 Axle)

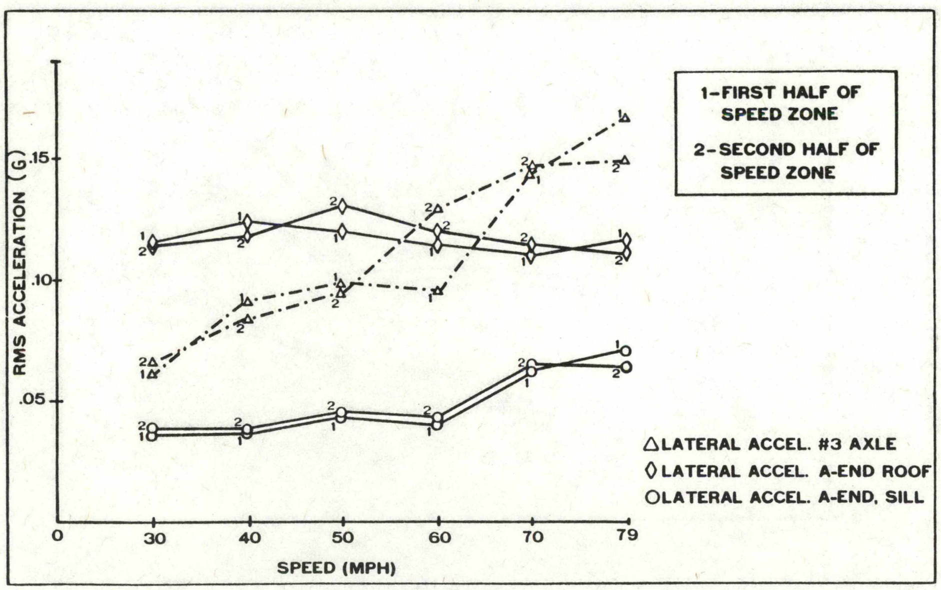


Figure 4-4. Fully Loaded, 100-Ton Box Car with Barber Trucks Over CWR Track (Lateral Acceleration, #3 Axle)

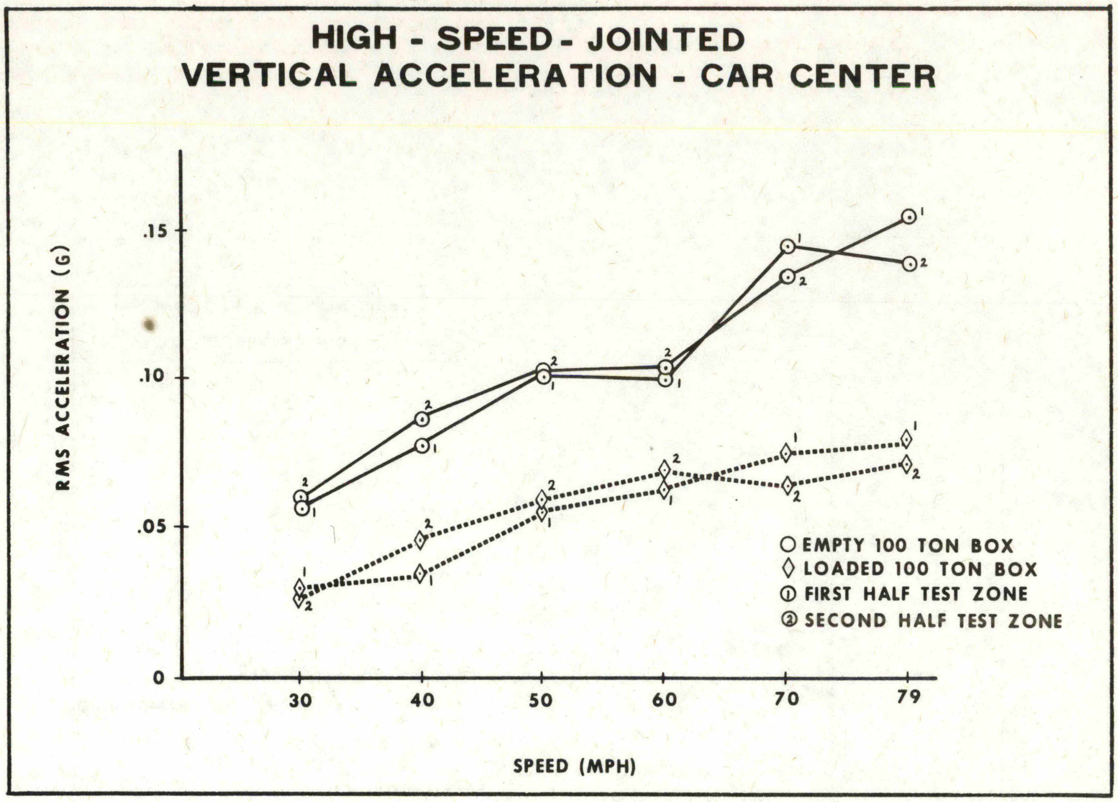


Figure 4-5. Empty vs Loaded rms Acceleration Plots (Jointed Track)

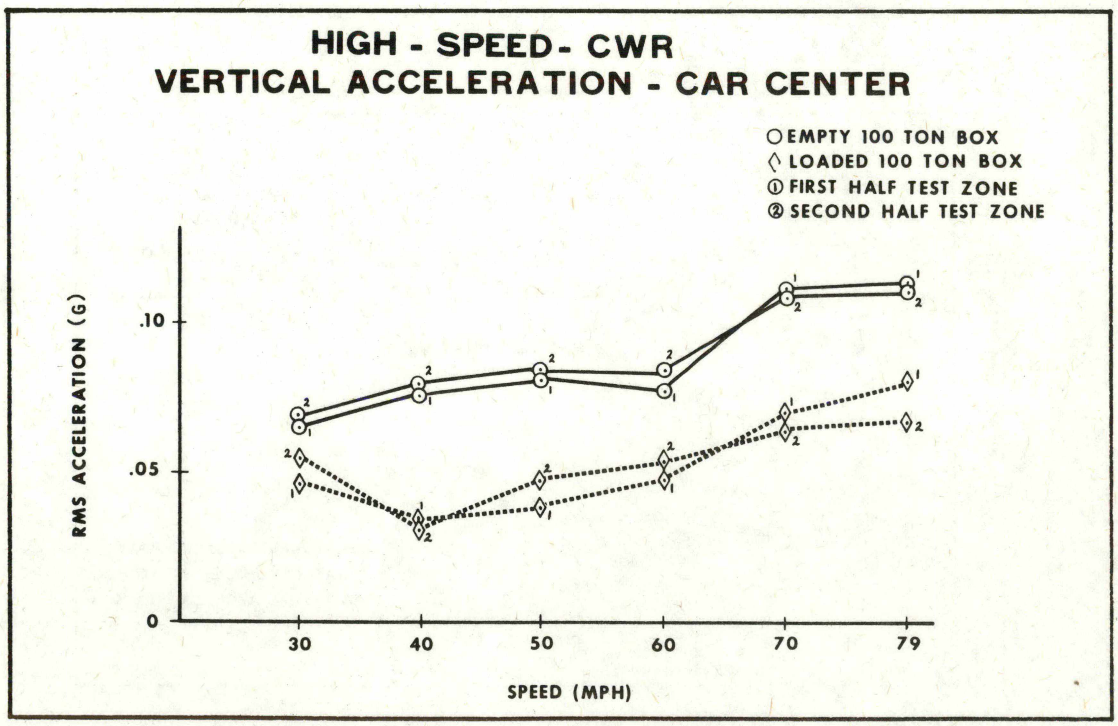


Figure 4-6. Empty vs Loaded rms Acceleration Plots (CWR Track)

4.4 SECONDARY INFLUENCES ON RIDE QUALITY

Most of the distinctions (carbody type, wheel profile, rail type) investigated had only a secondary influence on the ride quality. These are shown in Figures 4-7 through 4-9 which compare plots of rms acceleration for new vs. worn wheels, Barber vs. ASF truck, and 100-ton vs. 70-ton box cars. In each of these cases, the difference in rms acceleration is less than in previous plots. In particular, the type of carbody, the type of rail, and the accelerometer orientation all exhibited about .019 g rms effects. Regardless of the truck manufacturer, new wheels did not exhibit any influence that could be distinguished from zero at 5% confidence level.

Four carbodies were investigated: the 100-ton box car, the 70-ton box car, the 89-ft. flat car and the 100-ton hopper car. Only the 70-ton box car was significantly different from the other cars (averaging .0189 g rms more than the others). Interpreting the results for the 89-ft. flat car is compounded by the lack of data taken on trucks similar to the ones used in the other tests. Only the ASF low-level truck was run under the 89-ft. flat car, and this truck was not run under any other carbody. Data for the 89-ft. flat car in a loaded condition have not been considered to date (where flexible behavior might be expected). The similarity of the results for the different carbodies tends to suggest the cars were behaving rigidly.

The rail type (i.e., CWR or jointed rail) showed the expected effect: the CWR averaged .0186 g rms less than the jointed rail. This supports the hypothesis that the joints are one of the causes of the excitation.

Similarly, laterally oriented accelerometers averaged .0185 g rms less than vertically oriented accelerometers. This suggests that most of the motion excited from the rail is vertical (at least in the ride quality regime).

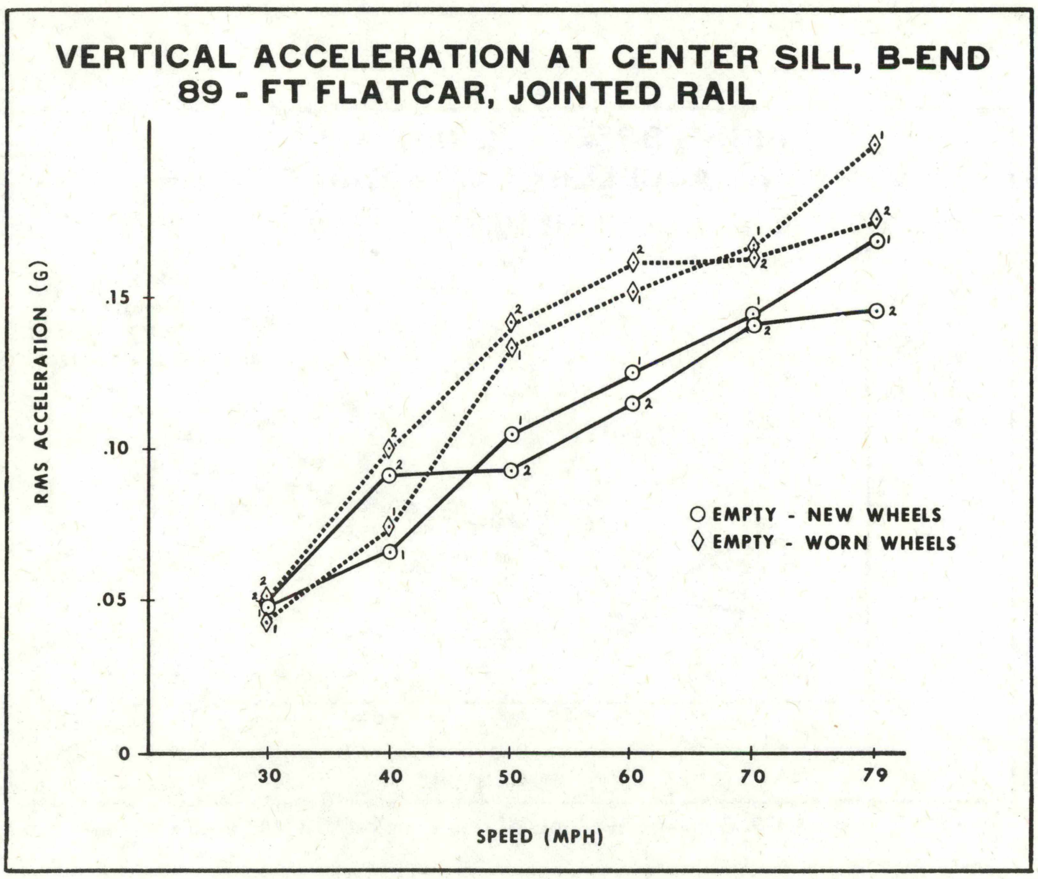


Figure 4-7. Comparative Plots of rms Acceleration (New vs Worn Wheels)

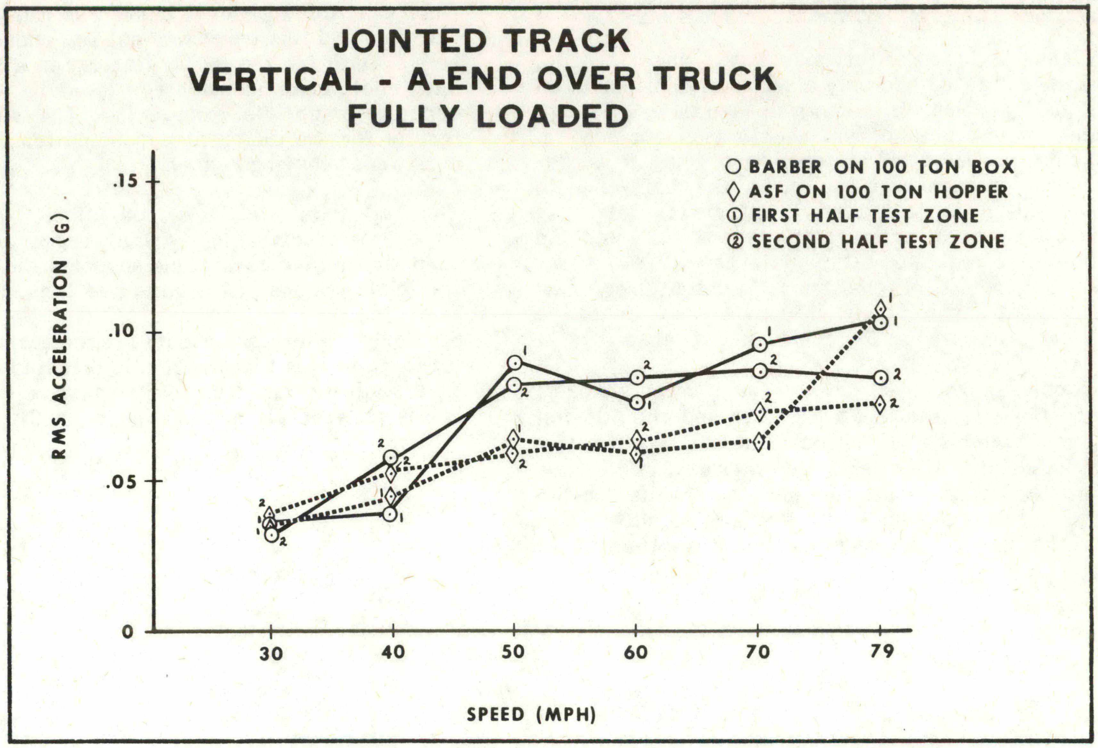


Figure 4-8. Comparative Plots of rms Acceleration (Barber vs ASF Truck)

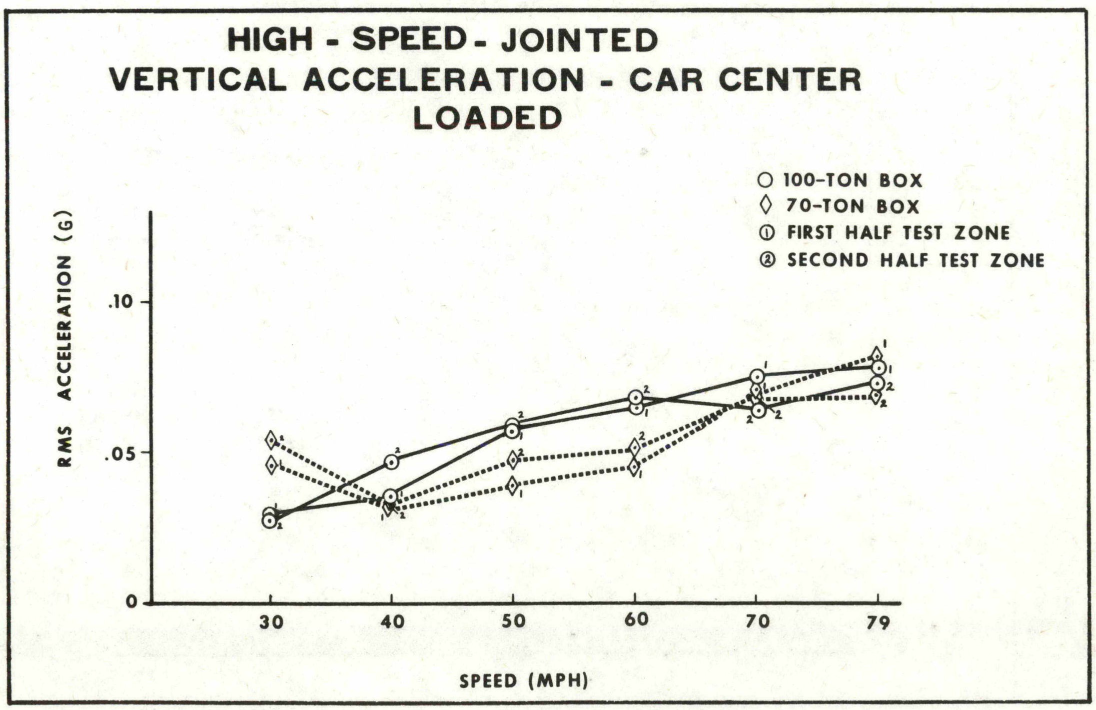


Figure 4-9. Comparative Plots of rms Acceleration (100 ton vs 70 ton)

4.5 RELATION TO ECONOMICS

Based upon the size of the measured effects (level of g rms), it seems doubtful that the levels and distinctions being reported here are large enough to have a major effect on lading damage (i.e., differences in the .02 g rms range probably are too small to play a major role in lading damage). The one exception is speed. From this analysis, it appears that operational considerations (train handling, humping, etc.) and sensitivity of the lading probably play a larger role in lading damage than the items discussed in Table 4-2. This is not to say that resonant phenomenon like harmonic roll or instabilities like hunting are not important in determining lading damage; however, for this pilot program, the concentration was on ride quality, rather than on these other performance regimes.

Another interpretation of these results is that the performance index selected (acceleration) does not measure the source of the problem. For example, the peak acceleration levels might be quite different from the rms. To assess this, the preceding analysis was rerun with peak acceleration and average absolute amplitude as performance indices rather than rms. Naturally, this changed the numbers obtained. However, the ratio between the numbers did not change significantly. Essentially, rms accleration was as good a prediction of the size of differences between carbodies (for example) as peak acceleration. One exception was observed during the course of this analysis, but it was traced back to an accelerometer with insufficient sensitivity.

SECTION 5 - CONCLUSIONS

After acquiring the Phase I data, necessary changes were made to the SPTCo software (the Post Processing Program) to make it operational on the Interdata computer. The task of modifying the Post Processing Program to run on the Interdata computer proved to be quite difficult. The sorting routine that Wyle developed made it possible to obtain an accurate idea of what was available in terms of test configurations from the Phase I data. While there were many gaps in the available data as noted in this report, it was still possible to derive useful information from the data. This was demonstrated by the pilot program for the ride quality regime.

5.1 APPLICABILITY OF DATA TO PHASE II

The applicability of the Phase I test data to Phase II was evaluated from three points of view. The first was completeness of the test matrix. To determine this Wyle developed the TDOP data sorting routine; the results of this routine are shown in the series of matrix tables in Section 3.2. This analysis showed that the preponderance of the testing was conducted on the 70-ton refrigerator car with the ASF truck and new wheels. Wyle believes that the refrigerator car was not typical of most cars in service and that using these data from these measurements in any extensive manner might tend to bias the results of the analytical work. Thus, these data were not used in the pilot program and may be used only sparingly in the analytical and engineering tasks. Furthermore, some significant configuration combinations are missing from the test matrix.

The second manner in which the Phase I data were evaluated was from the point of measurement accuracy; how well did a given combination or set of channels reproduce the desired measurement parameter? In all areas except two, the quality of measurements was acceptable. These two unacceptable areas were in measurement of lateral wheel force at the wheel/rail interface and in the detection of ALD targets. In particular, the lack of lateral forces at the wheel/rail interface is of critical importance to TDOP Phase II. Without it, there is little that may be done in validating curving models or assessing the curve negotiation performance indices on the Type I truck. Also, these missing data will have a secondary influence on the analysis of lateral stability because the time-domain models cannot be validated. The lack of ALD target detection (not being able to correlate ALD targets with response) limits the usefulness of the data for analysis of the trackability regime. The lack of ALD correlation hampers the ride quality evaluation to a lesser degree.

The third point of view was in the Phase I data's adequacy to perform the Type I truck model validation and specification of performance indices. In paragraph 3.4, the required data vs. available data from Phase I is shown. The data in the regimes of ride quality and lateral stability appear to be adequate for the Phase II effort. In the regimes of curve negotiation and trackability, the lack of adequate measurements of wheel/rail forces makes it more difficult to extract meaningful information from the data.

In summary, the one critical flaw with the Phase I data was the lack of lateral force measurements at the wheel/rail interface. This deficiency will require correction via additional testing of the Type I truck during TDOP Phase II.

5.2 USAGE OF DATA DURING PHASE II

This evaluation and analysis study was conducted to determine the applicability of data acquired during Phase I to the analytical and engineering effort being conducted on TDOP Phase II. The results of this applicability were discussed in detail in Section 3. The usage of data will be addressed in the analytical and engineering task efforts.

The data analysis routines in the Post Processing Program were reviewed and corrected so that correctly analyzed data will be obtained from the data analysis.

5.3 RECOMMENDATIONS FOR FUTURE TESTING

The critical lack in Phase I data of lateral and vertical force measurements at the wheel/rail interface must be corrected in TDOP Phase II. The primary goal of testing on the Type I truck during Phase II will be to measure these forces. The first step will be to conduct an extensive study of available techniques for measuring these forces and to prepare recommendations for a technique to be used during Phase II. The second step will be to develop the transducers necessary to provide the required measurements. To measure the angle of attack of the wheels relative to the rail, we plan to use displacement transducers which will measure the relative position of the wheel and rail.

To provide a positive correlation between track geometry and carbody response data, an ALD system will be developed which will explicitly determine the test car location relative to the track. The ALD systems will consist of a buried magnet or tuned coil and a detector system on the instrumentation car which will sense the field of the buried target as the car passes over it. By placing the ALD system prior to starting Phase II testing and by using the same ALD system on all testing (track geometry, friction snubber, Type I truck, and Type II truck), it will be possible to correlate all measured data taken during Phase II of TDOP.

To complete the test matrices, test carbodies will be tested, using new and worn wheel profiles. The primary concentration of Phase II testing on Type I trucks will be in the curve negotiation performance regime. However, tests will be conducted as well for the trackability and lateral stability performance regimes. Data for the ride quality may then be extracted from the other three regimes. These tests should be run on vehicle configurations already prepared and instrumented for the curve negotiation tests and should not require any additional preparation time. The purposes for running the additional trackability and lateral stability tests are:

a. To complete information not previously obtained during Phase I (i.e., 100-ton hopper car on the ASF truck and a hopper car with worn wheels).

b. To provide some degree of continuity between Phase I and Phase II data (by repeating one or two Phase I runs, a comparison may then be made between data from the two programs).

c. To provide a final validation check of models (i.e., models validated using the Phase I data may be used to predict Phase II test results).

d. To provide test data over yard track to assess the ability of the truck to traverse severe changes in track configuration.

REFERENCES

1. FRA Report No. FRA/ORD-78/34, "TDOP Phase I Data Evaluation and Analysis Plan," September 1978.

2. FRA Report No. FRA/ORD-78/12.XIII, Volume 12, "TDOP Post Processing Program Manual," February 1978.

3. Wyle document TDOP TR-OX, "User Operator's Manual for Post Processing Program Operation on Interdata 8/32," May 1978.

4. FRA Report No. FRA/ORD-78/12, "Freight Car Truck Design Optimization, Volume I, Executive Summary; Volume VI, Critique of Phase I - Test Series Results Reports; Volumes VII through X, Results Report for Test Series 1 through 5," February 1978.

5. FRA Report No. FRA/ORD-79/24, "Friction Snubber Force Measurement System Field Test Report," August 1979.

APPENDIX A

INVENTORY OF PHASE I DATA

01/26/78

```
      ..DESCRIPTION          LOCATION
------------------------------------------

BOX 1 TAPES 301-303,310-319
TAPE 0301 INPUT 11             BOX 1
          010104TEM001
          010104TEH001
          010104TSR001

TAPE 0302  INPUT 10            BOX 1
          010104TSM001
          010104TWA001

TAPE 0303 INPUT 4              BOX 1
          010104CNE001
          010104CN0001

TAPE 0310 INPUT 3              BOX 1
          010103TEM001
          010103TEH002
          010103TEH003
          010103TWA003

TAPE 0311 INPUT 1              BOX 1
          010103TSM000
          010103TSR002

TAPE 0312  INPUT 1             BOX 1
          010101TWA001
          010101TWA002
          010101TEM001

TAPE 0313  INPUT 1             BOX 1
          010101TEH001
          010101TSM001
          010101TSR001

TAPE 0314  INPUT 7             BOX 1
          010101TSM002
          010101TWA000
          010101TEM002

TAPE 0315 INPUT 8              BOX 1
          010102TSM001
          010102TSR001

TAPE 0316                      BOX 1
          010102TWA001
          010102TEM001
          010102TEH001

TAPE 0317 INPUT 9              BOX 1
          010102TEH002
          010105TSM001
          010105TSR001

TAPE 0318 INPUT 4              BOX 1
          010105TWA001
          010105TEM001
          010105TEH001

TAPE 0319 INPUT 3              BOX 1
          010106TEM001
          010106TEH001
          010106TWA001

0320      INPUT 13             BOX 2
          010106TSR001
          010106TSM001

0321      INPUT 22             BOX 2
          010106CNE001
          010106CN0001
          010105CNE001

0322      INPUT 21             BOX 2
          010105CN0001
          010106CNE001
          010102CX0001

0323      INPUT 20             BOX 2
          010101CNE001
          010101CN0001
          010103CNE003
          010101CN0002

0324      INPUT 8              BOX 2
          010302TEM001
          010302TEH001
          010302TWA001

TAPE 325                       BOX 2
          010303TSM001
          010302TSR001

0326      INPUT 7              BOX 2
```

```
      ..DESCRIPTION          LOCATION
------------------------------------------

          010302TWA001
          010301TEH001
          010301TSM001

0327      INPUT 2              BOX 2
          010301TSR001
          010301TWA001

0328      INPUT 23             BOX 2
          010202CNE001
          010202CN0001
          010201CNE001

0329      INPUT 8              BOX 2
          010201CN0001
          010203CNE001
          010203CN0001

TAPE 330   INPUT 24            BOX 2
          010204CNE001
          010204CN0001
          010206CNE001

TAPE 331  INPUT 25             BOX 2
          010206CN0001
          010205CNE001
          010205CN0001

0332      INPUT 9              BOX 2
          010202TEM001
          010202TEA001
          010202TSR001
          010202TSM001

0333      INPUT 22             BOX 2
          010202TWA001
          010205TWA001
          010204TWA001

0334      INPUT 10             BOX 2
          010204TEM001
          010204TEH001
          010204TSR001
          010204TSM001

0335      INPUT 21             BOX 2
          010203TWA001
          010203TEM001
          010203TEH001
          010203TSR001

0336      INPUT 2              BOX 2
          010203TSM001
          010201TSR001
          010201TSM001

TAPE 0337 INPUT 20             BOX 3
          010201TWA001
          010201TEM001
          010201TEH001

TAPE 0338 INPUT 12             BOX 3
          010206TEM001
          010206TEH001
          010206TSM001
          010206TSR001

TAPE 0339 INPUT 23             BOX 3
          010206TWA001
          010206TEM001
          010206TEH001

TAPE 0340 INPUT 11             BOX 3
          010205TSM001
          010205TSR001

TAPE 0341 INPUT 1              BOX 3
          020102TWA001
          020102TEM001
          020102TSM001

TAPE 0342 INPUT 9              BOX 3
          020102TSR001
          020102TEH001
          020101TEM001

TAPE 0343 INPUT 1              BOX 3
          020101TSM001
          020101TSR001

TAPE 0344 INPUT 11             BOX 3
          020101TWA001

TAPE 0345                      BOX 3
```

```
      ..DESCRIPTION          LOCATION
------------------------------------------

          020205TWA001
          020205TEM001
          020205TEH001

TAPE 0346 INPUT 1              BOX 3
          020205TSM001
          020205TSR001

TAPE 0347 INPUT 1              BOX 3
          020206TEM001
          020206TEH001
          020206TWA001

TAPE 0348 INPUT 10             BOX 3
          020206TSM001
          020206TSR001
          020203TEM001

TAPE 0349  INPUT 11            BOX 3
          020203TEH001
          020203TWA001
          020204TWA001

BOX 4 TAPES 350-361
TAPE 350  INPUT 7              BOX 4
          020204TEM001
          020204TEH001
          020204TSM001
          020204TSR001

TAPE 0351  INPUT 26            BOX 4
          020203TSR001
          020203TSM001
          020203CNE001

TAPE 0352 INPUT 27             BOX 4
          020203CN0001
          020203CNE001
          020203CN0001

TAPE 0353  INPUT 13            BOX 4
          020303CNR001
          020303TEM001
          020303TEH001

TAPE 0354  INPUT 4             BOX 4
          020303TSR001
          020303TSM001
          020303TWA001

TAPE 0355  INPUT 8             BOX 4
          020306TEM001
          020306TEH001

TAPE 0356  INPUT 3             BOX 4
          020306TWA001
          020306TSM001
          020306TSR001

TAPE 0357  INPUT 5             BOX 4
          020304TEM001
          020304TEH001
          020304TWA001

TAPE 358   INPUT 3             BOX 4
          020304TSM001
          020304TSR001

TAPE 0359  INPUT 1             BOX 4
          020305TSM001
          020305TSR001

TAPE 0360  INPUT 1             BOX 4
          020305TEM001
          020305TEH001
          020305TWA001

TAPE 0361  INPUT 5             BOX 4
          020401TSM001
          020401TSR001
          020401TEM001

BOX 5  TAPES 362 TO 372
TAPE 0362  INPUT 1             BOX 5
          020401TEH001
          020401TWA001

TAPE 0363 INPUT 2              BOX 5
          020402TSM001
          020402TSR001

TAPE 0364 INPUT 2              BOX 5
          020402TWA001
          020402TEH001
```

DESCRIPTION	LOCATION
020402TEM001	
TAPE 0365 INPUT 8	BOX 5
020403TEM001	
020403TEH001	
020403TWA001	
TAPE 0366 INPUT 2	BOX 5
020403TSM001	
020403TSR001	
TAPE 0367 INPUT 8	BOX 5
020404TSM001	
020404TSR001	
020404TWA001	
TAPE 0368 INPUT 7	BOX 5
020404TEM001	
020404TEH001	
TAPE 0369 INPUT 9	BOX 5
020405TWA001	
020405TSM001	
020405TSR001	
TAPE 0370 INPUT 16	BOX 5
020405TEM001	
020405TEH001	
TAPE 0371 INPUT2	BOX 5
020406TEM001	
020406TEH001	
020406TSM001	
TAPE 0372 INPUT 2	BOX 5
020406TSR001	
020406TWA001	
BOX 6 TAPES 373-383	
TAPE 0373 INPUT 2	BOX 6
020407TEM001	
020407TEH001	
020407TWA001	
TAPE 0374 INPUT 2	BOX 6
020407TSM001	
020407TSR001	
TAPE 0375 INPUT 6	BOX 6
020408TSM001	
020408TSR001	
TAPE 0376 INPUT 1	BOX 6
020408TEM001	
020408TEH001	
020408TWA001	
TAPE 0377 INPUT 14	BOX 6
030102TWA001	
030102TEM001	
TAPE 0378 INPUT 15	BOX 6
030102TEH001	
TAPE 0379 INPUT 10	BOX 6
030102TSM001	
030102TSR001	
TAPE 0380	BOX 6
030202TSM001	
030202TSR001	
030202TEM001	
TAPE 0381	BOX 6
030202TEH001	
TAPE 0382	BOX 6
030202TWA001	
TAPE 0383 INPUT 1	BOX 6
030202CNE001	
030202CN0001	
BOX 7 TAPES 384-394	
TAPE 0384 INPUT 30	BOX 7
030102CNE001	
030102CNR001	
030102CN0001	
TAPE 0385 INPUT 31	BOX 7
030101CNE001	
030101CN0001	
TAPE 386 INPUT 32	BOX 7
030201CNE001	
030201CNR001	
030201CN0001	
TAPE 387 INPUT 11	BOX 7
030201TSM001	
030201TSR001	
TAPE 388 INPUT 9	BOX 7
030201TEM001	
TAPE 389 INPUT 12	BOX 7
030201TWA001	
030201TEH001	
TAPE 390 INPUT 30	BOX 7
030101TSR001	
030101TSM001	
030101TEM001	
TAPE 391 INPUT 31	BOX 7
030101TEH001	
030101TWA001	
TAPE 0392 INPUT 32	BOX 7
030302TWA001	
030302TEM001	
030302TEH001	
TAPE 0393 INPUT 2	BOX 7
030302TSM001	
030302TSR001	
TAPE 0394 INPUT 33	BOX 7
030501TSM001	
0030501TSR001	
030501TWA001	
TAPE 0395 INPUT 34	BOX 8
030501TEM001	
030501TEH001	
TAPE 0396 INPUT 15	BOX 8
030501CNE001	
030501CN0001	
TAPE 0397 INPUT 1	BOX 8
030302CNE001	
030302CN0001	
TAPE 0398 INPUT 34	BOX 8
030301CNE001	
030301CN0001	
030301CNR001	
TAPE 0399 INPUT 15	BOX 8
050203MOD001	
050203TSM001	
050203TWA001	
TAPE 400 INPUT 20	BOX 8
050203TEA001	
TAPE 401 INPUT 17	BOX 8
050502CNE001	
050502CNR001	
050502CN0001	
TAPE 402 INPUT 2	BOX 8
030301TSM001	
030301TSR001	
TAPE 403 INPUT 30	BOX 8
030301TEM001	
030301TEA001	
030301TWA001	
TAPE 404 INPUT 35	BOX 8
030301CNR001	
030301CN0002	
TAPE 405 INPUT 36	BOX 8
030502CWE002	
030502CW0002	
BOX 9 TAPES 406-416	
TAPE 406 INPUT 14	BOX 9
030502TEM002	
030502TEH001	
030502TSM002	
TAPE 407 INPUT 15	BOX 9
030502TSR002	
030502TWA002	
TAPE 408 INPUT 33	BOX 9
030503TEM001	
030503TEH001	
TAPE 409 INPUT 34	BOX 9
030503TWA001	
TAPE 410 INPUT 33	BOX 9
030401CNE001	
030401CN0001	
030401CNR001	
TAPE 411 INPUT 10	BOX 9
030401TEM001	
030401TEH001	
TAPE 412 INPUT 13	BOX 9
030401TSR001	
030401TSM001	
TAPE 413 INPUT 11	BOX 9
030401TWA001	
TAPE 414 INPUT 2	BOX 9
030402CNE001	
030402CN0001	
TAPE 415 INPUT 12	BOX 9
030402TEM001	
030402TEH001	
TAPE 416 INPUT 13	BOX 9
030402TWA001	
030402TSM001	
030402TSR001	
BOX 10 TAPES 417-427	
TAPE 417 INPUT 6	BOX 10
050204MOD001	
050204TSM001	
050204TWA001	
TAPE 418 INPUT 7	BOX 10
050204TEA001	
TAPE 419 INPUT 8	BOX 10
050204CNE001	
050204CNR001	
050204CN0001	
TAPE 420 INPUT 9	BOX 10
050205CNE001	
050205CNR001	
050205CN0001	
TAPE 421 INPUT 7	BOX 10
050205MOD001	
050205TSM001	
050205TWA001	
TAPE 422 INPUT 9	BOX 10
050205TEA001	
TAPE 423 INPUT 16	BOX 10
050103MOD001	
050103TSM001	
TAPE 424 INPUT 14	BOX 10
040101TEM002	
040101TEH002	
040101TWA003	
TAPE 425 INPUT 20	BOX 10
040102TEM002	
040102TEH002	
040102TWA002	
TAPE 426 INPUT 9	BOX 10
040103TEM002	
040103TEH002	
040103TWA002	
TAPE 427 INPUT 3	BOX 10
040104TEM002	
040104TEH002	
040104TWA002	
428 INPUT 12	BOX 11
040106TEM002	
040106TEH002	
040106TWA002	
429 INPUT 4	BOX 11

	DESCRIPTION	LOCATION
	040105TEM002	
	040105TEH002	
	040105TWA002	
430	INPUT 9	BOX 11
	050103TEA001	
	050103TWA001	
431	INPUT 1	BOX 11
	050103CNE001	
	050103CNO001	
432	INPUT 1	BOX 11
	040201TSM001	
	040201TSR001	
	040201TWA002	
0433	INPUT 8	BOX 11
	040201TEM002	
	040201TEH001	
434	INPUT 21	BOX 11
	040202TWA001	
	040202TEM001	
	040202TEA001	
435	INPUT 2	BOX 11
	040202TSM001	
	040202TSR001	
436	INPUT 8	BOX 11
	040204TWA001	
	040204TEM001	
	040204TSM001	
437	INPUT 4	BOX 11
	040204TSM001	
	040204TSM001	
438	INPUT 3	BOX 11
	040203TSM001	
	040203TSR001	
BOX 12	TAPES 439-449	
TAPE 439	INPUT 17	BOX 12
	040203TWA001	
	040203TEM001	
	040203TEH001	
TAPE 440	INPUT 3	BOX 12
	040302TSM001	
	040302TSR001	
TAPE 441	INPUT 9	BOX 12
	040302TEM001	
	040302TEH001	
	040302TWA001	
TAPE 442	INPUT 7	BOX 12
	040301TWA001	
	040301TSM001	
	040301TSR001	
TAPE 443	INPUT 7	BOX 12
	040301TEM001	
	040301TEH001	
TAPE 444	INPUT 8	BOX 12
	040304TWA001	
	040304TEM001	
	040304TEH001	
TAPE 445		BOX 12
	040304TSM001	
	040304TSR001	
TAPE 446	INPUT 3	BOX 12
	040303TSM001	
	040303TSR001	
TAPE 447	INPUT 22	BOX 12
	040303TEM001	
	040303TEH001	
	040303TWA001	
TAPE 448	INPUT 37	BOX 12
	040401CNE001	
	040401CNO001	
	040402CNE001	
TAPE 449	INPUT 38	BOX 12
	040402CNO001	
	040403CNE001	
	040403CNO001	
BOX 13	TAPES 450-460	
TAPE 450	INPUT 1	BOX 13
	040401TSM001	
	040401TSR001	
	040402TSM001	
TAPE 451		BOX 13
	040402TSR001	
	040403TSM001	
	040403TSR001	
TAPE 452	INPUT 1	BOX 13
	040403TWA001	
	040401TWA001	
	040402TWA001	
TAPE 453	INPUT 2	BOX 13
	040401TEM001	
	040401TEH001	
	040402TEM001	
	040402TEH001	
TAPE 454	INPUT 3	BOX 13
	040403TEM001	
	040403TEH001	
TAPE 455	INPUT 10	BOX 13
	040404CNE001	
	040404CNO001	
TAPE 456	INPUT 15	BOX 13
	040404CNR001	
	040405CNE001	
	040405CNO001	
TAPE 457	INPUT 11	BOX 13
	040406CNE001	
	040406CNO001	
	040406CNR001	
TAPE 458	INPUT 7	BOX 13
	040404TEM001	
	040404TEH001	
	040405TEM001	
	040405TEH001	
TAPE 459	INPUT 7	BOX 13
	040406TEM001	
	040406TEH001	
TAPE 460	INPUT 4	BOX 13
	040406TWA001	
	040404TWA001	
	040405TWA001	
BOX 14	TAPES 461-470	
TAPE 461	INPUT 16	BOX 14
	040404TEH001	
	040404TSM001	
	040404TSR001	
TAPE 462	INPUT 1	BOX 14
	040405TSM001	
	040405TSR001	
TAPE 463	INPUT 2	BOX 14
	040406TSM001	
	040406TSR001	
TAPE 464	INPUT 3	BOX 14
	040501TEM001	
	040501TEH001	
	040501TSM001	
TAPE 465	INPUT 4	BOX 14
	040501TSR001	
	040501TWA001	
TAPE 466		BOX 14
	040501CNE001	
	040501CNR001	
	040501CNO001	
TAPE 467	INPUT 13	BOX 14
	040502CNE001	
	040502CNO001	
TAPE 468	INPUT 16	BOX 14
	040502TEM001	
	040502TEH001	
TAPE 469	INPUT 10	BOX 14
	040502TSM001	
	040502TSR001	
	040502TWA001	
TAPE 470		BOX 14
	050104CNE001	
	050104CNO001	
472	INPUT 7	BOX 15
	050104TWA001	
	050104TEA001	
471	INPUT 5	BOX 15
	050104MOD001	
	050104TSM001	
	050104TWA001	
473	INPUT 10	BOX 15
	050403MOD001	
	050403TSM001	
474	INPUT 12	BOX 15
	050101TEA002	
475	INPUT 11	BOX 15
	050101TWA002	
476	INPUT 10	BOX 15
	050403TWA001	
477	INPUT 14	BOX 15
	050101CNE001	
	050101CNO001	
478	INPUT 15	BOX 15
	050101MOD002	
	050101TSM003	
479	INPUT 13	BOX 15
	050102MOD001	
	050102TSM001	
	050102TWA001	
480	INPUT 14	BOX 15
	050102TEA001	
481	INPUT 1	BOX 15
	050102TSM002	
BOX 16	TAPES 482-492	
TAPE 482	INPUT 15	BOX 16
	050102CNE001	
	050102CNO001	
TAPE 483	INPUT 21	BOX 16
	050201MOD001	
	050201TSM001	
	050201TWA001	
TAPE 484	INPUT 22	BOX 16
	050201TEA001	
TAPE 485	INPUT 16	BOX 16
	050201CNE001	
	050201CNR001	
	050201CNO001	
TAPE 486	INPUT 15	BOX 16
	050403CNE001	
	050403CNR001	
	050403CNO001	
TAPE 487	INPUT 16	BOX 16
	050404CNE001	
	050404CNR001	
	050404CNO001	
TAPE 488	INPUT 11	BOX 16
	050404MOD001	
	050404TSM001	
TAPE 489		BOX 16
	050404TWA001	
	050404TEA001	
TAPE 490		BOX 16
	050405CNR001	
	050405CNE001	
	050405CNO001	
TAPE 491	INPUT 12	BOX 16
	050405MOD001	
	050405TSM001	
TAPE 0492	INPUT 23	BOX 16
	050405TEA001	
	050405TWA001	

DESCRIPTION	LOCATION
BOX 17 TAPES 493-503	
TAPE 0493 INPUT 13	BOX 17
050402MOD001	
050402TSM001	
TAPE 0494 INPUT 10	BOX 17
050402TEA001	
050402TWA001	
TAPE 0495 INPUT 14	BOX 17
050401MOD001	
050401TSM001	
050401TWA001	
TAPE 0496 INPUT 16	BOX 17
050401TEA001	
TAPE 0497 INPUT 5	BOX 17
050305MOD001	
050305TSM001	
TAPE 0498 INPUT 7	BOX 17
050305TEA001	
050305TWA001	
TAPE 0499 INPUT 4	BOX 17
050304MOD001	
050304TSM001	
TAPE 0500 INPUT 9	BOX 17
050304TEA001	
050304TWA001	
TAPE 501 INPUT 24	BOX 17
050301MOD001	
050301TSM001	
050301TWA001	
TAPE 0502 INPUT 25	BOX 17
050301TEA001	
TAPE 0503 INPUT 2	BOX 17
050301CNE001	
050301CN0001	
BOX 18 TAPES 504-511	
TAPE 0504 INPUT 1	BOX 18
050302CNE001	
050302CN0001	
TAPE 0506 INPUT 18	BOX 18
TAPE 0508 INPUT 7	BOX 18
050303TWA001	
050303TEA001	
TAPE 0505 INPUT 9	BOX 18
050302MOD001	
050302TSM001	
050302TWA001	
TAPE 0509 INPUT 1	BOX 18
050303CNE001	
050303CN0001	
TAPE 0510 INPUT 8	BOX 18
050303CNE002	
050303CN0002	
TAPE 511 INPUT 7	BOX 18
050303MOD001	
050303TSM001	
BOX 19 ENSCO TRACK DATA	
INTEGRATED EXCEPTIONS, CURVATURE	BOX 19
AND PSD DATA REDUCTION REPORT	
TEST OBJECTIVE TEST RG-97.2	
PSD DATA REDUCTION	BOX 20
TEST OBJECTIVE RG-97.2	
COMPARE DATA REDUCTION REPORT	BOX 21
TEST OBJECTIVE RG 97.3	
INTEGRATED EXCEPTION REPORT	BOX 21
TEST OBJECTIVE RG 97.3	
TEST OBJECTIVE RG 97.4	
TEST OBJECTIVE RG 97.5	
OUTPUT PAPER JULY 75 TRACK DATA	BOX 21
EBM SUISUN (EASTBOUND)	
WBM SUISUN (WESTBOUND)	
OUTPUT PAPER MAY 75 TRACK DATA	BOX 21
EBM SUISUN (WESTBOUND)	

DESCRIPTION	LOCATION
WBM SUISUN (EASTBOUND)	
SCHELLVILLE BR (EASTBOUND)	
OUTPUT PAPER JULY 75 TRACK DATA	BOX 21
SCHELLVILLE (R.R. WESTBOUND)	
NILES LINE (EASTBOUND	
BOX 22 75 TRACK DATA	
OUTPUT PAPER JULY 75 TRACK DATA	BOX 22
EMB SUISLN(WESTBOUND)	
WBM SUISLN(EASTBOUND)	
SCHELLVILLE BR EASTBOUND	
NILES LINE(WESTBOUND)	
OUTPUT PAPER MAY 75 TRACK DATA	BOX 22
EASTBOUND NILES LINE	
N.B.NILES LINE	
OUTPUT PAPER TRACK GEOMETRY MEASUREMENTS	BOX 22
EBM SUISUN	
WBM SUISUN	
SHELLVILLE BRANCH (R.R.WESTBOUND)	
LOMBARD SHEMMARD TRACK(R.R.WESTBOUND)	
NILES LINE (EASTBOUND)	
OUTPUT PAPER LOAD TWA 40 MPH ZONE	BOX 23
ON DISK	
OUTPUT PAPER WESTBOUND MAINLINE,	BOX 23
SUISUN-BAHAI HIGH SPEED	
OUTPUT PAPER LOAD TWA 50 MPH ZONE	
BOX 24 SERIES 1-1-X	
OUTPUT PAPER	BOX 24
010101TWA002	
010101TWA001	
010101TWA003	
010104TSR001	
010104TSM001	
010105TSM001	
010105TSR001	
010106TSR001	
010106TSM001	
010101TSM001	
010101TSR001	
010102TSM001	
010103TSR001	
010103TSM004	
010103TSR002	
010101TEM001	
010101TEH001	
010102TEM001	
010102TEA001	
010103TEM001	
010103TEH002	
010104TEM001	
010104TEH001	
010105TEM001	
010105TEH001	
010106TEM001	
010106TEH001	
010104TWA001	
010105TWA001	
010106TWA001	
010101TWA001	
010102TWA001	
010103TWA003	
010104CNE001	
010106CNE001	
010105CNE001	
010102CNE001	
010101CNE001	
010103CNE003	
010106CN0	
010105CN0	
010104CN0	
010103CN0002	
010102CN0001	
010101CN0001	
BOX 25 OUTPUT PAPER 1-1-X/1-2-X	
OUTPUT PAPER	BOX 25
010201TEM001	
010201TEH001	
010202TEM001	
010202TEH001	
010203TEM001	
010203TEH001	
010204TEM001	
010204TEH001	
010205TEM001	
010205TEH001	
010206TEM001	

DESCRIPTION	LOCATION
010204TEH001	
010201TWA001	
010202TWA001	
010205TWA001	
010204TWA001	
010203TWA001	
010206TWA001	
010101CNO	
010202CNO001	
010201CNO001	
010203CNO001	
010204CNO001	
010206CNO001	
010205CNO001	
010202CNE001	
010201CNE001	
010203CNE001	
010204CNE001	
010206CNE001	
010205CNE001	
010201TSM001	
010201TSMOR	
010202TSM/R	
010203TSM/R	
010204TSM/R	
010205TSM/R	
010206TSM/R	
BOX 26 SERIES 1-1/2-X	
OUTPUT PAPER	BOX 26
010201TWA001	
010201TEM001	
010201TEH001	
010203TWA001	
010205TWA001	
010101TWA001	
010101TWA	
010205TWA	
010203TWA	
010201TEM/H	
010201TWA	
010101CNO	
010103CNO	
010105CNO	
010206CNO	
010206CNO001	
010101CNO001	
010101CNE001	
010101CNE	
010206CNO	
010101CNO	
010103CNO	
010105CNO	
010206CNO	
010101CNE	
BOX 27 SERIES 1-3-X, SERIES 2-1/2/3-X	
OUTPUT PAPER	BOX 27
020101TEM/H	
020102TEM/H	
020101TSM/R	
020102TSM/R	
020101TWA	
020102TWA	
020203CNE	
020203CNO	
020205TSM/R	
020203TWA	
020206TWA	
020203TWA	
020203TEM/H	
020206TWA	
020206TEM/H	
020205TWA	
020205TEM/H	
020203TWA	
020204TWA	
020203TEM/H	
020204TEM/H	
020203TSM/R	
020203TSM/R	
020204TSM/R	
020205TSM/R	
020206TSM/R	
020203CNO	
020303CNE	
020303CNO	
020303TEM/H	
020304TEM/H	
020303TSM/R	
020304TSM/R	
020304TSM/P	
020305TSM/R	

DESCRIPTION	LOCATION
020304TWA	
020304TEM	
020304TEH	
020303TWA	
020303TEM/H	
020305TWA	
020305TEM/H	
OUTPUT PAPER SERIES 2	BOX 28
010101TSM	
020303TSM	
050203TSM	
010103TSM	
010103TSR	
020401TSM	
020401TSR	
020404TSM	
020404TSR	
010201TWA	
020203TWA	
050101TWA	
050102TWA	
050103TWA	
050104TWA	
020401TSM	
020401TSR	
020402TSM	
020402TSR	
020403TWA	
020404TWA	
020405TWA	
020407TSM	
020407TSR	
020408TSM	
020408TSR	
020404TEM	
020404TEM	
020403TEM	
020403TEH	
OUTPUT PAPER	BOX 29
030101TSM/R	
030102TSM/R	
030101TSM/R	
030102TSM/R	
030401TSM/R	
030402TSM/R	
HOPPER TSM	
030101 TWA	
030102 TWA	
030101 TEM	
030102 TEM	
030101 TEH	
030102 TEH	
030401TWA	
030402TWA	
030401TEM/H	
030401TEM/H	
030101TEM/H	
030102TEM/H	
030101CNE	
030102CNE	
030101CNO	
030102CNO	
030101CNR	
030102CNR	
REEFER CURVES	
BOX TSM/R 3	
030202TSM/R	
030201TSM/R	
030201CNE	
030201CNO	
030201CNR	
030202CNR	
BOX 30 OUTPUT PAPER SERIES 3-2/3-X	BOX 30
OUTPUT PAPER	
SCL CURVE	
030201TSM/R	
030202TSM/R	
030201CNO	
030202CNO	
030201TEM/H	
030202TEM/H	
030201TWA	
030202 TWA	
BOX CURVES	
BOX HIST.	
100 TON BOX SERIES 3 CURVES	
SCL TSM/R	
030301 TSM/R	
030302 TSM/R	

DESCRIPTION	LOCATION
030301 TWA	
030202 TWA	
332/1 CNE/O	
030301 CNR	
030302/1 TWA	
030301/2 TSM/R	
OUTPUT PAPER	BOX 31
030401TWA	
030401TEM/H	
030402TWA	
030402TEM/H	
030401CNO	
030402CNO	
HOPPER CURVES	
030401CNE	
030401CNO	
030401CNR	
030402CNE	
030402CNO	
030402CNR	
030401TSM/R	
HOPPER HIST.	
030501TEM/H	
030502TEM/H	
030503TEM/H	
STAC PAC TSM	
SCHEIIVILLE STAC PAC	
SERIES 3 STAC PAC CURVES	
030502TWA	
030501TWA	
030503TWA	
030501TEM/H	
030502TEM/H	
030503TEM/H	
BOX 32 SERIES 4-1-X	BOX 32
040101TWA003	
040102TWA002	
040201TWA002	
040202TWA001	
040203TWA001	
040204TWA001	
040103TWA002	
040104TWA002	
040105TWA002	
040106TWA002	
040501TSM/P	
040504TSM/R	
040101TEM/H	
040502TEM/H	
040501TWA	
010101TWA	
040502TWA	
010101TEM/H	
040501TEM/H	
040501CNO	
010101CNO	
040501CNO	
010101CNO	
040101TWA	
040202TWA	
040203TWA	
040303TWA	
040401TWA	
040402TWA	
040403TWA	
040102TWA	
040104TWA	
040105TWA	
010201TWA	
040101TWA	
010201TWA	
040101TEM/H002	
040102TEM/H002	
040103TEM/H002	
040104TEM/H002	
040105TEM/H002	
040106TEM/H002	
BOX 33 OUTPUT PAPER SERIES 4-1/2/3/4-X	BOX 33
040301TEA	
040304TEA	
040101TWA	
040102TWA	
040103TWA	
040104TWA	
040105TWA	
040106TWA	
040101TWA	
040303TWA	
040201TWA002	
040202TWA001	
040203TWA001	
040204TWA001	

DESCRIPTION	LOCATION
0402n1TEM/H	
0402n2TEM/H	
0402n3TEM/H	
0402n4TEM/H	
0402n1TWA002	
0402n2TWA001	
0402n3TWA001	
0402n4TWA001	
0403n1TWA001	
0403n2TWA001	
0403n3TWA001	
0403n4TWA001	
0402n1TSM/R	
0402n2TSM/R	
0402n3TSM/R	
0402n4TSM/R	
0403n1TSM/R	
0403n2TSM/R	
0404n1TWA001	
0404n2TWA001	
0404n3TWA001	
0404n4TWA	
0404n5TWA	
0404n6TWA	
0404n4CNE	
0404n5CNE	
0404n6CNE	
0405n1CNE	
0404n6CNE	
0404n4TSM/R	
0404n5TSM/R	
0404n6TSM/R	
0404n1TSM/R	
0404n2TSM/R	
0404n3TSM/R	
0404n4TEM/H	
0404n5TEM/H	
0404n6TEM/H	
0404n1TEM/H001	
0404n2TEM/H001	
0404n2TEM/A001	
0404n1CNO	
0404n2CNO	
0404n3CNO	
0404n4CNO	
0404n5CNO	
0404n6CNO	
0404n1CNE	
0404n2CNE	
0404n3CNE	
SERIES 2 BOOK 8 TIME DOMAIN GRAPHS NEW WHEELS REDUCED SPRINGING WITH n=5 SPRINGS	BOX 34
SERIES 5 BOOK 1 70-TON CAR HIGH SPEED JOINTED RAIL 05010XTWA 05020XTWA	BOX 34
SERIES 5 BOOK 2 70-TON CAR HIGH SPEED WELDED RAIL 05010XTEA 05020XTEA	BOX 34
SERIES 5 BOOK 3 70-TON CAR MODIFIED TRACK 05010XMOD 05020XMOD	BOX 34
SERIES 5 BOOK 4 70-TON CAR MEDIUM SPEED JOINTED RAIL 05010XTSM 05020XTSM	BOX 34
OUTPUT PAPER	BOX 34
0403n3TEM/H	
0401n1TEM/H	
0403n4TEM/H	
0401n2TEM/H	
0403n1TEM/H	
0403n2TEM/H	
0403n3TEM/H	
0403n4TEM/H	
0402n1TEM/H	
0402n2TEM/H	
0402n3TEM/H	
0402n4TEM/H	
0102n1TSR	
0405n2TSR	
0405n1TSR	
0405n1TSM	
0101n1TSR	
0101n1TSM	
0401n1TWA	
0403n2TWA	
0405n1CNO	
0404n6CNO	
0405n2TEM/H	
0404n3TEM/H	
0401n2TEM/H	
0401n4TEM/H	

DESCRIPTION	LOCATION
0405n2CNE	
0404n3CNE	
0405n2CNO	
0404n3CNO	
0405n2TSM/R	
0404n3TSM/R	
0404n4TEM/H	
0405n1TEM/H	
0405n1CNR	
0404n6CNR	
0404n4CNR	
OUTPUT PAPER	BOX 35
0403n1TWA	
0402n4TWA	
0403n2TWA	
0402n3TWA	
0403n3TWA	
0401n1TWA	
0102n1TEM	
0403n4TWA	
0403n1TWA001	
0403n2TWA001	
0403n3TWA001	
0403n4TWA001	
0501n1MOD	
0501n2MOD	
0501n1TEA002	
0501n4TEA001	
0501n3TEA001	
0501n1TWA002	
0501n3TWA001	
0501n4TWA001	
0501n4MOD001	
0501n1TWA002	
0501n2TEA001	
0501n1TEA002	
0401n1TEM002	
0501n3CNE001	
0501n3CNO001	
0501n1CNO001	
0501n1CNO001	
OUTPUT PAPER	BOX 36
0501n1TSM003	
0501n1MOD002	BOX 36
OUTPUT PAPER	BOX 36
0501n1MOD002	
0501n4MOD001	BOX 36
0501n3MOD001	BOX 36
OUTPUT PAPER	BOX 36
0501n3MOD001	BOX 36
514CNE001	BOX 36
514CNO001	BOX 36
OUTPUT PAPER SERIES 5 70 TON CURVES	BOX 36
OUTPUT PAPER	BOX 36
0101n1CNO	
0203n3CNO	
0502n2CNO	
0502n3TSM001	
0502n4TSM001	
0502n5TSM001	
0502n1CNE	
0502n1CNR	
0502n1CNO	
0502n4CNE	
0502n4CNR	
0502n4CNO	
0502n1MOD	
0502n3MOD	
0502n3TEA	
0502n3TWA	
0502n3TEA	
0502n4TEA	
0502n5TEA	
0502n3MOD001	
0502n4MOD001	
0502n5MOD001	
OUTPUT PAPER	BOX 37
0502n3TEA	
0502n1TEA	
0502n1TWA	
0501n1TWA	
0501n3TWA	
0501n4TWA	
0502n3TWA	
0502n4TWA	
0502n5TWA	

DESCRIPTION	LOCATION
0501n4TSM001	
0501n3TSM001	
0501n1TSM001	
0502n4TSM001	
0502n5TSM001	
0502n3TWA001	
0502n3TWA001	
0502n5TWA001	
0502n1MOD	
0502n3MOD	
0502n1TSM	
0502n5MOD001	
0502n5TEA	
0502n4TEA	
0502n3TWA001	
0502n3TEA001	
0502n5TWA001	
0503n4TEA001	
0503n1TEA001	
0503n2TEA001	
0503n5TEA001	
0503n3TEA001	
0503n5TEA001	
0503n3CNO001	
0503n3CNE001	
0503n2CNO001	
0503n2CNE001	
BOX 38 SERIES 5-3-X OUTPUT PAPER	
OUTPUT PAPER	BOX 38
0503n1TWA001	
0503n4TWA001	
0503n5TWA001	
0503n2TWA001	
0503n1TEA001	
0503n2TEA001	
0503n4TEA001	
0503n5TEA001	
0503n1TSM	
0503n2TSM	
0503n3TSM	
0503n4TWA001	
0503n4TEA001	
0503n3MOD001	
0503n1 TSM	
0503n2 TSM	
0503n3 TSM	
0503n4 TSM	
0503n5 TSM	
0503n2CNE001	
0503n2CNO001	
0503n3CNE001	
0503n3CNO001	
0503n1CNE001	
0503n1CNO001	
0503n1MOD001	
0503n3 TWA	
0503n2 TWA	
0503n1 TWA	
0504n3 TWA	
0504n4 TWA	
0504n5 TWA	
0503n1TWA001	
0503n3TWA001	
0503n2TWA001	
0503n1TEA001	
0503n3CNE001	
0503n3CNE002	
0503n3CNO001	
0503n3CNO002	
0503n1CNE001	
REPORT NO. FRA-OR+D 75-81B 16 COPIES	BOX 39
OUTPUT PAPER SERIES 5-3/4-X	BOX 39
0503n1TSM	
0503n2TSM	
0503n3TSM	
0503n4TSM	
0503n5TSM	
0503n5MOD001	
0503n4MOD001	
SPRING COMPARISON EMPTY	
0503n1CNO001 BOX TSM	
0503n3TWA001	
0503n2MOD	
0503n1MOD	
0503n3MOD	
0503n1MOD	
0503n2MOD	
0503n1TSM	
0503n4TSM	
0503n5TSM	
0506n2TWA001	

DESCRIPTION	LOCATION
050602TEA001 050401TEA001 050401TWA001 050403CNO001 050401TWA 050402TWA 050405TWA 050301TWA 050302TWA 050305TWA	
BOX 40 OUTPUT PAPER SERIES 5-4-X OUTPUT PAPER 050405TSM001 050403TSM001 050404TSM001 050404MOD001 050402MOD001 050401MOD001 050404TWA001 050404TEA001 050405CNO001 050405CNE001 050405CNR001 050404CNR001 050405TEA001 050401TEA001 050402TEA001 050405TWA001 050402TWA001 050401TWA001 050405TEA001 050403TEA001 050404TEA001 050404CNR001 050403CNR001 050405CNR001 050403CNR001 050403CNE001 050403MOD001 050405TWA001 050404CNO001 050404MOD001 050403MOD001 050405MOD001 050403TWA001 050404TWA001 050405TWA001 050405TSM 050405TSM 050404TSM 050403TSM 050405TSM 050402TSM 050401TSM 050403TWA001 050403TEA001 050403CNO001 050404CNO001 050405CNO001 050403CNE001 050404CNE001 050405CNE001	BOX 40
SERIES 1 ORIGINALS	BOX 41
SERIES 2 PLOTS TIME DOMAIN 8.5X11	BOX 42
SERIES 3 PLOTS, REEFER, BOX SCL	BOX 43
SERIES 3 PLOTS FLAT SCL	BOX 44
SERIES 4 PLOTS	BOX 45
SERIES 3 PLOTS REEFER, BOX SCL	
SERIES 5 PLOTS 8.5 X 11	BOX 46
SERIES 2 ORIGINALS	BOX 47
SERIES 5 TIME PLOTS, ORIGINALS	BOX 48
SERIES 1 BOOK 1 LOADED REEFER:	BOX 49
SERIES 1 BOOK 2 HALF LOADED	BOX 49
SERIES 3 BOOK 1 MECHANICAL REFRIGER-ATOR LOADED TEST 030102 BOOK 2 MECHANICAL REFRIGER-ATOR LOADED TEST 030101 BOOK 3 60-FT 100-TON BOX CAR LOADED TEST 030201	BOX 49
SERIES3 BOOK4 60-FT 100-TON BOX CAR EMPTY TEST 030202	BOX 50
SERIES 3 BOOK 5 50-FT 70-TON BOX CAR LOADED TEST 030301	BOX 50
SERIES 3 BOOK 6 50-FT 70-TON BOX CAR EMPTY TEST 030302	BOX 50
SERIES 3 BOOK7 100-TON COVERED HOPPER LOADED TEST 030401	BOX 50
SERIES 3 BOOK 8 100-TON COVERED HOPPER EMPTY TEST 030402	BOX 50
SERIES 3 BOOK 9 89-FT FLAT CAR LOADED TEST 030502	BOX 51
SERIES 3 BOOK 10 89-FT FLAT CAR EMPTY TEST 030501	BOX 51
SERIES 2 BOOK 1 RMS, HISTOGRAMS AND PSD's	BOX 52
SERIES2 BOOK 2 TIME DOMAIN GRAPHS AVERAGE WORN WHEELS (EMPTY)	BOX 52
SERIES 4 BOOK 5 CURVED RAIL EMPTY TESTS 040X0YCNE,040X0YCNO	BOX 52
SERIES 4 BOOK 4 CURVED RAIL LOADED TESTS:040X0YCNR,040X0YCNE 040X0YCNO	BOX 52
SERIES 4 BOOK 3 MEDIUM SPEED JOINTED RAIL TESTS:040X0YTSM,040X0YTSR	BOX 52
SERIES 2 BOOK 3 TIME DOMAIN GRAPHS WORN WHEELS D-5 SPRINGS (LOADED)	BOX 53
SERIES 2 BOOK 4 TIME DOMAIN GRAPHS WORN WHEELS D-3 + D-7 SPRINGS (LOADED)	BOX 53
SERIES 2 BOOK 5 TIME DOMAIN GRAPHS WORN WHEELS D-5 SPRINGS (EMPTY)	BOX 53
SERIES 2 BOOK 6 TIME DOMAIN GRAPHS WORN WHEELS D-3 + D-7 SPRINGS (EMPTY)	BOX 53
SERIES 2 BOOK 7 TIME DOMAIN GRAPHS NEW WHEELS,D-5 SPRINGS,2/3 SNUBBING (LOADED AND EMPTY)	BOX 53
SERIES 3 BOOK 11 89-FT FLAT CAR EMPTY WORN WHEELS TEST 030503	BOX 53
SERIES 4 BOOK 1 HIGH SPEED JOINTED RAIL TEST 040X0Y TWA	BOX 53
SERIES 4 BOOK 2 HIGH SPEED WELDED RAIL TEST:040X0YTEM,040X0YTEH	
SERIES 2 GRAPHS BOOK 8	BOX 54
SERIES 5 GRAPHS BOOK 1-4	BOX 54
SERIES 5 BOOK5 70-TON CAR CURVED TRACK OVER-EQ. SPEED 0501mxCNO 0502mxCNO BOOK 6 70-TON CAR CURVED TRACK EQUILIBRIUM SPEED 0501mxCNE 0202mxCNE BOOK 7 70-TON CAR CURVED TRACK RESONANT SPEED 0502mxCNR BOOK 8 100-TON CAR HIGH-SPEED JOINTED RAIL 0503mxTWA 0504mxTWA BOOK 9 100-TON CAR HIGH-SPEED WELDED RAIL 0503mxTEA 0504mxTEA BOOK 10 100-TON CAR MODIFIED TRACK 0503mxMOD	BOX 55

```
DESCRIPTION                                        LOCATION
-----------------------------------               -----------

     05040XMOD

SERIES 5 BOOK 11 100-TON CAR MEDIUM                BOX 56
     SPEED JOINTED RAIL 05030XTSM
     05040XTSM

SERIES 5  BOOK 12 100-TON CURVED TRACK             BOX 56
     OVER-EQ. SPEED 05030XCNO 05040XCNO

SERIES 5  BOOK 13 100-TON CAR CURVED               BOX 56
     TRACK EQ. SPEED 05030XCNE
     05040XCNE

SERIES 5  BOOK 14 100-TON CAR CURVED TRACK         BOX 56
     RESONANT SPEED 05040XCNR

CLEAN TAPES.                                       BOX 100
     16249-77-2-40
     16249-77-2-38
     16249-77-2-30
     16249-77-2-44
     16249-77-2-42
     16249-80-3-41
     16249-80-2-39
     16249-80-3-31
     16249-80-3-29
     16249-80-3-49

TDOP DRAWINGS                                      BOX 57

     ROLL A

     ROLL B SCL BOX CLASS X-5-8

     ROLL C R-70-24

     ROLL D B-100-33

     ROLL E L + N HOPPER

     ROLL F F-70-65

     ROLL G 70 TON ASF RIDE CONTROL

     ROLL H 70 TON BARBER S-2 STABLIZED

     ROLL I 100 TON BARBER S-2 STABLIZED
     LOW PROFILE

     ROLL J 70 TON ASF LOW LEVEL

     ROLL K 100 TON ASF A3 RIDE CONTROL

     ROLL L TIMKEN MOD + STD ADAPTERS
     70 + 100 TON

BOX 101 BLANK TAPES                                BOX 102
     16249-67-3-15
     16249-67-3-05
     16249-69-3-38
     16249-67-3-13
     16249-67-3-11
     16249-69-3-42
     16249-69-3-40
     16249-69-3-46
     16249-69-3-44
     16249-67-3-17

BLANK TAPES.                                       BOX 103
     16249-77-1-36
     16249-77-1-50
     16249-77-1-30
     16249-77-1-28
     16249-77-1-32
     16249-77-1-48
     16249-77-1-34
     16249-77-1-20
     16249-77-1-1
     16249-77-1-16

BLANK TAPES.                                       BOX 104
     16249-80-4-31
     16249-80-4-35
     16249-77-1-14
     16249-80-4-25
     16249-80-4-27
     16249-77-2-14
     16249-80-4-17
     16249-80-4-21
     16249-80-4-47
     16249-80-4-09

BLANK TAPES.
     16249-80-4-37
```

```
DESCRIPTION                              LOCATION
-----------------------------           -------------

     16249-77-3-18
     16249-77-3-49
     16249-77-4-48
     16249-77-4-41
     16249-77-3-43
     16249-77-4-34
     16249-77-4-46
     16249-77-3-10
     16249-77-3-09

BLANK TAPES.                             BOX 105
     16249-69-2-46
     16249-69-2-44
     16249-69-2-42
     16249-69-2-40
     16249-69-1-10
     16249-69-1-16
     16249-69-1-46
     16249-69-1-20
     16249-67-3-26
     16249-69-2-30
  14:11:30  /ENDJOB
  14:11:35  /FINI
```

APPENDIX B - COMPUTER PROGRAMS

PHASE I DATA SORTING ROUTINE

Wyle Laboratories developed a data sorting routine to provide a ready access to, and analysis of, Phase I data. A subsequent upgrading consisted of bringing the sort program parameter into agreement with the information contained in the Phase I Final Report, (1) and in the magnetic data tape headers. The tape header for those runs that the data were reduced are contained in Appendix C.

The sorting routine permits the user to specify a given set of test conditions; the program then lists all test runs which meet that set of requirements. The program sorts on the nineteen parameters or test conditions listed in Table B-1. Shown below each parameter in this table are the possible variations of the parameter and the user code which is specified for a search on that parameter. Any combination of the user codes may be used when making a search. However, many combinations will produce a null set. As an example, a sort for 100-ton box car and 70-ton ASF ride control truck will produce a sort with no entries.

An example of a typical sort printout is contained in Table B-2. This was a sort for all tests which were run over high-speed, jointed track on a fully loaded 100-ton box car, with a Barber 100-ton truck equipped with new wheels. The result was one test run consisting of six entries, one each at 30, 40, 50, 60, 70 and 79 mph. The Test ID, inventory box location, and the tape number are contained in the first two lines. With this information, it is possible to determine the required tape and retreive it for data reduction. This sorting program was used extensively in the evaluation of the Phase I data.

POST PROCESSING PROGRAM

The Post Processing Program developed by SPTCo. was used to analyze the Phase I data. It was received from the FRA on magnetic tape and converted to run on Wyle's Interdata computer. Documentation for the program was provided by the Post Processing Program manual.(2) The effort required to convert this program to the Interdata computer proved more difficult than originally anticipated. The original program was supplied in EBCDIC and required conversion to seven-bit ASCII for the Interdata computer. The assembly language subroutines were completely rewritten using the Interdata assembly language and one subroutine was modified to work with the ASCII decimal equivalents rather than the EBCDIC decimal equivalents. To get the Post Processing Program to fit on the Interdata computer, it had to be overlayed and the number and size of plots that could be requested was reduced to 10 plots with 20 lines.

The original manual for the program was revised (3) to include the changes that were made for operation on the Interdata computer. It contains samples of all files used in building the load module, a sample request deck, and the output from the request deck.

Some problems were also experienced in the original version of the program and have been noted. These problems were discovered during the course of reducing data and show that the program is not yet fully checked out. For example, at least one plot must be requested as there are many FORTRAN do-loops which use the total number of plots as the upper limit, and zero is not an acceptable value. Also, at least one set of equation cards must be included, even if the data are not required, because a zero equation is unacceptable to the program logic. Also, the original manual was not clear as to where blank cards must be positioned nor where they may be detected. These problems were eliminated in the revised version of the program.

SPTCo. recommended that at least 450k bytes of memory core be available for operation of the Post Processing Program. This total did not include space for such things as the operating system or any enhancements to the system, which would rule out use of the program without extensive modification on any machine with less than 512k bytes of core. Problems were also encountered by going to a non-IBM system, e.g., file structures were different, routines required rewriting, the EBCDIC-to-ASCII conversion was necessary, etc.

Difficulty may be encountered even when trying to install the Post Processing Program on an IBM computer. The manner in which the program handles peripheral devices, such as I/O and disk storage, would make its use on any IBM machine difficult, unless the system had a nearly identical set of peripherals to that for which the program was written. For example, the program was written to output to three separate line printers, and would require modification if a lesser number of line printers were available.

As previously discussed, a program manual is available from NTIS for running the Post Processing Program. While this manual was an invaluable guide in making the program operational on the Interdata computer, anyone attempting to use it should be aware of certain errors and unclear passages in the manual, as discussed in this report. Some of these have been noted in this report, however, not all analysis combinations were tried and some errors may still exist.

Program Validation

To assure the accuracy of data analyzed by using the Post Processing Program, Wyle executed a sequence of procedures to validate the operation of the program on the Interdata computer.

---

(1) FRA Report No. FRA/ORD-78/12.II, "Freight Car Truck Design Optimization Volume II, Phase I Final Report," February 1978.

(2) FRA Report No. FRA/ORD-78/12.XIII, Volume 12, "TDOP Post Processing Manual," February 1978.

(3) Wyle Document TDOP TR-0X, User Operator's Manual for Post Processing Program Operation on Interdata 8/32," May 1978.

Table B-1. Sort Program Parameters

TAPE NO.	
WHERE N = TAPE NO.	USER CODE = 1, N,
CARBODY TYPE	
70 TON M RFR	USER CODE = 2, 1,
100 TON 60' BOX	USER CODE = 2, 2,
70 TON 50' BOX	USER CODE = 2, 3,
89' FLT CAR	USER CODE = 2, 4,
100 TON C HPR	USER CODE = 2, 6,
TRUCK TYPE	
ASF 70 TON R.C.	USER CODE = 3, 1,
ASF 70 TON L.L.	USER CODE - 3, 2,
ASF 100 TON R.C.	USER CODE = 3, 3,
BARBER 70 TON	USER CODE = 3, 4,
BARBER 100 TON	USER CODE = 3, 5,
TRUCK CENTER	
45' 9''	USER CODE = 4, 1,
46' 3''	USER CODE = 4, 2,
41' 3''	USER CODE = 4, 3,
40' 10''	USER CODE = 4, 4,
64' 0''	USER CODE = 4, 5,
PER CENT LOAD	
EMPTY	USER CODE = 5, 1,
HALF FULL	USER CODE = 5, 2,
FULLY LOADED	USER CODE - 5, 3,
WHEEL PROFILE	
1-20 (NEW)	USER CODE = 6, 1,
1-40 (NEW)	USER CODE - 6, 3,
CYLINDRICAL	USER CODE = 6, 3,
HALF WORN	USER CODE = 6, 4,
WORN	USER CODE = 6, 5,
NO. OF OUTER SPG	
N	USER CODE = 7, N,
WHERE N = NO. OFSPGS.	
SPG TYPE (OUTER)	
D1	USER CODE = 9, 1,
D2	USER CODE = 9, 2,
D3	USER CODE = 9, 3,
D4	USER CODE = 9, 4,
D5	USER CODE = 9, 5,
D6	USER CODE = 9, 6,
D7	USER CODE = 9, 7,
D8	USER CODE = 9, 8,
NO. OF INNER SPG	
N	USER CODE = 11, N,
WHERE N = NO. OF SPGS.	
SPG TYPE (INNER)	
D1	USER CODE = 13, 1,
D2	USER CODE = 13, 2,
D3	USER CODE = 13, 3,
D4	USER CODE = 13, 4,
D5	USER CODE = 13, 5,
D6	USER CODE = 13, 6,
D7	USER CODE = 13, 7,
D8	USER CODE = 13, 8,
SNUBBING (OUTER)	
ASF 3091	USER CODE = 15, 1,
2/3 NORMAL	USER CODE = 15, 2,
B 432	USER CODE = 15, 3,
ASF 3221	USER CODE = 15, 4,
B 421	USER CODE = 15, 6,
B 422	USER CODE = 15, 8,
SNUBBING (INNER)	
B 433	USER CODE = 16, 1,
ASF 3222	USER CODE - 16, 2,
ASF 3092	USER CODE = 16, 3,
8442	USER CODE = 16, 4,
B 422	USER CODE - 16, 5,
B 433	USER CODE = 16, 7,
3091	USER CODE - 16, 8,
SNUB. AUG.	
NO AUGMENTATION	USER CODE = 17, 1,
VOLUTE	USER CODE = 17, 2,
HYDRAULIC	USER CODE = 17, 3,
TRUCK CEER AUG.	USER CODE = 17, 4,
C PLT. FRICTION	
STEEL-MOLY	USER CODE = 18, 1,
COMP. STEEL	USER CODE = 18, 2,
STEEL-STEEL	USER CODE = 18, 3,
FILE NO.	
N	USER CODE = 19, N,
WHERE N = FILE NO.	
TRACK	
CURVED	USER CODE = 20, 1,
SHIMMED	USER CODE = 20, 2,
HI SPD JTD	USER CODE = 20, 3,
HI SPD CWR	USER CODE = 20, 4,
MED SPD JTD	USER CODE = 20, 5,
SPEED	
N	USER CODE = 21, N,
WHERE N = SPEED	
OUTER GIB CLEARANCE	
1/4 OGC	USER CODE = 22, 1,
5/8 OGC	USER CODE = 22, 2,
SIDE BEARING	
3/8 SB CLR	USER CODE = 23, 1,
1/4 SB CLR	USER CODE = 23, 2,
5/8 SB CLR	USER CODE = 23, 3,
1/8 SB CLR	USER CODE = 23, 4,
2.5 K PRELOAD	USER CODE = 23, 5,
5. K PRELOAD	USER CODE = 23, 6,
7.5 K PRELOAD	USER CODE = 23, 7,

Table B-2. Sort Example

TEST CONDITIONS, CAR TYPE	100 TON 60' BOX	USER CODE = 2, 2,		
TEST CONDITIONS, TRUCK TYPE	BARBER 100 TON	USER CODE = 3, 5,		
TEST CONDITIONS, WHEEL PROFILE	1-20 (NEW)	USER CODE = 6, 1,		
TEST CONDITIONS, PER CENT LOAD	FULLY LOADED	USER CODE = 5, 3,		
TEST CONDITIONS, TRACK	HI SPD JTD	USER CODE = 20, 3,	NUMBER OF ENTRIES =	6

ID. 030201TWA001	ID. 030201TWA001	ID. 030201TWA001	ID. 030201TWA001	ID. 030201TWA001	ID. 030201TWA001
BOX 7 TAPE 389	BOX 7 TAPE 389	BOX 7 TAPE 389	BOX 7 TAPE 389	BOX 7 TAPE 389	BOX 7 TAPE 389
FILE NO. 1	FILE NO. 1	FILE NO. 1	FILE NO. 1	FILE NO. 1	FILE NO. 1
TAPE NO. 89	TAPE NO. 89	TAPE NO. 89	TAPE NO. 89	TAPE NO. 89	TAPE NO. 89
100 TON 60' BOX	100 TON 60' BOX	100 TON 60' BOX	100 TON 60' BOX	100 TON 60' BOX	100 TON 60' BOX
BARBER 100 TON	BARBER 100 TON	BARBER 100 TON	BARBER 100 TON	BARBER 100 TON	BARBER 100 TON
46' 3''	46' 3''	46' 3''	46' 3''	46' 3''	46' 3''
FULLY LOADED	FULLY LOADED	FULLY LOADED	FULLY LOADED	FULLY LOADED	FULLY LOADED
1-20 (NEW)	1-20 (NEW)	1-20 (NEW)	1-20 (NEW)	1-20 (NEW)	1-20 (NEW)
7-D50/7-D5I	7-D50/7-D5I	7-D50/7-D5I	7-D50/7-D5I	7-D50/7-D5I	7-D50/7-D5I
8-B432	8-B432	8-B432	8-B432	8-B432	8-B432
8-B433 SNUBBERS	8-B433 SNUBBERS	8-B433 SNUBBERS	8-B433 SNUBBERS	8-B433 SNUBBERS	8-B433 SNUBBERS
NO AUGMENTATION	NO AUGMENTATION	NO AUGMENTATION	NO AUGMENTATION	NO AUGMENTATION	NO AUGMENTATION
STEEL-MOLY	STEEL-MOLY	STEEL-MOLY	STEEL-MOLY	STEEL-MOLY	STEEL-MOLY
HI SPD JTD	HI SPD JTD	HI SPD JTD	HI SPD JTD	HI SPD JTD	HI SPD JTD
30 MPH	40 MPH	50 MPH	60 MPH	70 MPH	79 MPH
5/8 OGC	5/8 OGC	5/8 OGC	5/8 OGC	5/8 OGC	5/8 OGC
1/4 SB CLR	1/4 SB CLR	1/4 SB CLR	1/4 SB CLR	1/4 SB CLR	1/4 SB CLR

This first step in these procedures was to run the test case described in the SPTCo. documentation for the program. The test run used was 050101TWA002 and the results are documented. The results agreed exactly with those the SPTCo obtained except the Interdata computer plotted only two time-history plots on a page versus six for the SPTCo case.

In the second step of the validation process, Wyle compared independently developed time histories to verify conversion of raw, multiplexed data (in volts) to a correct time history in engineering units. During the initial TDOP Phase II proposal effort, Wyle independently developed software for a limited analyses of the TDOP Phase I tapes from NTIS. A five-second, time-history plot was made, using an in-house program, which is shown in Figure B-1 for each speed zone run during the test. The measurements used consisted of channels 5 and 9. These same channels and corresponding mileposts were run using the Post Processing Program and are shown in Figures B-2 to B-6. The starting time for each of the plots in Figure B-1 is noted on the corresponding plot in Figures B-2 through B-6.

The two curves agree exactly in amplitude indicating that the conversion to engineering units was made correctly. However, when comparing the response at a specific milepost between the two time histories, a difference is noted in that the two time histories show a shift in the milepost at which a particular event occurs. As shown in Table B-3, the milepost comparison grew progressively worse the longer the test was run. This problem is discussed in more detail in the problems with the automatic location detector (ALD).

PSD Calculations

PSD calculations in the Post Processing Program do not use the same technique described by MITRE for the frequency domain model.(4) The PSDs are calculated by summing the squares of the Fourier coefficients (sine and cosine) at each of 200 evenly spaced frequency points from 0.1 to 20 Hz. According to the TDOP Post Processing Program Manual, all of the TDOP data were filtered by 20 Hz low-pass filters, and therefore, the higher frequency points of the PSD were not calculated. The data were acquired at a rate of 200 samples per second requiring 2000 data points for a 0.1 Hz resolution. Each PSD plot uses 4000 data points in the following manner: 10 PSD calculations are made; each using 2000 points. (The first PSD calculation is made using points 1-2000, the second from 200-2200, etc.) As may be seen, 1800 points of each PSD calculated overlap those of the previous calculation. These 10 PSDs are then averaged to form one PSD for the plot. Smoothing in the frequency domain followed the summing of the PSD values. This smoothing in the frequency domain is the equivalent of applying a Hanning window in the time domain.

The Fourier coefficients are calculated by FORIT, an IBM scientific subroutine. This subroutine uses a variation of the direct method for calculating Fourier coefficients with the sine and cosine terms calculated recursively to reduce computational times. The subroutine allows calculation of less frequency points than what is possible, therefore, allowing only 200 frequency points to be calculated rather than the possible 1000 points. Although not nearly as efficient as an FFT routine, this method for calculating the Fourier coefficients is valid.

Statistics

The statistical quantities calculated by the Post Processing Program are the mean value, the mean value of the rectified signal, the rms of the signal, and the standard deviation. The standard deviation calculated is not that of the rectified signal; however, there is evidence in the program listing that it was once done this way. There was controversy in the past when the SPTCo. calculated the standard deviation using the rectified signal. There was no agreement as to what the significance of the calculation was in relation to interpreting the data. This practice was apparently dropped later in Phase I and the standard deviation is now calculated using an unrectified signal. No errors were found in the calculation of these statistics. It should be noted that the rms and standard deviation of a signal with a zero mean are mathematically identical and provide no additional information. For those signals with a mean, the only significant information is derived from the standard deviation and is the value used in the analytical work.

---

(4) FRA Report No. FRA/ORD-78/12.III, Freight Car Truck Design Optimization, Phase I Frequency Domain Model, February 1978.

Table B-3. Time-History Comparison

Speed	Time (Figure B-1)	Milepost (Post Processing)	Milepost (Ft)	Error	Figure
30	25	48.2902	48.2879	12'	B-2
40	129	47.2587	47.2424	86'	B-3
50	174	46.7110	46.6761	184'	B-4
60	292	44.9764	44.9266	263'	B-5
79	463	41.7914	41.7006	479'	B-6

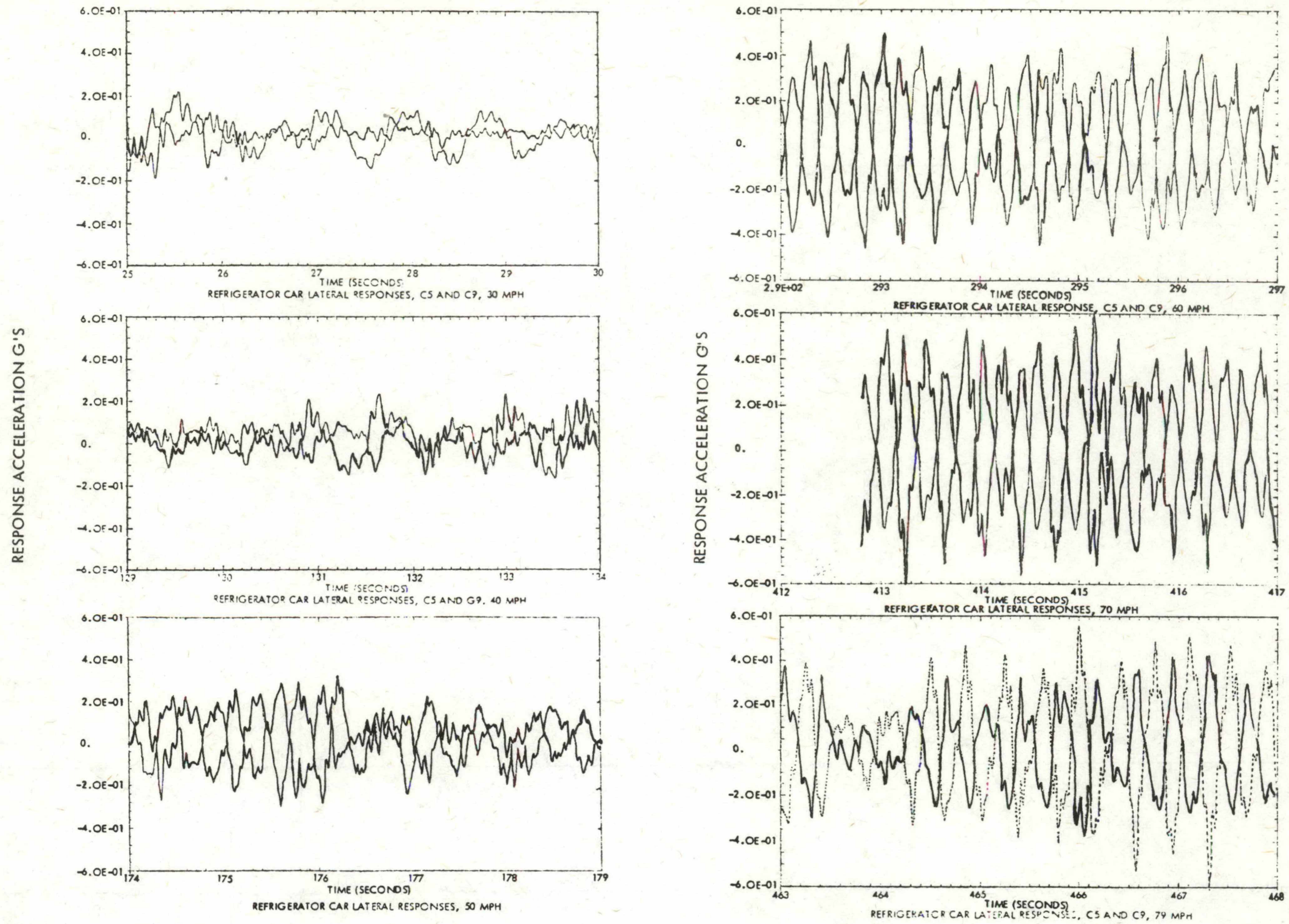
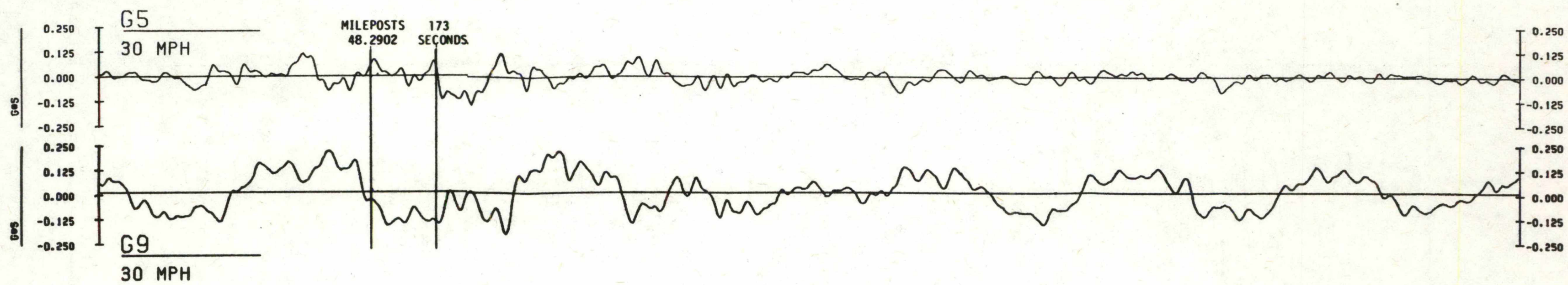


Figure B-1. Car Lateral Response



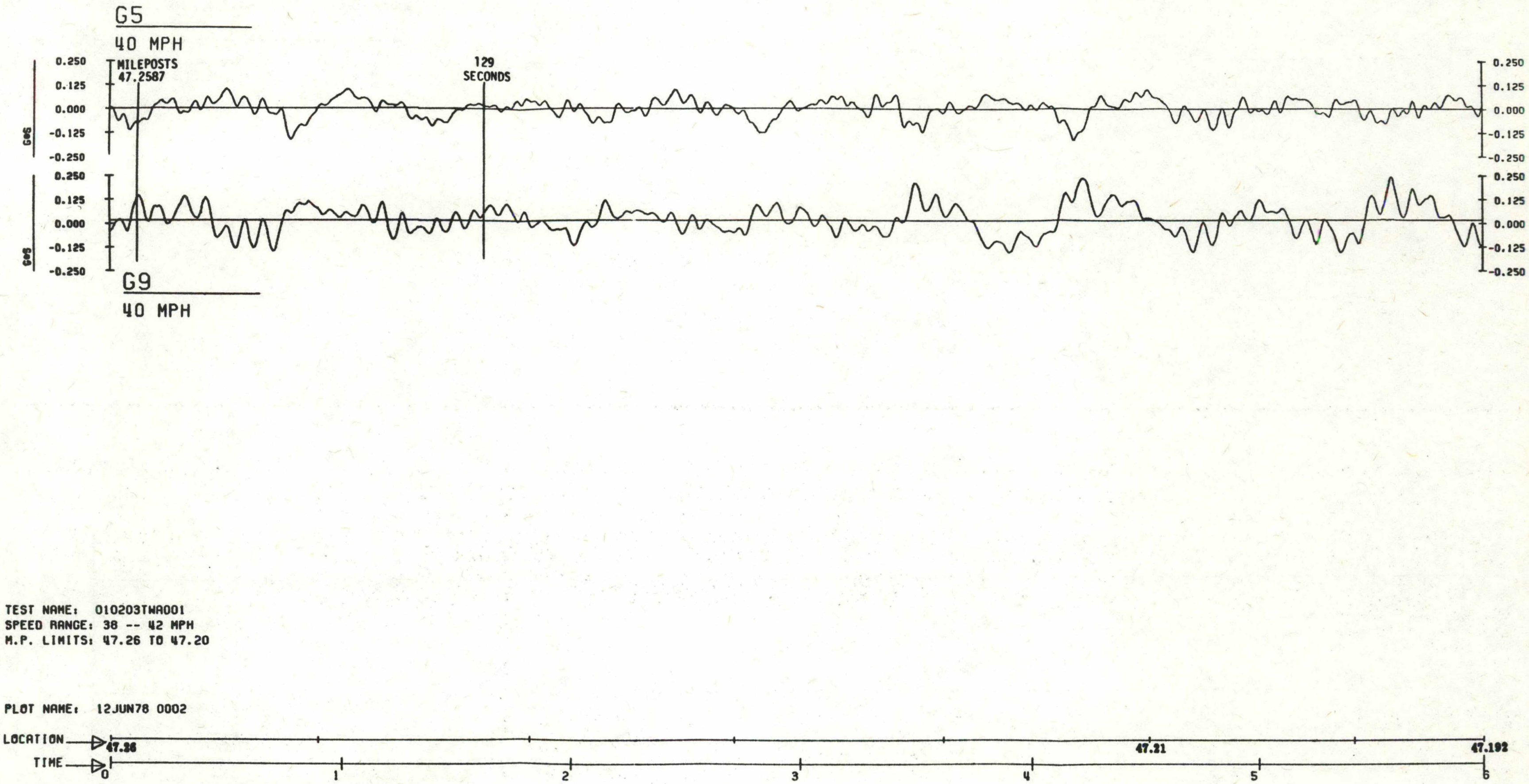
TEST NAME: 010203TWA001
SPEED RANGE: 28 -- 32 MPH
M.P. LIMITS: 48.30 TO 48.24

PLOT NAME: 12JUN78 0001

LOCATION 48.30 48.25
TIME 0 1 2 3 4 5 6

REFRIGRATOR CAR LATERAL RESPONSES
COMPARISON OF WYLE : POST PROCESSING PROGRAM OUTPUT

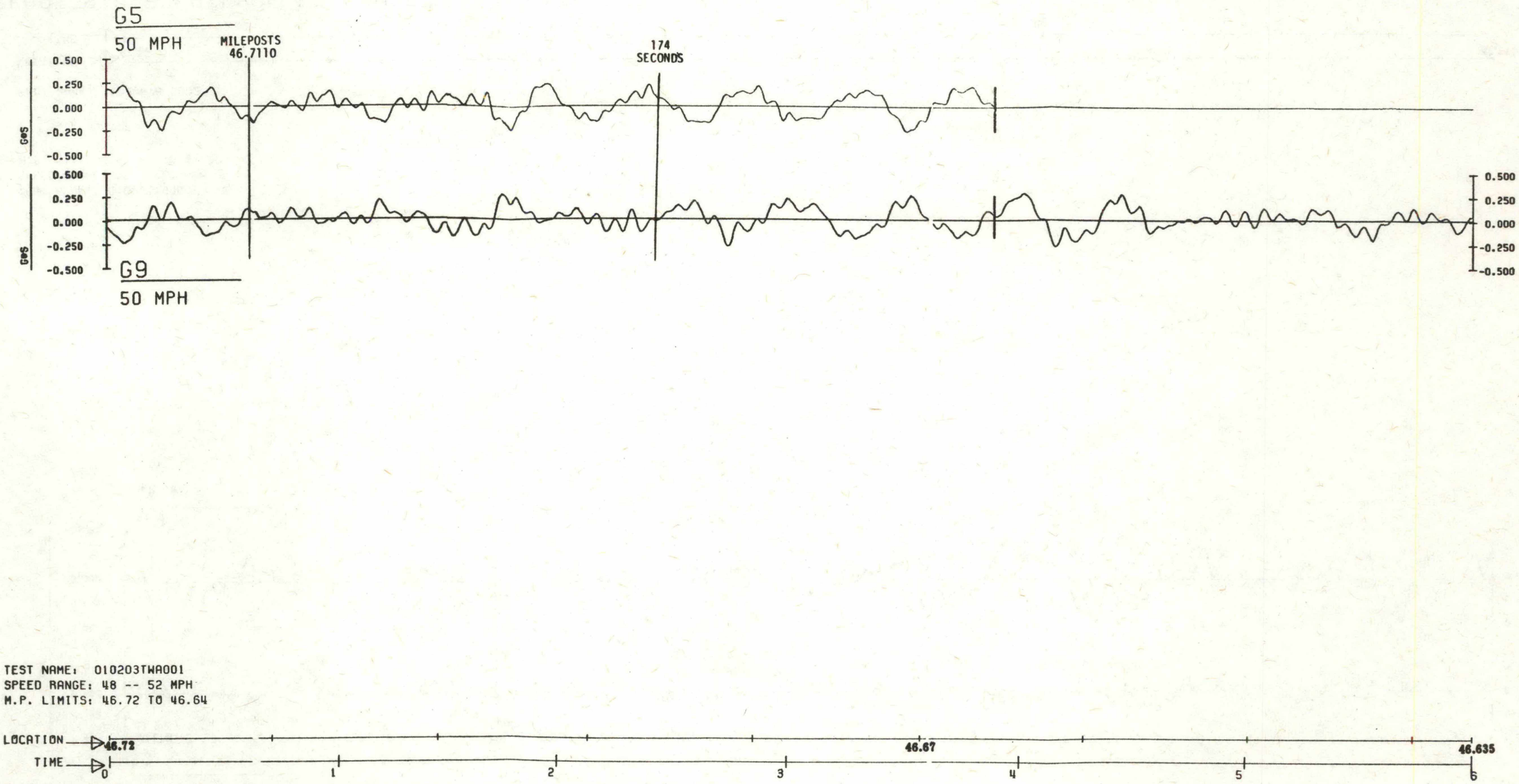
Figure B-2



REFRIGRATOR CAR LATERAL RESPONSES

COMPARISON OF WYLE : POST PROCESSING PROGRAM OUTPUT

Figure B-3



REFRIGRATOR CAR LATERAL RESPONSES
COMPARISON OF WYLE : POST PROCESSING PROGRAM OUTPUT

Figure B-4